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Nutrition and body composition as risk factors of non-communicable diseases in Saudi Arabia

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Dedication

"To my mother (Moneerah) who left me too early

Before she could see this happening"

Abstract

Background: Saudi Arabia is an affluent nation faced with steep population increase (~75% in just over 10 years) and a young population (63% aged under 30) in the context of globalized dietary habits and food supply leading to increase the trend of consumption junk food use. However, there are no national dietary surveys to give more accurate details. With existing high prevalence of obesity, it is foreseeable that Saudi Arabia (SA) will face a significant increase in the burden of non-communicable diseases (NCDs) in a short space of time. Reducing the behavioural and environmental risk factors associated with NCDs (physical activity, alcohol overuse, exposure to tobacco smoke, and low nutritionally balanced diet including high salt and energy intake and low intake of fruit and vegetables) requires cross-community sectors, including health, education, agriculture, and planning. Early detection and intervention also require reliable and cost effective tools. The relationship between chronic high salt intake and CVDs has already been established. This thesis examines the relationship between body composition and nutrition, and NCDs using techniques from the full breadth of Human Nutrition Research.

Methods: The first cross-sectional study focused on developing and validating a culture-specific FFQ for salt intake against 24-h urinary outputs and repeated 24-h dietary recall, to identify relationships between salt intake, socio-economic factors and blood pressure (BP); and explore dietary sources of salt intake.

In the second study, a secondary analysis of integrated data from five Saudi National Surveys assessed the performance of different anthropometric measures (body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR)) and body composition indices (estimated skeletal muscle mass (SMM), the percentage of skeletal muscle mass to body weight (%SMM) and Skeletal Muscle Mass Index (SMI)) in predicting metabolic diseases. Saudi nationals only were included in the study. ROC analysis was used to explore the best predictor of metabolic diseases and develop new thresholds. To assess the agreement and misclassification of overweight and obesity using BMI and WC measurements, BMI in combination with WC measurements were used to classify participants as [High-Risk Adiposity by BMI and WC], [High-Risk Adiposity by BMI only], and [High Risk Adiposity by WC only] based on the action levels. Each anthropometric and muscle mass indices were categorised to deciles. Additionally calculated were age-adjusted odds ratios by applying logistic

regression models of the different metabolic risk factors in case of an increase of one decile of the respective anthropometric and estimated SMM parameter.

In the third study, a cross-sectional survey was developed using the Theory of Planned Behaviour to provide a holistic understanding of factors that may influence food choices and behaviours, and in particular, intentions of adopting a nutritionally-balanced diet. External variables including age, gender, socio-economic status, and being aware of health and nutrition policies and others were included into the model as they were potentially related to TPB constructs. Attitude toward behaviour, subjective norms, perceived behavioural control and knowledge as actual barriers to behaviour were assessed.

Results: In the first study, the newly developed Saudi FFQ was found to be of moderate validity in ranking people based on their estimated salt intake, and performed as well as other salt FFQ developed for other nations. The Riyadh population used in this survey consumed 8.7 g salt per day (estimate), higher than the recommended level of salt (>5 g/d for salt). A minority (18%) met the recommended level. The main sources of salt were, surprisingly, vegetables and un-processed foods, and a positive relationship between income and salt intake was observed. Meanwhile, salt intake, defined by FFQ, was associated with systolic BP only ($R=0.089$, $p=0.036$), an association which disappeared when adjusted for age, WC and gender.

The second study highlighted that a majority of Saudi adults could be categorized as overweight or obese (72%). Worryingly, short of half of those with a normal BMI (18.5–25) aged over 45 also had a large waist. Combining WC and BMI did not improve their value as predictors of metabolic diseases and WC was the best overall predictor of metabolic diseases while BMI was the poorest. This study suggests new cut-off points for WC in SA, in a context of metabolic diseases, ranging between 90 to 92 cm (women) and 94 to 99 cm (men). The newly developed WC cut-offs are higher than the cut-offs for Asian men and women (90 and 80 cm, respectively). The new WC cut-off for women is higher than the cut-off for Caucasian women (88 cm); and the WC cut-off for men is lower than the cut-offs for Caucasian men (102 cm).

The obesity prevalence based on BMI and WC also increased proportionately with both SMM (kg) and SMI (kg/m^2) increase while the obesity decreased proportionately with %SMM increase. SMI was a poor predictor of metabolic diseases while %SMM was the best, having the highest AUC levels. New (defined) cut-off points for %SMM for

metabolic diseases were defined, ranging from 29 to 32% for men and 26 to 28% for women.

The third study highlighted that very few SA adults have been exposed to national nutrition and health guidelines (18%). Awareness of these was the strongest predictor of attitude toward behaviour, social norms and knowledge of nutritionally-balanced diet whilst perceived social pressure to engage in behaviour toward a more nutritionally balanced diet (SN) was the strongest predictor of subjects' intention.

Conclusion: Study 1 added a new and unexpected source of salt intake including vegetables and unprocessed foods. These findings raise a concern regarding the encouragement to increase intake of vegetables without including advice regarding cooking advice, in light of the risk of higher salt intake in SA. It would be worthwhile to consider education strategies towards the use of alternative ingredients or dressings in salad and cooked vegetables.

Study 2 added an evidence about the weakness of BMI and SMI in predicting metabolic diseases and misclassifying the population. The study suggests using WC and %SMM as alternative measures and adopting the newly developed cut-offs.

Study 3 sheds the light on possible avenues for policies, health promotions and nutrition interventions to focus on Saudi adults, in order motivate the population to adopt nutritionally balanced diet by increasing population knowledge and awareness.

Table of contents

List of tables

List of figures

Publications

Published abstracts

- Alkhalaf M. M., Edwards C. A. and Combet E. (2015) Current reported and observed hypertension status, sodium intake practices and body composition of adults in Riyadh city, Saudi Arabia. Proceedings of the Nutrition Society 74 (OCE1), E22.

- Alkhalaf M. M., Edwards C. A., Lean MEJ and Combet E. (2015) Skeletal muscle mass estimation in Saudi adults – relationship with obesity and hypertension. Proceedings of the Nutrition Society 74 (OCE2), E170.

- Alkhalaf M. M., Edwards C. A. and Combet E. (2015) Validation of a food frequency questionnaire specific for salt intake in Saudi Arabian adults using urinary biomarker and repeated multiple pass 24-hour dietary recall. Proceedings of the Nutrition Society 74 (OCE5), E337.

- Alkhalaf M. M., Lean MEJ., Edwards C. A., and Combet E. (2016) Skeletal muscle mass characteristics and elevated noncommunicable diseases in Saudi adults. FASEB 30 (1), Supplement 678.23.

- Alkhalaf M. M., Edwards C. A., Lean MEJ. and Combet E. (2016) Risk classification paradox of anthropometric measurements in Saudi Arabia: need for further consideration. Proceedings of the Nutrition Society 75 (OCE3), E43.

- Alkhalaf M. M., Edwards C. A., Lean MEJ. and Combet E. (2016) Diet and obesity – driving the rise of non-communicable diseases in Saudi Arabia. ESPEN SUN-P190.

Oral Presentaions

- Body composition, sodium intake practices and hypertension status of adults in Riyadh city, Saudi Arabia (Food and Obesity Forum, 2014) Riyadh, Saudi Arabia.

- Body Composition Assessments from Surveys in Saudi Arabia: body size distributions and age (RDC-2016) Riyadh, Saudi Arabia.

Abbreviations

24-HDR	multiple pass 24-hour dietary recall
ATT	attitudes towards behaviour
AUC	area under curve
BF	body fat
BMI	body mass index
BP	blood pressure
CI	confidence interval
CVDs	cardiovascular diseases
DBP	diastolic blood pressure
FFQ	food frequency questionnaire
HbA1c	Glycated haemoglobin
HDL	high density lipoprotein
IDF	the International Diabetes Federation
IQR	inter quartile range
LOA	limits of agreement
NCDs	non-communicable diseases
OR	odds ratio
PABA	para-aminobenzoic acid
PBC	perceived behavioural control
ROC	the receiver operating characteristic curves
RS	Spearman's Correlation
SBP	systolic blood pressure
SE	standard error
SMI	skeletal muscle mass index
SMM	skeletal muscle mass
SN	subjective norms
T2DM	type 2 diabetes mellitus
TATM	total adipose tissue mass
TATFM	total adipose tissue fat mass
TPB	theory of planned behaviour
TGA	triglycerides
WC	waist circumference
WHR	waist to hip ratio
WHtR	waist to height ratio
WHO	World Health Organization

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Author’s Declaration

I declare that I am the author of this thesis, and that no part of the work in this thesis has formed part of any other thesis.

Urine analyses were conducted by the staff of the IDAC Laboratory in Riyadh city, Saudi Arabia. I am familiar with all the procedures, and have conducted the majority of them under supervision. The data entery of 24-HDR were entered by Seham Eid S. Almasoudi as part of her master degree work.

I alone completed all other work reported in this thesis. The research for this thesis was carried out between February 2013 and February 2017.

Majid M. Alkhalaf

Chapter One

General Introduction

1.1 Introduction

Non-communicable diseases (NCDs), including type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVDs), cancer and chronic respiratory diseases are responsible for approximately 75% of death worldwide, causing more than 38 million deaths annually (WHO 2015). In the past four decades, the incidence of NCDs has risen dramatically, mainly in low- and middle-income countries (74%) (Miranda, Kinra et al. 2008). Sixteen million NCD deaths (42% of total NCD deaths) occured before the age of 70, and 82% of these "premature" deaths occurred in low- and middle-income countries. Most of NCDs deaths were caused by CVDs and T2DM (17.5 million (46%); and 1.5 million (4%), respectively). The increasing burden of NCDs is considered the main barrier to global development goals including economic stability, poverty reduction, health equity, and human security (Beaglehole, Bonita et al. 2011). NCDs can lead to continued expenditures that snare poor households in cycles of debt and illness, and continuing economic and health inequalities. They also delay a family's ability to provide for and educate children by diminishing household earnings (Mahal, Karan et al. 2010).

Although this increase is associated with metabolic, hormonal and genetic risk factors (WHO 2003; James, Jackson-Leach et al. 2004; Farooqi and O'Rahilly 2006; Kyrou, Chrousos et al. 2006; Srivastava, Lakhan et al. 2007; Kaila and Raman 2008; Miranda, Kinra et al. 2008), an overwhelming body of research indicates that much of the burden of NCDs is attributable to behavioural and environmental factors, including a diet of low or imbalanced nutrition, decreased physical activity, and exposure to tobacco smoke (Lau, Douketis et al. 2007; James 2008; Miranda, Kinra et al. 2008; Tsigos, Hainer et al. 2008). Behavioural and environmental factors lead to key metabolic and physiological changes, such as elevated blood pressure, adiposity, hyperlipidemia and hyperglycemia (WHO 2011). These "intermediate risk factors" can lead to CVDs and T2DM (WHO 2015) (Figure 1.1-1).

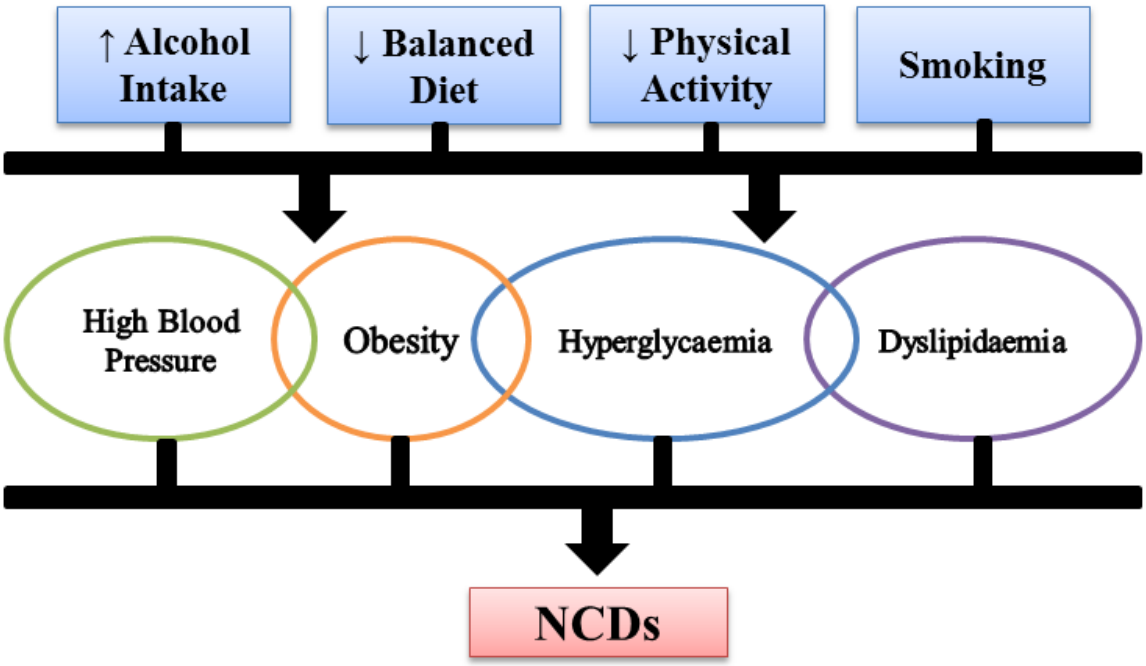


Figure 1.1-1: Model describing the relationship between low levels of physical activity and high energy and salt intakes, T2DM mellitus and cardiovascular diseases.

Abbreviations*: NCDs: Non-communicable diseases; T2DM: type2 diabetes mellitus; CVD: cardiovascular diseases.*

This thesis focuses on prevention and future management of NCDs in Saudi Arabia (SA) through salt intake, body composition and psychological factors such as intention, knowledge and awareness. Socioeconomic status and lifestyle (including dietary habits) have dramatically changed in SA (Alwan 1997; Khatib 2004) following the discovery of oil in the Gulf region in the 1950's (MOPM 2014). As SA also imports nearly two-thirds of its food (Al-Kandari and Jukes 2012), rapid unplanned urbanisation has been accompanied by globalization of nutritionally poor diets and sedentary lifestyles. Currently, SA suffers from a high burden of NCDs and related risk factors (Al-Nozha 2004; Al-Nozha 2004; Al-Nozha, Abdullah et al. 2007; Kilpi 2014) (Table 1.1-1). National surveys in SA indicated that most of the population are physically inactive (68%) and eating less fruits and vegetables (84%) than recommended (WHOSTEPwise 2005). The recent National Health Survey (SHIS) (El Bcheraoui, Basulaiman et al. 2014; El Bcheraoui, Memish et al. 2014; Memish, El Bcheraoui et al. 2014) in 2013 revealed that the prevalence of hypertension, T2DM, and obesity in SA are 15.2%, 13.4% and 28.7%, respectively. These high prevalence levels in the Saudi population are consistent with data from other Arabian Gulf countries (Musaiger and Al-Mannai 2001; Al Rashdan and Al Nesef 2010; Ng, Zaghloul et al. 2011; Musaiger and Al-Hazzaa 2012) such as Kuwait and Bahrain (Musaiger and Al-Mannai 2001). These results are also comparable

with results from the United States of America (USA) and Mexico (OECD 2014; WHO 2014).

In addition, the Ministry of Health (MOH) database indicated that from 1992 to 2010, T2DM diagnosis increased two-fold (Alhowaish 2013). The population of SA has increased by approximately 75% since 2004, with 60% of the current population aged less than 30 years (MOEP 2015). This is as a result of death rate of SA population falling gradually down from 17.7/1,000 people in 1960s to 3.4/1,000 people in 2015 (Knoema 2017). Furthermore, infant mortality rate (per 1000 live births) went gradually down from 45 per 1000 live births in 1990 to 18 per 1000 live births in 2012 (WHO 2012). Life expectancy at birth has increased from 53.9 years in 1970 to 73.8 years in 2013, with a 2.9% growth rate (MOH 2013) which is high in comparision with western countries such as the UK and the USA (0.80%) (The World Bank Group 2017). There is concern that this steep rise in the youthful population will escalate the burden of NCDs in the forthcoming decades alongside the increase of NCDs risk factors (elevated blood pressure, adiposity, hyperlipidemia and hyperglycemia). Evidently, this will cause a financial burden on health care expenses in SA.

Although the primary causes have not been fully elucidated, many of the risk factors associated with NCDs are lifestyle-related and thus, modifiable (WHO/FAO 2003). There is a large body of evidence suggesting that NCDs are potentially preventable providing the risk factors are identified, and prevented early (WHO 2003). Appropriate lifestyle modifications such as diet, physical activity and weight loss are recognised to be similar in effect, or even better, than medical interventions in preventing or delaying the onset of NCDs in high risk people (Goldman and Cook 1984; Tuomilehto, Lindström et al. 2001; Group 2002; Appel, Champagne et al. 2003; Molitch, Fujimoto et al. 2003; Elmer, Obarzanek et al. 2006).

Table 1.1-1: Prevalence (%) of NCDs risk factors in the Kingdom of Saudi Arabia, by sex.

NCDs Factors	Year	Age range	Total	Women	Men
			% (N)	% (N)	% (N)
Current daily Smoking [(1)] (WHOSTEPwise 2005)	2005	15-64	11 (517/4,750)	1.2 (28/2,414)	21 (489/2,336)
Physical inactivity [(2)] (WHOSTEPwise 2005)	2005	15-64	68 (3,109/4,592)	74 (1,740/2,343)	61 (1,369/2,249)
Overweight [(3)] (Memish, El Bcheraoui et al. 2014)	2013	≥15	33 (3457/10,347)	30 (1,599/5,249)	36 (1,858/5,098)
Obesity [(4)] (Memish, El Bcheraoui et al. 2014)	2013	≥15	29 (3,040/10,347)	34 (1,767/5,249)	25 (1,273/5,098)
Increased-risk WC [(5)] (Memish, El Bcheraoui et al. 2014)	2013	≥15	17 (1,808/10,473)	16 (867/5,327)	18 (941/5,146)
High-risk WC [(6)] (Memish, El Bcheraoui et al. 2014)	2013	≥15	34 (3,541/10,473)	44 (2,355/5,327)	23 (1,186/5,146)
Low fruit/vegetables intake [(7)] (WHOSTEPwise 2005) (<5 servings/day)	2005	15-64	99 (4,464/4,528)	99 (2,342/2,360)	98 (2,122/2,168)
Low fruit/vegetables intake [(8)] (WHOSTEPwise 2005) (≤1 servings/day)	2005	15-64	84 (3,799/4,528)	84 (1,983/2,360)	83 (1,816/2,168)

[(1)] Current daily smoking: the percentage of the population who smoke tobacco on a daily basis; [(2)] Physical inactivity: the percentage of the population engaging in less than 30 minutes of moderate activity per week or less than 20 minutes of vigorous activity three times per week, or the equivalent based on Global Physical Activity Questionnaire (GPAQ); [(3)] Overweight: the percentage of the population having a BMI between 25 and 29.99 kg/m^2; [(4)] Obesity: the percentage of the population having a BMI ≥ 30 kg/m^2; [(5)] Increased-Risk WC: the percentage of the population having a WC between 80 and 88 cm for women, and WC between 94 and 102 cm for men; [(6)] High-Risk WC: the percentage of the population having a WC >88 cm for women, and WC >102 cm for men; [(7)] Low fruit and vegetable intake: less than 5 servings of fruit/vegetables per day. [(8)] Very low fruit and vegetable intake: less than or equal 1 serving of fruit/vegetables per day.

WC: waist circumference; BMI: body mass index (weight in kg/height in m^2).

1.2 Obesity and overweight

1.2.1 Aetiology of obesity and overweight

The primary function of adipose tissue is to store excess nutrients as triacylglycerols and to release free fatty acids during fasting (Makki, Froguel et al. 2013). However, when adipose tissue is in excess, chronic metabolic disease such chronic low-grade inflammation, insulin resistance, T2DM and cardiovascular disease (CVD) occurs (Minihane, Vinoy et al. 2015). Therefore, obesity has been defined by the World Health Organization (WHO) as a condition of abnormal and excessive fat accumulation in adipose tissue to the extent that health may be adversely affected (WHO 2000). The increase of body fat appears when daily energy intake (EI) is higher than daily energy expenditure (EE). Total energy expenditure under normal conditions is as follows: 75% of total energy expenditure comes from inactive energy expenditure, indicated by the Basal Metabolic Rate (BSR) ; 10–15% from thermogenic activities; and 10–15% from physical activity or exercise (Yu, Teoh et al. 2006). The increase of body fat is multifactorial and is the result of a complex interaction between behavioural, environmental (including stress), metabolic, hormonal and genetic risk factors (James, Jackson-Leach et al. 2004; Farooqi and O'Rahilly 2006; Kyrou, Chrousos et al. 2006; Srivastava, Lakhan et al. 2007; Kaila and Raman 2008). However, the dramatic increase in the prevalence of obesity over the last three decades is postulated to be mainly a result of behavioural and environmental factors which lead to the adoption of a sedentary lifestyle and increased food energy intake (Lau, Douketis et al. 2007; James 2008; Tsigos, Hainer et al. 2008).

1.2.2 Epidemiology of obesity and overweight

1.2.2.1 Worldwide

The worldwide prevalence of obesity and overweight has nearly doubled in the past 3 decades (Ng, Fleming et al. 2014) (Figure 1.2-1) and is now estimated to affect over 600 million people (WHO 2016). The incidence of obesity and overweight has risen dramatically, not only in high-income countries, but also in low- and middle-income countries (WHO 2014). Obesity and overweight are responsible for more than 36 million deaths annually (63% of global deaths) (Flegal, Kit et al. 2013; WHO 2014) and are considered to be major contributors to the development of non-communicable diseases (NCDs) (NIH-NHLBI 2000; WHO 2000; WHO 2008).

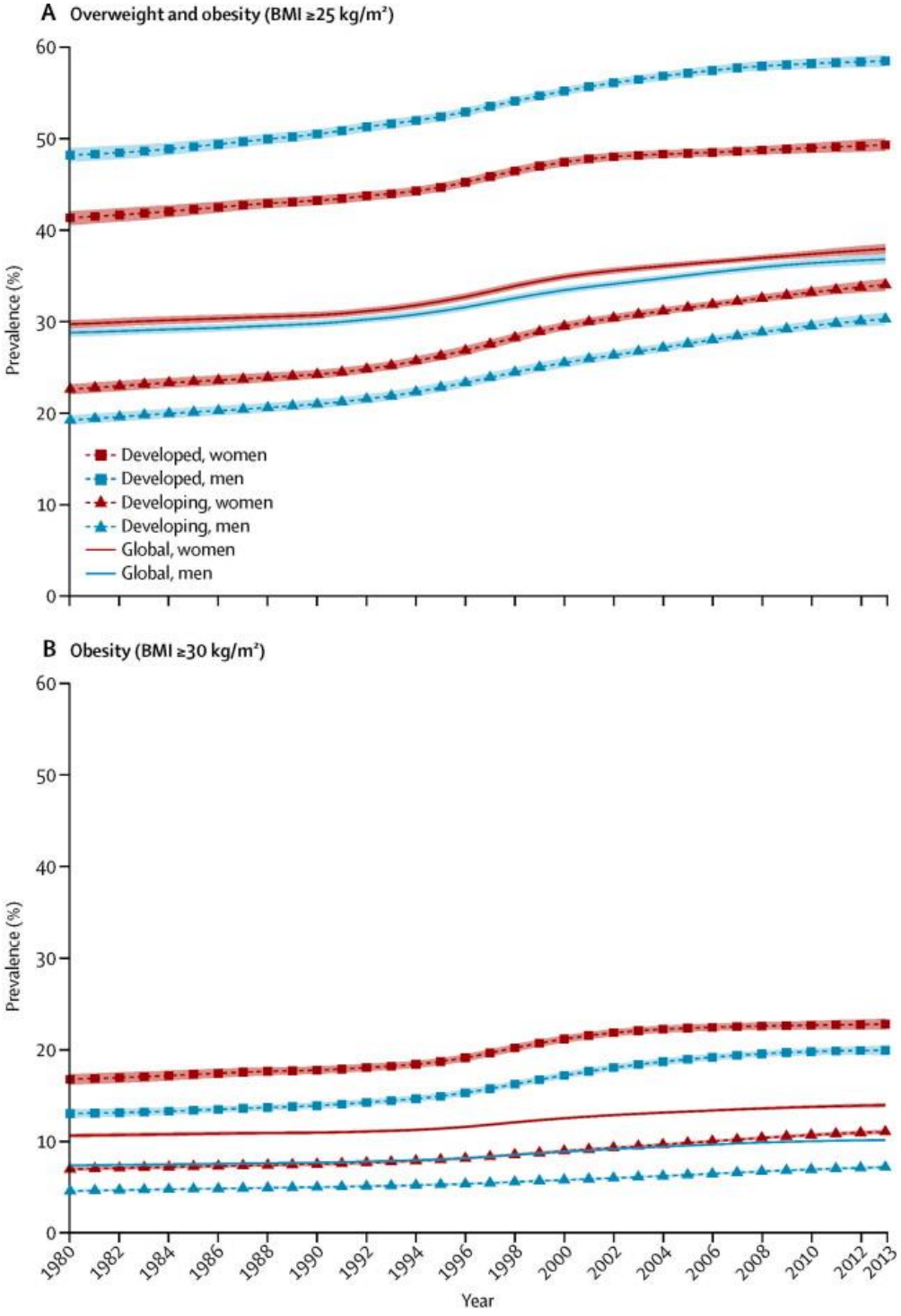


Figure 1.2-1: Age-standardised prevalence of overweight and obesity and obesity alone, aged ≥20 years, by gender, 1980–2013 (Adopted from Ng M et al 2014 (Ng, Fleming et al. 2014))

1.2.2.2 In Saudi Arabia (SA)

Two household cross-sectional studies were conducted covering the whole of SA, in 2004 and 2013, to estimate the prevalence of some of the risk factors of NCDs through interview, physical examination and laboratory examination of blood samples of study participants (WHOSTEPwise 2005; Memish, El Bcheraoui et al. 2014). The recent National Health Survey (SHIS) in SA (2013) (Memish, El Bcheraoui et al. 2014) revealed that the prevalence of obesity in SA is 24 and 34% in men and women, respectively which is lower than that found by the Saudi National Health Survey (SNHS) (28% and 44%, in men and women respectively) (WHOSTEPwise 2005). A multistage stratified cluster random sampling technique was used in both SHIS and SNHS. Although the studies used different methodology and inclusion criteria (post-stratification technique) for their study samples, all studies followed a multistage stratified cluster random sampling of private households considering age and gender of the population. Table 1.2-1 shows the prevalence of obesity (BMI≥30 kg/m^2) in SA from 1985 to 2013. The prevalence of obesity by year-period of obesity (BMI≥30 kg/m^2) nearly doubled since 1985s in SA (**Figure** 1.2-2**)**. Table 1.2-2 shows the prevalence of obesity (BMI≥30 kg/m^2) in Riyadh region from 1985 to 2013.

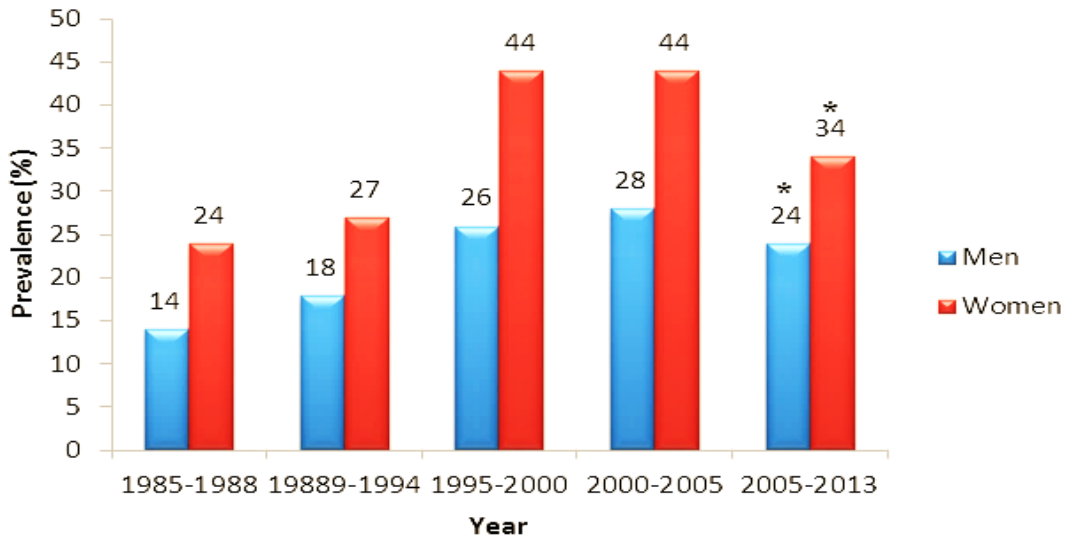


Figure 1.2-2: Estimated prevalence by year-period of obesity (BMI≥30 kg/m^2) among Saudi population, based on the studies outlined in Table 1.2-1.

These findings in this survey cannot be compared with the previous surveys, the prevalence were calculated based on post-stratification technique which eliminates some participants with morbidities.

Table 1.2-1: Obesity prevalence in Saudi Arabian men and women (whole country) from 1985 to 2013

Reference*	Year	Sample Size	Age Range	Obesity Prevalence (BMI≥ 30)			Comments
	(CE)	(N)	(Years)	Overall Obesity (%)	Men (%)	Women (%)	
(Al-Othaimeen, Al-Nozha et al. 2007)	1985-1988	19598	≥18	-	14.2	23.6	(Women: 58%)
(Osman and Al Nozha 2000)	1989-1994	19598	≥18	20.5	15.6	21	(Women: 58%)
(al-Nuaim, al-Rubeaan et al. 1996; Al-Nuaim 1997)	-	13177	15-95	-	16	24	(Women: 48%)
(al-Nuaim, Bamgboye et al. 1997; Alsaif, Khan et al. 2007);	1990-1993	10651	≥20	22.1	17.8	26.6	(Women: 48%)
(El-Hazmi and Warsy 1997; Warsy and El Hazmi 1999)	1992-1996	14660	>14	-	13.1	20.3	(Women: 57%)
(el-Hazmi and Warsy 2000)	1992-1996	14660	14-70	-	13.05	20.3	(Women: 57%)
(Al-Nozha, Al-Mazrou et al. 2005)	1995-2000	17232	30-70	35.6	26.4	44	(Women: 52%); Aged 30-70 years
(WHOSTEPwise 2005)	2004-2005	4758	15-64	36.1	28.3	43.8	(Women: 51%)
(Memish, El Bcheraoui et al. 2014)	2013	10,735	≥15	28.7%	24.1	33.5	(Women: 49%); Post-stratification applied

* All above studies followed a multistage stratified cluster random sampling of private households.

Table 1.2-2: Obesity prevalence in Saudi Arabian men and women in Riyadh region from 1985 to 2013.

Reference*	Year	Sample Size	Age Range	Obesity Prevalence (BMI≥ 30)			Comment
	(CE)	N	(Years)	Overall Obesity (%)	Men (%)	Women (%)	
(Al-Othaimeen, Al-Nozha et al. 2007)	1985-1988	-	≥18	21.7	-	-	-
(Osman and Al Nozha 2000)	1989-1994	1238	≥18	21.7	-	-	-
(al-Nuaim, al-Rubeaan et al. 1996; Al-Nuaim 1997);	-	3288	15-95	-	16	25	
(al-Nuaim, Bamgboye et al. 1997; Alsaif, Hakim et al. 2002);	1990-1993	2663	≥20	-	-	-	-
(al-Shammari, Khoja et al. 1994)	Sept. & Oct. 1992	1385	-	-	-	47	-
(Al-Shammari, Khoja et al. 1996)	May & June 1994	1580	-	-	28.6	-	-
(El-Hazmi and Warsy 1997; Warsy and El Hazmi 1999)	1992-1996	-	>14	-	16.03	24.4	-
(el-Hazmi and Warsy 2000)	1992-1996	1847	14-70		16.03	24.4	-
(Al-Nozha, Al-Mazrou et al. 2005)	1995-2000	-	30-70	40	-	-	Aged 30-70 years old
(WHOSTEPwise 2005)	2004-2005	-	15-64	-	-	-	-
(Al-Daghri, Al-Attas et al. 2011)	2010	9149	7-80	31.1	25.1	36.5	-
(Memish, El Bcheraoui et al. 2014)	April-June 2013	-	≥15	-	-	-	Post-stratification was applied

* All above studies followed a multistage stratified cluster random sampling of private households.

1.2.3 Metabolic features of obesity

1.2.3.1 Insulin resistance (IR) and type 2 diabetes mellitus (T2DM)

1.2.3.1.1 Aetiology of insulin resistance and type 2 Diabetes Mellitus (T2DM)

Several studies support the concept that insulin resistance (IR) and T2DM are states of chronic and low-grade inflammation (Fernández-Real and Ricart 2003; Pickup 2004). In obesity, adipose tissue hypertrophy (especially white adipose tissue) leads to immune cell infiltration, in particular T-cells and macrophages; and increase circulating levels of a local pro-inflammatory cytokines including cytokine tumor necrosis factor alpha (TNF-α), interleukin-L (IL-6) and interleukin-1β (IL-1β). These inhibit the insulin signaling cascade and consequently impair the action of insulin on glucose metabolism in body tissues, mainly the liver and skeletal muscle (Weisberg, McCann et al. 2003; Lumeng, DelProposto et al. 2008; Makki, Froguel et al. 2013). Prospective studies show that insulin resistance precedes the onset of T2DM by 10 to 20 years (DeFronzo, Bonadonna et al. 1992; Imamura, Mukamal et al. 2013). Moreover, cross-sectional studies have revealed that all patients with T2DM are insulin-resistant (Lillioja, Mott et al. 1988). Figure 1.2-3 illustrates the role of adipose tissue in insulin sensitivity and metabolic stress.

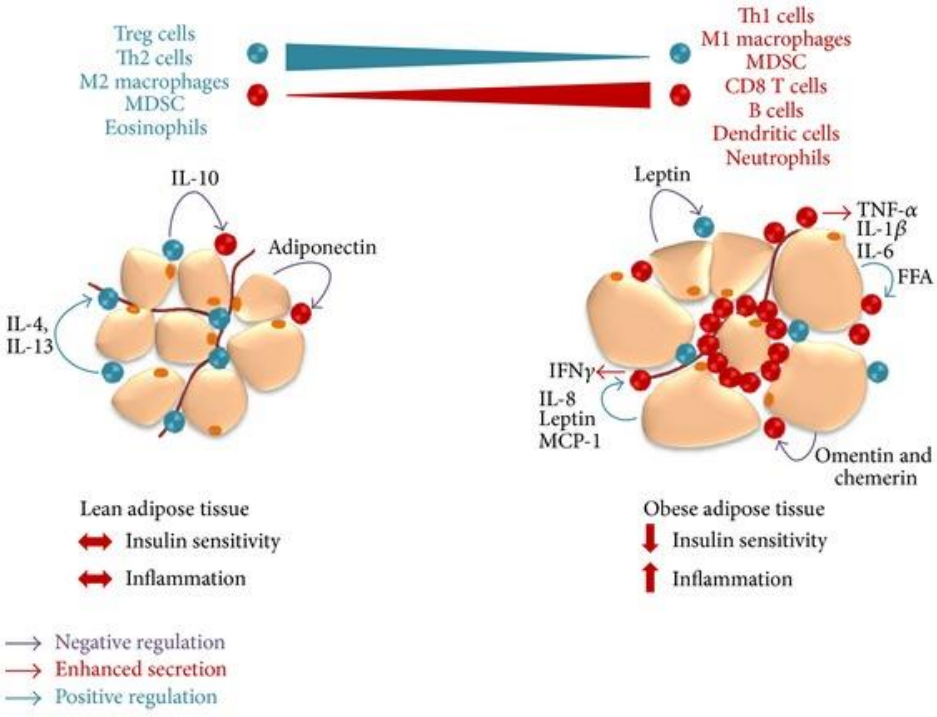


Figure 1.2-3: Adipose tissue-resident cells, hormones and cytokines: role in insulin sensitivity and metabolic stress (adapted and updated from Makki K et al (2013) (Makki, Froguel et al. 2013))

Diabetes mellitus has been defined as *"a chronic disease that occurs either when the pancreas does not produce enough insulin (a hormone that regulates blood sugar, or glucose), or when the body cannot effectively use the insulin it produces"* (WHO 2016). Also, Alberti and Zimmet for the WHO Consultation (1998) defined T2DM as a "chronic hyperglycaemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action, or both." (Alberti and Zimmet 1998). Moreover, insulin resistance is defined as "the inability of a known quantity of exogenous or endogenous insulin to increase glucose uptake and utilization in an individual as much as it does in a normal population." (Lebovitz 2001).

1.2.3.1.2 Epidemiology of insulin resistance and type 2 diabetes mellitus (T2DM)

- Worldwide

Approximately 9% of adults worldwide have been diagnosed with T2DM in 2014 and it is responsible for more than 1.5 million deaths annually (WHO 2016). Approximately 43% of all deaths due to high blood glucose occur before the age of 70, and an estimated 422 million (9% of the adult population worldwide) adults were living with diabetes in 2014, compared to 108 million (4.7%) in 1980 (WHO 2016). The largest number of deaths resulting from high blood glucose (≥ 7.0 mmol/L) occur in upper-middle income countries (1.5 million) and the lowest number in low-income countries (0.3 million) (WHO 2016) (**Figure** 1.2-4). No data is available in SA regarding income and death as result of T2DM. However, the Saudi government provided healthcare for every citizen as stated in Article 31 of the Basic Law of SA, "the State shall protect public health and provide healthcare to every citizen" (BECM 1992). Bloom and colleagues (2012) estimated that losses due to diabetes burden, in GDP, worldwide, from 2011 to 2030, will total US$ 1.7 trillion (including both the direct and indirect costs of diabetes). This comprises US$ 900 billion for high-income countries and US$ 800 billion for low- and middle-income countries (Bloom, Cafiero et al. 2012).

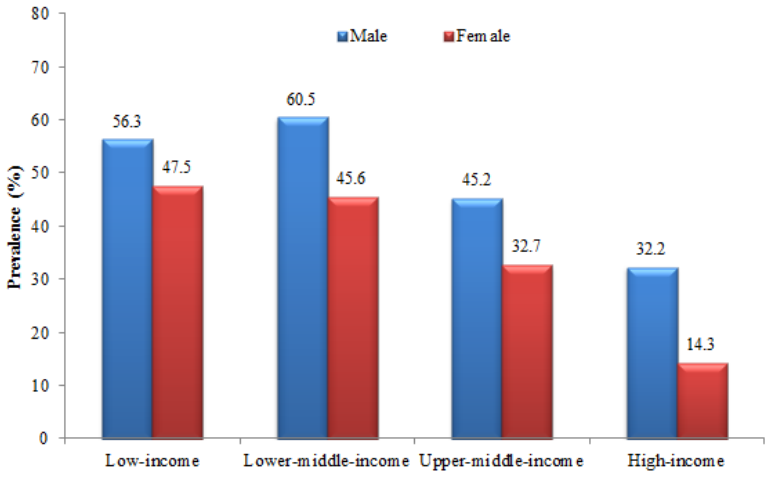


Figure 1.2-4: Percentage of deaths related to high blood glucose that occur at ages 20–69 years, by sex and country income group in 2012 (adopted from (WHO 2016)).

- In Saudi Arabia (SA)

In SA, the recent National Health Survey (SHIS) (2013) revealed that the prevalence of T2DM reached 13.4% (14.8 and 11.7% in men and women, respectively) lower than previously reported by the Saudi National Health Survey (SNHS) (15.3%; 15.8% and 14.9%, in men and women respectively) (WHOSTEPwise 2005; El Bcheraoui, Basulaiman et al. 2014). However, this significant difference in T2DM prevalence came from using different methodology and inclusion criteria for their study sample (Table 1.2-3). Despite differences between the two surveys, the prevalence of T2DM among Saudi adults is still high (WHOSTEPwise 2005; El Bcheraoui, Basulaiman et al. 2014) compared to other countries such as England (6%) in 2014 (PHE 2014). The Ministry of Health database in SA indicated that from 1992 to 2010, T2DM diagnosis increased two-fold (Alhowaish 2013), with a further increase from 12.3% in 2010 to 14.4% in 2014 (raised fasting blood glucose (≥7.0 mmol/L or on medication)) (WHO 2016). The estimated deaths (per 100,000) caused by T2DM increased from 29% (24% in women and 33% in men) in 2000 to 35% (27% in women and 43% in men) in 2012 (WHO 2016). In addition, Alhowaish estimated that the people diagnosed with T2DM have medical healthcare expenditures ten times higher ($3,686 vs. $380) than those without T2DM (Alhowaish 2013).

Table 1.2-3: Evidence table of T2DM prevalences in Saudi Arabian men and women in Riyadh region from 1989 to 2013.

Reference	Year	Sample Size	Age Range	Cut-off Level	T2DM Prevalence			Comment
	(CE)	(N)	(Years)	mmol/L	Overall T2DM (%)	Men (%)	Women (%)	
(Al-Nozha M 1996)	1989-1994	13700	≥18	≥6.1	12.9	-	-	Measured fasting blood sugar only
(El-Hazmi, Warsy et al. 1996); (Warsy and El Hazmi 1999)	1992-1996	14660	14-70	≥7.0	-	7.0	9.7	Measured fasting blood sugar only
(Al-Nozha, Al-Maatouq et al. 2004)	1995-2000	17232	30-70	≥7.0	23.7 (21.9*)	26.2 (22.4*)	21.5 (21.5*)	Measured fasting blood sugar only
(Saeed, Al-Hamdan et al. 2011) ; (WHOSTEPwise 2005)	2004-2005	4758	15-64	≥7.0	15.3	15.8	14.9	Diagnosed only
(El Bcheraoui, Basulaiman et al. 2014)	2013	10,735	≥15	≥8.5 (≥ 6.5%)	13.4	14.8	11.7	Measured blood sugar and/or having diabetes medications

* Adjusted with the census data in Saudi Arabia 2000; SBP: systolic blood pressure; DBP: diastolic blood pressure

1.2.3.2 Elevated blood pressure hypertension

Hypertension or elevated blood pressure (BP) is a condition in which the blood vessels have persistently raised pressure above certain threshold values (Giles, Materson et al. 2009) (Table 1.2-4). The World Health organization and The International Society of Hypertension (WHO/ISH) Guideline (WHO/ISH 2003) classified blood pressure to 3 grades of hypertension as illustrated in Table 1.2-4.

Table 1.2-4: The WHO/ISH blood pressure classification.

Blood Pressure	Grade 1	Grade 2	Grade 3
SBP (mm Hg)	140-159	160-179	≥ 180
DBP (mm Hg)	90-99	100-109	≥ 110

SBP: systolic blood pressure; DBP: diastolic blood pressure.

1.2.3.2.1 Aetiology of hypertension

The kidneys and hormones have a central role in maintaining sodium, water balance and blood pressure in human body through the renin-angiotensin system (RAS) (Lewis, Dirksen et al. 2014). Cells in the kidney release the enzyme called renin when blood volume or sodium levels in the body are low, or blood potassium is high. Renin converts angiotensinogen (produced in the liver) to the hormone angiotensin I. Then, angiotensin-converting enzyme (found in the lungs) metabolizes angiotensin I into angiotensin II. This causes blood vessels to be constricted and blood pressure increases due to the effect of the Angiotensin II. Also, Angiotensin II stimulates the release of aldosterone hormone (found in the adrenal glands). This causes the renal tubules to retain water and sodium and excrete potassium (Wilken and Juneja 2008; de Kloet, Krause et al. 2010). Figure 1.2-5 illustrates the mechanism behind blood pressure homeostasis and sodium regulation in the human body. However, some factors such as excess body fat and salt intake can affect this regulation, causing elevated blood pressure (hypertension). This relationship is complex, with multiple interconnected factors such as sodium intake and body fat participating in the pathophysiology of hypertension.

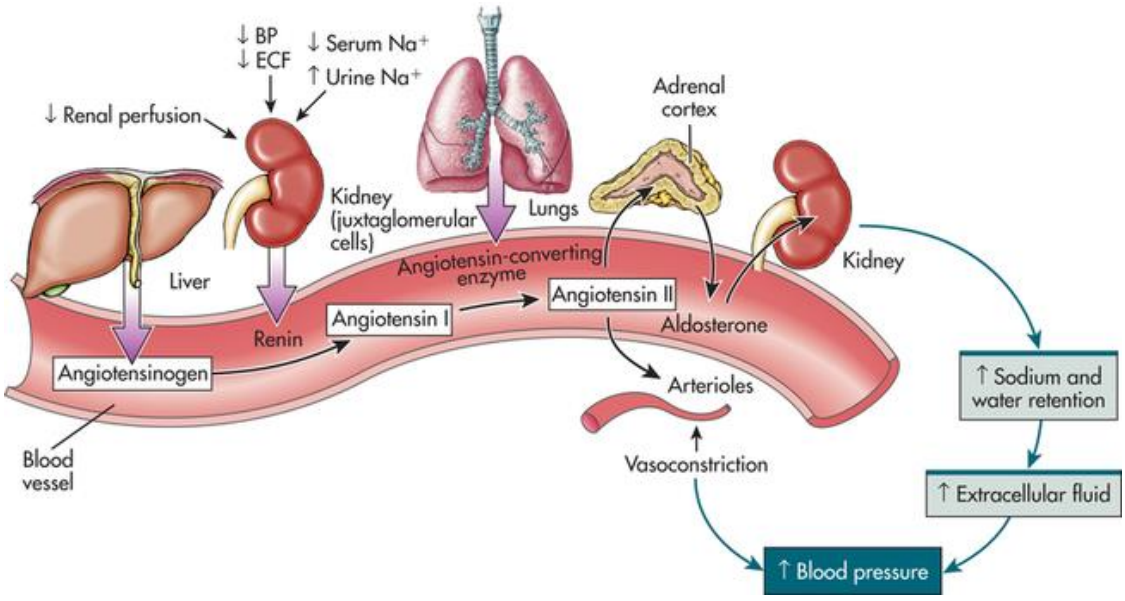


Figure 1.2-5: The mechanism of blood pressure homeostasis and sodium regulation in human body (adopted from Lewis et al 2014 (Lewis, Dirksen et al. 2014))

1.2.3.2.1.1 Excess adipose tissue and hypertension

Excess adipose tissue is an established risk factor for hypertension, insulin resistance and T2DM (Hotamisligil and Erbay 2008). In 1966, Welborn et al. first reported an association of elevated blood pressure and insulin resistance or hyperinsulinemia (Welborn, Breckenridge et al. 1966). Insulin has important effects on the endothelial cells by increasing production of nitric oxide (NO) and stimulating vasodilatation (Ritchie, Ewart et al. 2004). However, in insulin resistance state, reduction of NO bioavailability occurs, resulting in an endothelial dysfunction such as a defect on endothelium-blood interaction, abnormal vasomotor activity, development of a procoagulant endothelial surface, intimal growth and inflammation (Steinberg, Chaker et al. 1996; Villela, Kramer-Aguiar et al. 2009).

Adipose tissue, considered the major source of angiotensinogen after the liver, is a peptide hormone that causes vasoconstriction and could contribute to the elevation of blood pressure and thus cardiovascular diseases (Umemura, Nyui et al. 1997; Van Harmelen, Ariapart et al. 2000). Adiponectin regulates lipid and glucose metabolism, increases insulin sensitivity, protects against metabolic inflammations, and regulates body weight (Dridi and Taouis 2009; Liu and Liu 2010; Makki, Froguel et al. 2013). Adiponectin also increases NO production in endothelial cells and consequently enhances endothelial cell proliferation (angiogenesis) (Chen, Montagnani et al. 2003). However, levels of adiponectin were found to be significantly lower in obese people than healthy (Arita 2012). A prospective study among 18,225 males found that the highest quintile of adiponectin levels had a significantly decreased risk of Myocardial Infarction (relative risk [RR], 0.39; 95% confidence interval [CI], 0.23-0.64; P= 0.001) (Pischon, Girman et al. 2004). In addition, a prospective study on nearly 4,500 Caucasian men and women found that a low level of adiponectin is associated with hyperglycemia (impaired fasting glycaemia or T2DM) (p=0.005) (Fumeron, Aubert et al. 2004). Moreover, a cross-sectional study among 33 hypertensive and 33 normotensive BMI-matched subjects found a negative correlation between plasma adiponectin concentration and mean, systolic, and diastolic blood pressure (9.1 μg/mL (±4.5) and 13.7 μg/mL (±5.2) in hypertensive and normotensive subjects, respectively; $p<0.001$) (Adamczak, Wiecek et al. 2003).

-High salt intake, hypertension and NCDs

There is a strong body of evidence supporting the association between chronic high-sodium intake (in the form of salt (NaCl)), and hypertension (Meneton, Jeunemaitre et al.

2005; He and MacGregor 2009; Blaustein, Leenen et al. 2012; He and MacGregor 2015; Johnson, Raj et al. 2015), which is one of the main influential factors in the development of cardiovascular diseases (CVDs) such as stroke and heart diseases (independent from those adjusted for BMI, age and alcohol intake) (He, Burnier et al. 2011; Soga and Pandey 2011).

Intervention studies on normal Sprague-Dawley rats found that a prolonged high-salt diet decreased renal expression (mRNA) of vascular endothelial growth factor (VEGF) by 45% compared to the normal salt group (0.55±0.12 versus 1.0±0.16; n= 6;$p<0.01$) (Gu, Bailey et al. 2008; Gu, Young et al. 2009). A study on the same animal model found that inhibition of the VEGF receptor by high salt intake enhances -induced hypertension by increasing blood pressure (157.6 ±3.9 versus 125.9 ±4.3 mmHg, $p<0.01$); and increasing VEGF (10 ng/ml) significantly increased endothelial nitric oxide synthase protein levels by 29% in cultured human glomerular microvessel endothelial cells (HGMEC) (Gu, Manning et al. 2009).

The INTERSALT study assessed the association between salt intake (using 24 hour urine samples) and blood pressure in over 10,000 subjects in 52 locations worldwide (Elliott 1988). This cross-sectional study found a significant positive association between 24 hour urinary sodium excretion and systolic blood pressure after adjustment for age, sex, BMI, and alcohol intake (regression coefficient: 0.003 mm Hg/year/mmol sodium; $p<0$ 001). However, when 4 centres with low urinary sodium excretion (0.2–50 mmol/24 hour) were excluded, the effect was lost. The rank order (Spearman) correlation coefficients were significant in the analyses for both n=52 and n=48 centres ($r=0.451$, $p<0$ 001; and $r=0$ 305, $p=0.03$, respectively). The study results were re-analysed in 1996 and confirmed the relationships between sodium excretion and blood pressure across and within-population (Elliott, Stamler et al. 1996). Individual 24 hour urinary sodium excretion higher than 100 mmol (5.8 gram salt/day) was associated with systolic/diastolic blood pressure higher on average by 3/0 to 6/3 mm Hg (with and without BMI adjustment). Across populations (n=52), a sample median 24 hour sodium excretion higher than 100 mmol (5.8 gram salt/day) was associated with median systolic/diastolic pressure higher on average by 5-7/2-4 mm Hg than those with 24 hour sodium excretion less than 100 mmol (Elliott, Stamler et al. 1996).

In most recent meta-analyses of randomised controlled trials (2013) (He, Li et al. 2013) a longer-term modest reduction in salt intake (4.4 g/day) resulted in significant reduction in

blood pressure in both men and women, hypertensive and normotensive individuals, in all ethnic groups, and in all age groups (He, Li et al. 2013). In normotensive people, the mean effect was −2.4 mm Hg (−3.5 to −1.3, I^2=66%) for SBP and -1.00 mm Hg (-1.85 to -0.15, I^2=66%) for DBP. Also, in people with hypertension the mean effect was −5.4 mm Hg (-6.62 to -4.15, I^2=61%) for SBP and -2.8 mm Hg (-3.54 to -2.11, I^2=52%) for DBP, respectively. All above heterogeneity results (I^2) were above 50% which is considered to be important. Although there was a variation in the extent of the fall in BP among different groups, the significant effect of salt reduction on BP was demonstrated.

In 2014, the Prospective Urban Rural Epidemiology (PURE) study, the largest cohort in 18 countries enrolling 102,216 subjects, showed increments of 2.1 mm Hg in systolic blood pressure and 0.78 mm Hg in diastolic blood pressure for each 1 g increment in estimated sodium excretion (Mente, O'Donnell et al. 2014). However, the slope of association was steeper for those with hypertension (2.49 mm Hg/gram) than those without (1.30 mm Hg/gram, P<0.001 for interaction). The most recent analysis of 133,118 individuals from 49 countries in four large prospective studies found that increased sodium intake was associated with greater increases in systolic blood pressure in individuals with hypertension (2.08 mm Hg change per gram sodium increase) compared with individuals without hypertension (1.22 mm Hg change per g; P<0.0001 for interaction). However, both of these studies (Mente, O'Donnell et al. 2014; Mente, O'Donnell et al. 2016) (above) used a formula-derived estimate of 24h urinary sodium excretion from spot urine sample, not actual 24-H urinary excretion measurements which may affect the accuracy of salt intake (He, Ivkovic et al. 2015). In contrast, a systematic review (2015) of 11 clinical salt studies; and 186,357 individual) confirmed a causal relationship between increasing dietary salt and increased blood pressure (Johnson, Raj et al. 2015) and the authors concluded that the findings of the systematic review were consistent with previous data relating increased dietary salt to increased blood pressure and adverse health outcomes.

In SA, there is little information on habitual salt intake apart from one study in the Eastern region (8.1 g/day) using 24-Hour urinary samples, not representative of the general population (Alkhunaizi, Al Jishi et al. 2013). Some samples from potential kidney donors and patients who underwent work-up for nephrolithiasis were used in this study.

Several studies have linked hypertension and elevated blood pressure with NCDs and premature death. A meta-analysis of individual data for 1 million adults in 61 prospective studies found that the blood pressure (SBP/DBP) starting at 115/75 mm Hg is a major cause of cardiovascular diseases (CVD) (Lewington, Clarke et al. 2002). These authors also concluded that, at ages 40-69 years, each difference of 20 mm Hg usual SBP (or 10 mm Hg usual DBP) is associated with more than a twofold difference in the stroke death rate, and with twofold differences in the death rates from IHD and from other vascular causes. A longitudinal study (n=6,859) (the Framingham Heart Study) also revealed that blood pressure values in the 130/85 to 139/89 mm Hg range are associated with a more than 2-fold increase in relative risk from CVDs compared with those with blood pressure levels less than 120/80 mm Hg (Vasan, Larson et al. 2001).

In 2010, a recent updated analyses of the Global Burden of Disease Study (GBD) revealed that 10% (1.7 million/17.5 million) of annual deaths from CVD causes have been attributed to excess sodium (salt) intake (>2 g sodium/day, equivalent to 5 g salt/day); more deaths occur in men than women (Mozaffarian, Fahimi et al. 2014). The GBD study also considered high blood pressure as a leading risk factor in 2010 causes of adult chronic disease, especially cardiovascular diseases and cancers and followed by tobacco smoking, household air pollution, diets low in fruits, and alcohol use (**Figure** 1.2-6) (Lim, Vos et al. 2013). High blood pressure was also considered the first leading risk factor in 2010 for global disease burden (7.0% (95% uncertainty interval 6.2–7.7) of global DALYs). In this analysis, 1.65 million deaths in 2010 were linked to dietary salt in excess of 5 g of salt per day (>2.0 g sodium/day) (Lim, Vos et al. 2013).

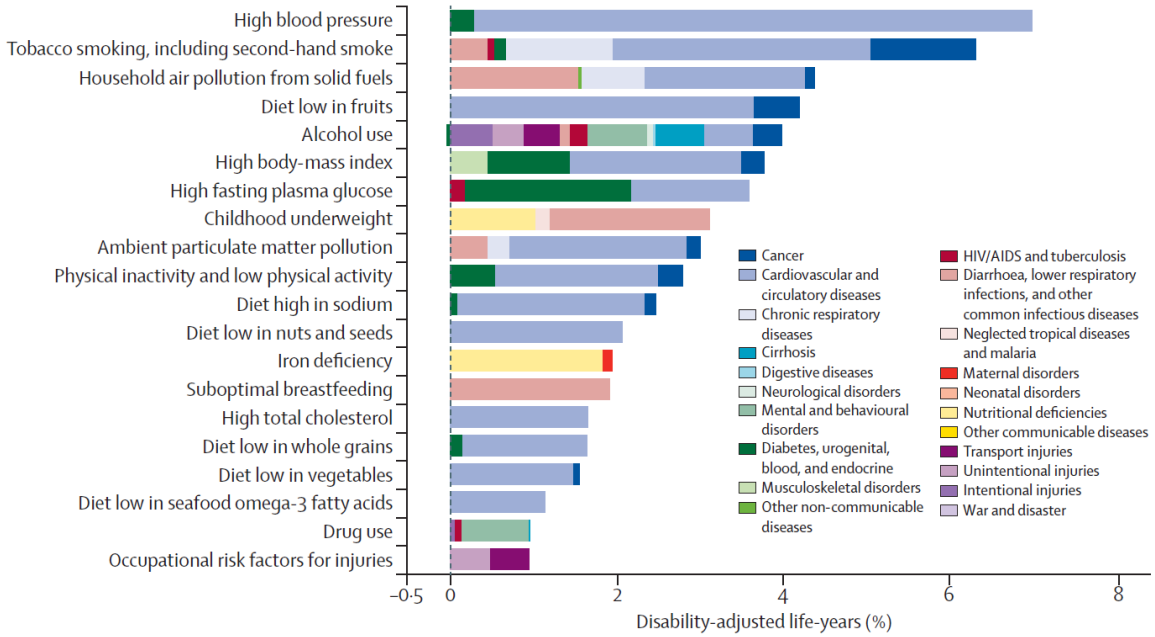


Figure 1.2-6: Burden of disease attributable to 20 leading risk factors in 2010, expressed as a percentage of global disability-adjusted life-years (DALYs) for both men and women (adapted from Lim SS et al 2013 (Lim, Vos et al. 2013).

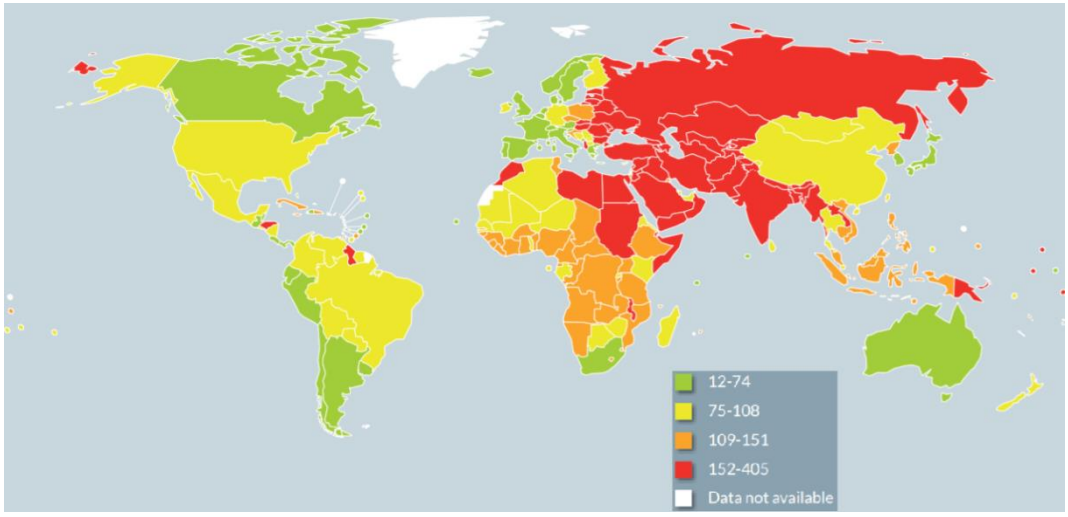
In the most recent study among 133,118 individuals from 49 countries in four large prospective studies, (Mente, O'Donnell et al. 2016) found a U-shape association between salt intake, and CVDs and death. There was also a higher risk (HRs) of CVDs and death only in individuals with hypertension (prescribed antihypertensive drugs or 140/90 mm Hg or greater) consuming more than the recommended levels (>6 g salt/day) using Cox proportional hazards models. This study concluded that the lowering sodium efforts should target those individuals with high sodium intake and who are hypertensive. However, both of these studies (above) used a formula-derived estimate of 24-H urinary sodium excretion from spot urine sample, not actual 24-H urinary excretion measurements. Therefore, the value of salt intake might be inaccurate although this measurement was validated (He, Ivkovic et al. 2015). Salt intake varies from day to day – that even a single 24 hour urine collection cannot account for (Cappuccio and Campbell 2016). Also, when people are dying their salt intake is low due to low food intake or no food at all. Therefore, it is their illness that is causing their low salt intake and death, not their low salt intake causing their death (Cappuccio and Campbell 2016).

1.2.3.2.2 Epidemiology of hypertension

In 2008, approximately 40% of adults worldwide, aged 25 and above, were diagnosed with hypertension, which is responsible for more than 9 million deaths annually (WHO

2013). Hypertension is responsible for at least 51% of deaths due to stroke and 45% of deaths due to heart disease (WHO 2011; WHO 2013) (Figure 1.2-7). In 2014, high-income countries had a lower prevalence of hypertension than other income groups (Low-income, Lower middle income, and Upper middle income countries) (WHO 2011; WHO 2015) (Figure 1.2-8). The recent National Health Survey (SHIS) in SA (2013) (El Bcheraoui, Memish et al. 2014) revealed a prevalence of hypertension of 15 (18 and 13% in men and women, respectively) which is lower than that been found by the Saudi National Health Survey (SNHS) (21%; 24% and 19%, in men and women respectively) (WHOSTEPwise 2005) (Table 1.2-5). However, the prevalence of hypertension is still high (El Bcheraoui, Memish et al. 2014; MOH 2014).

(a)



(b)

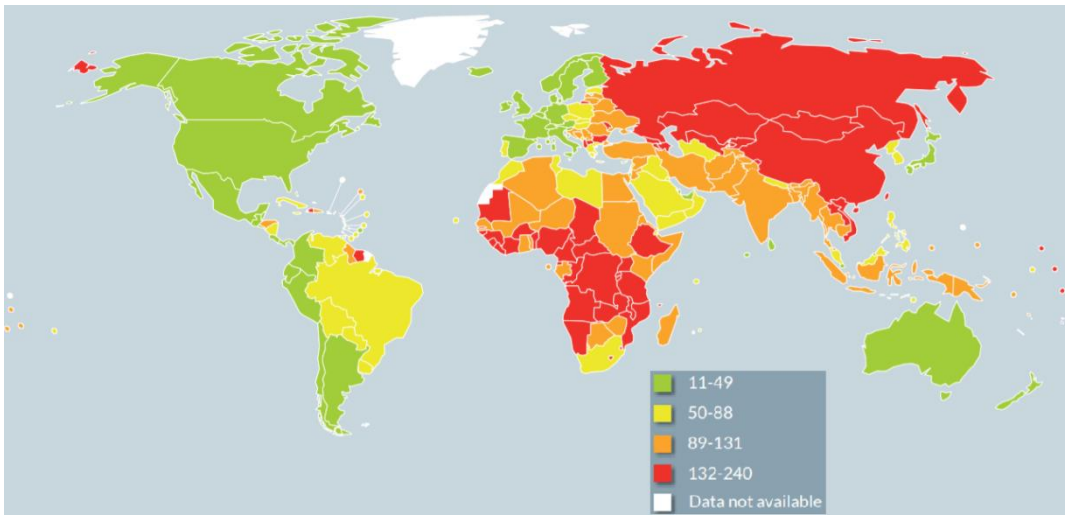


Figure 1.2-7: Total ischemic heart disease mortality rates (a) and cerebrovascular disease mortality rates (b) adopted from WHO report (WHO 2013).

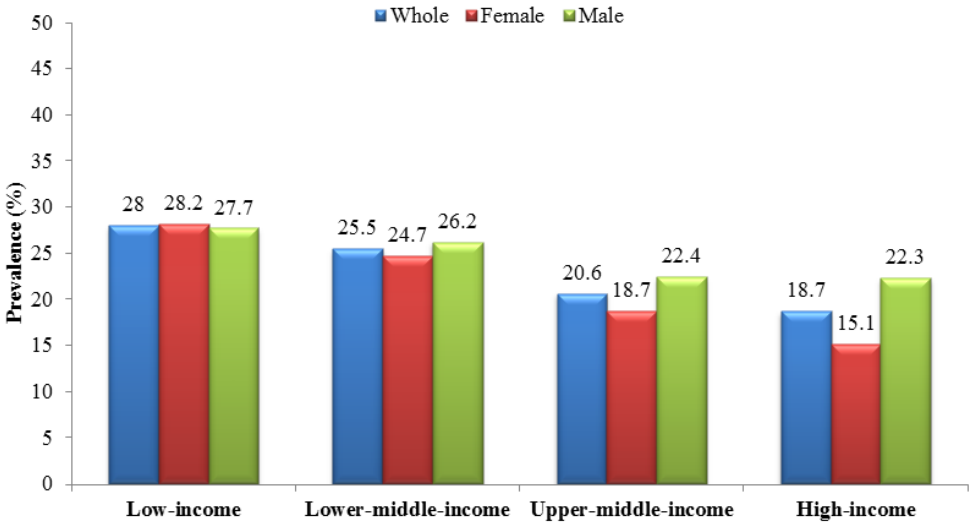


Figure 1.2-8: Prevalence of raised blood pressure (SBP≥140 OR DBP≥90)* based on categorised income countries (age-standardized estimate) (Figure was created based on the Global Health Observatory Data Repository, WHO (WHO 2015)) [£ $].

[*] *SBP: systolic blood pressure; DBP: diastolic blood pressure.*

[$] *Countries were categorised to four different groups; Low-income countries (e.g. Afghanistan, Bangladesh, Malawi and Nepal); Lower-Middle-income countries (e.g. Armenia, Brazil; Pakistan and Sri Lanka); Upper middle income countries (e.g. Albania, Algeria, Angola, Argentina); and High income (e.g. Australia, Austria, Bahamas, Bahrain).* [£] *This regional grouping classifies countries, areas and territories according to the World Bank analytical income of economies based on the 2015 Atlas gross national income per capita estimates (World Bank list of economies, July 2016 (WHO 2016)).*

Table 1.2-5: Hypertension prevalences in Saudi Arabian men and women in Riyadh region from 1985 to 2013.

Reference	Year	Sample Size	Age Range	Cut-off Level	Hypertension Prevalence			Comment
	(CE)	(N)	(Years)	mmHg	Overall (%)	Men (%)	Women (%)	
(Al-Nozha, Ali et al. 1997); (Al-Nozha and Osman 1998)	1989-1994	13700	≥18	≥160/≥95	5.2(SBP) & 7.3(DBP)	5.3(SBP) & 8.2 (DBP)	5.2(SBP) & 6.6 (DBP)	Measured blood pressure only
(Al-Nozha, Ali et al. 1997); (Al-Nozha and Osman 1998)	1989-1994	13700	≥18	≥140/≥90	20.4(SBP) & 25.9(DBP)	-	-	Measured blood pressure only
(Al-Nozha, Abdullah et al. 2007)	1995-2000	17230	30-70	≥140/≥90	26.1 (24.3*)	28.6	23.9	Adjusted with the census data in SA 2000
(El-Hazmi and Warsy 1999); (Warsy and El Hazmi 1999)	1992-1996	14660	14-70	≥140/≥90	-	5.39	3.65	Measured blood pressure only
(Saeed, Al-Hamdan et al. 2011) ; (Saeed and Al-Hamdan 2013); (WHOSTEPwise 2005)	2004-2005	4758	15-64	≥140/≥90	21.3	24.2	18.5	Measured blood pressure and/or having hypertensive medications
(El Bcheraoui, Memish et al. 2014; MOH 2014)	2013	10,735	≥15	>139/>89	15.2	17.7	12.5	Measured blood pressure and/or having hypertensive medications

* Adjusted with the census data in Saudi Arabia 2000; SBP: systolic blood pressure; DBP: diastolic blood pressure.

- Salt reduction and NCDs

Several clinical studies, meta-analysis and systematic reviews of the impact of salt intake reduction show improved flow-mediated vasodilation and aortic stiffness, reduction in systolic and diastolic blood pressure, and reduction in stroke and ischaemic heart disease (IHD) prevalence.

A systematic review of clinical salt studies shows that the reduction of salt intake improved flow-mediated vasodilation and aortic stiffness (Johnson, Raj et al. 2015). In a meta-analysis of randomized trials (2002) (He and MacGregor 2002) (17 trials in hypertensives (n=734) and 11 trials in normotensives (n=2,220)) found a reduction of 100 mmol/day (6 g salt/day) in salt intake based on 24-h urinary sodium excretion predicted a fall in blood pressure of 7/4 mmHg ($P<0.001$ for both SBP and DBP) in hypertensives and 3.6/1.7 mmHg in normotensive individuals (SBP: $P<0.001$; DBP: $P<0.05$). This meta-analysis estimated that a reduction of 6 g/day in salt intake would

reduce stroke by 24% and ischaemic heart disease (IHD) by 18%. It would also be predicted to reduce stroke deaths immediately by ≈6% and coronary deaths by ≈4% in normotensives, and reduce stroke and coronary deaths by ≈14 and ≈9%, in hypertensives, respectively (He and MacGregor 2002).

The Dietary Approaches to Stop Hypertension (DASH) diet trial (Sacks, Svetkey et al. 2001) is a well-conducted clinical trial in total of 412 subjects who were provided the DASH diet (rich in fruits and vegetables and low fat dairy products) compared to a typical American diet for 30 consecutive days. Reduction in salt intake to below the current recommendation of 5.8 g salt per day (<100 mmol/day) and the DASH diet both were significantly associated with lower systolic blood pressure by 2.1 mm Hg ($P<0.001$) for controlled diet and 1.3 mm Hg ($P=0.03$) for DASH diet.

Cook and colleagues (2014) conducted a reanalysis of a cohort study that examined the relationship between sodium intake and CVD (Cook, Appel et al. 2014). This analysis included 1,855 pre-hypertensive subjects aged 30 to 54 years from 1987 to 1990, and 1,191 subjects from 1990 to 1995 from phases 1 and 2 of the Trials of Hypertension Prevention (TOHP). The cohort findings showed that risk of CVD for subjects whose salt intake was <5.75 g per 24 hours (sodium <2300 mg) was 32% lower compared with those who had salt intakes from 9 g to <12 g per 24 hours (sodium 3600–<4800 mg). Also, findings showed a linear 17% increase in risk per 2.5-g increase in salt (sodium 1000 mg and concluded that the study findings were consistent with overall health benefits of reducing salt intake to between 3.75 g and 5.75 g/day (sodium 1500– 2300 mg/day) agreeing with current guidelines.

Analysis of the data from the Health Survey for England (n=31,672) was conducted to determine the relationship between reduction in population salt intake and fall in BP and mortality from stroke and ischaemic heart disease (IHD) during 2003 to 2011 (He, Pombo-Rodrigues et al. 2014). The authors analyzed the Health Survey data for England for subjects aged 16 years and older. The study revealed a reduction in mortality from stroke by 42% and from IHD by 40% from 2003 to 2011. There was also a fall in systolic (3.0 ±0.33) and diastolic blood pressure (1.4 ±0.20 mmHg), an increase in fruit and vegetable consumption of 0.2 (±0.05) per day, a reduction in smoking prevalence from 19% to 14%, a reduction in blood cholesterol levels (of 0.4 ±0.02 mmol/L), and an increase in body mass index (BMI) of 0.5 ±0.09 kg/m^2. After adjusting for age, alcohol consumption, BMI, education, ethnic group, sex, fruit and vegetable intake, and

household income in subjects not treated for hypertension, there was a fall in systolic (2.7 ±0.34) and diastolic blood pressure (1.1 ±0.23 mm Hg). At the same time, there was a reduction of salt intake (24-hour urinary sodium) by 1.4 g salt/day (sodium 560 mg/day) between 2003 and 2011. It was concluded that the reduction in salt intake between 2003 and 2011 was likely to be an important contributor to the fall in blood pressure. As a result of this, the reduction of salt intake could have played an important role in the mortality reduction of stroke and IHD during this period (He, Pombo-Rodrigues et al. 2014).

1.3 Body composition measurement instruments (adiposity and muscle mass assessment tools)

1.3.1 Imaging, scanning and impedance analysis techniques

1.3.1.1 Magnetic resonance imaging (MRI) and Computed tomography (CT)

Computed tomography (CT) and Magnetic resonance imaging (MRI) can measure skeletal muscle mass (SMM) and adipose tissue volumes accurately (Fosbøl and Zerahn 2015). CT been validated for body composition measurement by studies of human cadavers (Rössner, Bo et al. 1990; Engstrom, Loeb et al. 1991; Mitsiopoulos, Baumgartner et al. 1998). Moreover, MRI been validated for body composition measurement by studies of human cadavers, phantoms and animals, showing good agreement with values produced by dissection and chemical analysis (Fowler, Fuller et al. 1991; Ross, Leger et al. 1991; Abate, Burns et al. 1994; Mitsiopoulos, Baumgartner et al. 1998). Ross et al. (1991) shows that MRI was correlated strongly with CT in predicting visceral fat (r=0.98, standard error of estimate (SEE) =6.8 cm^2), subcutaneous fat (r=0.98, SE=6.5 cm^2) and total adipose tissue volumes (r=0.99, SE=9.0 cm^2) (P <0.001) in rodents. MRI also correlated strongly with lipid values (r=0.99, SE=6.9) (Ross, Leger et al. 1991). Human cadavers were used to examine the validity of MRI abdominal subcutaneous and visceral adipose tissue estimates. The overall agreement between dissection weight and MRI-estimated adipose tissue weights was 6% with less than 5% bias (Abate, Burns et al. 1994). Human cadavers were also used by to examine the validity of MRI and CT adipose tissue-free skeletal muscle (ATFSM) (Mitsiopoulos, Baumgartner et al. 1998). This study shows that both MRI and CT estimates of ATFSM

were highly correlated with corresponding cadaver values (MRI: r =0.99, SEE= 3.9 cm^2, P<0.001; and CT: r=0.99, SEE=3.8 cm^2, P<0.001). Also, this study found a strong correlation between MRI-ATFSM and the cadaver values (r=0.99, SEE=8.7 cm^2, P<0.001).

Nevertheless, these methods are not feasible for large epidemiologic studies and in clinical settings because of the high cost, high radiation exposure in CT, and they are time consuming (Springer, Ehehalt et al. 2012; Fosbøl and Zerahn 2015). MRI measurement is difficult to perform in subjects with extreme adipose tissue and skeletal muscle (Peeters, Tanamas et al. 2016) and cannot measure variations in fat within cells (e.g. the muscle or liver) (Peeters, Tanamas et al. 2016).

1.3.1.2 Dual-energy X-ray absorptiometry (DEXA)

Dual-energy X-ray absorptiometry (DEXA) has been used to measure bone mineral content, bone mineral density, and body composition including body fat and fat-free mass in vivo (FSANZ 1998; Peeters, Tanamas et al. 2016). Body fat and appendicular portion of skeletal muscle mass can be measured with good precision using DEXA (with ≈5.1% bias) (Heymsfield, Smith et al. 1990; Wang, Visser et al. 1996) which accounts for >75% of total body skeletal muscle and ≈83% for total body fat (Snyder, Cook et al. 1974; Plank 2005; Chen, Wang et al. 2007). DEXA is based on deriving total body volume by integrating information obtained from several cross-sectional CT images computerized axial tomography (CT) images. However, DEXA is not suitable for a routine body composition assessment because of its associated radiation exposure (ionizing radiation) and cost (Wang, Visser et al. 1996). Gradmark et al. (2010) found that simple anthropometric measures, especially waist circumference (r=0.85; P<0.0001) yielded better estimates of visceral adipose tissue than DEXA (r=0.70; P<0.0001) using CT as a validation tool (Gradmark, Rydh et al. 2010). However, Micklesfield et al. (2012) (Micklesfield, Goedecke et al. 2012) and Kaul et al. (2012) (Kaul, Rothney et al. 2012) confirmed the validity of DEXA (r=0.93) in assessing visceral adipose tissue against CT.

1.3.1.3 Body impedance analysis (BIA)

Body impedance analysis (BIA) method is the most commonly used body composition technique in published studies to derive data on both body fat and lean tissues (Ellis and Wong 1998). BIA is an indirect method to measure body composition. It is inexpensive,

low maintenance, portable, and has quick and safe application, and needs minimal operator training (Kushner 1992; Ellis and Wong 1998). BIA analysis is based on the principle that electric current flows at different rates through the body and depends on the water content of body composition. (Peeters, Tanamas et al. 2016). As adipose tissue is significantly less conductive than muscle or bone (Scharfetter, Schlager et al. 2001), the electric current flows are proportional to total body water and to high water concentration tissues such as skeletal muscles. Therefore, the percentage fat mass and fat-free mass from BIA are estimated based on derived equations age, height, gender and weight (Dehghan and Merchant 2008). ESPEN guidelines suggest that BIA works well in healthy subjects as well as in patients with a stable balance of water and electrolytes and with a validated BIA equation that is appropriate regarding to age, sex and race (Kyle, Bosaeus et al. 2004).

Malavolti and colleagues show that eight-polar BIA provides valid and accurate estimates of total and appendicular body composition when validated against DEXA (Malavolti, Mussi et al. 2003). However, they raised questions about the accuracy of using BIA in body composition research. BIA estimated results (e.g. fat-free mass) can be affected by body position, dietary intake, hydration status, previous exercise and skin temperature (Konings, Kooman et al. 2003; Peeters, Tanamas et al. 2016), and the quantitative evaluation of body fat such as visceral adipose tissue may not be performed accurately (Springer, Ehehalt et al. 2012). BIA analysis has less reliable estimates with individuals with relatively high or low fat mass (Fosbøl and Zerahn 2015; Otto, Färber et al. 2015). As it is known that the body fat outcomes from BIA are highly dependent on these equations (Fosbøl and Zerahn 2015; Peeters, Tanamas et al. 2016), there is an intra-individual (ranging from 2% to 3.5%) variability (Lukaski, Johnson et al. 1985; Segal, Gutin et al. 1985; Ward, Byrne et al. 1997) even though some equations in specific populations were validated and have minimal bias (Kyle, Bosaeus et al. 2004).

1.3.2 Anthropometric measures

This section discusses the obesity-related anthropometric measures such as body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR).

1.3.2.1 Body mass index (BMI)

Body mass index (BMI) was first developed in 1832 by the Belgian astronomer and statistician Adolphe Quetelet, for use in comparing populations (Eknoyan 2008). Keys et al (1972) performed a study examining the efficacy of several height-weight formulas in relation to body fat percentage (Keys, Fidanza et al. 1972). The authors found Quetelet's formula to be the best predictor of body fat percentage at that time and renamed it as "body mass index". In 1988, Garrow *et al.* introduced BMI ideal weight range categories based on mortality rates (Table 1.3-2) (Garrow 1988). In 1997, WHO revised these categories and added two new categories as follows: class I obesity (30.0-34.9), class II obesity (35.0-39.9), and class III obesity (≥40.0), overweight (pre-obese, 25.0-29.9), normal (18.5- 24.9), and underweight (<18.5) (WHO 2000). BMI is the most commonly used in assessing obesity in population health surveys (Peeters, Tanamas et al. 2016).

BMI does not take into account age, ethnicity, gender and physical activity level (Heymsfield and Cefalu 2013). BMI also does not discriminate between body fat and muscle mass, which have contradictory health effects on human body (Prentice and Jebb 2001; Vlassopoulos, Combet et al. 2013) and significantly underestimated visceral adipose tissue (VAT) in non-European groups including Chinese and South Asians (Lear, Humphries et al. 2007). In 2010, a meta-analysis estimated the sensitivity of BMI to identify high adiposity at around 50% (CI: 43%–57%) (Okorodudu, Jumean et al. 2010). Furthermore, a meta-analysis of 82,864 participants from nine cohort studies found that BMI was the poorest predictor of cardiovascular disease mortality (hazard ratio (HR) 1.05, 95% CI 0.98–1.14)) compared to WC (1.15, CI 1.04–1.27) and waist to hip ratio (1.15, CI 1.05–1.25) (Czernichow, Kengne et al. 2011). The HR is used in survival analysis (Cox regression) which is the ratio of the hazard rates corresponding to the conditions described by two levels of an explanatory variable (Stare and Maucort-Boulch 2016). The odd ratio (OR) using logistic regression represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure (Scotia 2010; Stare and Maucort-Boulch 2016).

A cross-sectional study among 6,123 white participants found that 29% of subjects were classified as lean and 80% of individuals classified as overweight according to BMI had a body fat percentage within the "obesity range" (≥25% for men and ≥35% for women) (Gómez-Ambrosi, Silva et al. 2012). Some studies amended BMI to strengthen the relationship of BMI and body fat percentage for specific populations. Goh et al. (2004)

changed BMI from 30 kg/m^2 to 25 kg/m^2 for women and 27 kg/m^2 for men, which increased the sensitivity and specificity for Asian populations from 7% and 13% to 47% and 61%, respectively to predict body fat percentage (Goh, Tain et al. 2004). However, the sensitivity and specificity of the new cut-off levels are still poor.

As will be explained below that WC was found to be a better indicator of total body fat than BMI (Lean ME 1996). Therefore, a recent study using national Scottish and English data found that approximately 41% of older adults with normal BMI (65 years and over, BMI=18.5–25 kg/m^2) had elevated waist circumference (WC>94cm for men, WC>80cm for women) (Vlassopoulos, Combet et al. 2013). In the Australian Diabetes, Obesity, and Lifestyle (AusDiab) study, 40% of individuals with BMI<30 kg/m^2 had a high-risk WC (WC (♀)>88cm and WC (♂)>102cm) (Tanamas, Shaw et al. 2014). For the above reasons, there are some drawbacks of using BMI as a health indicator. In SA, BMI had a weak performance with poor sensitivities and specificities (<0.63 and <0.62, respectively) in predicting chronic health risks (diabetes mellitus and hypertension) among 197,681 Saudi adults in the east province of Saudi Arabia (Almajwal, Al-Baghli et al. 2009). This study also highlights that the optimal BMI cut-offs using the receiver operating characteristic (ROC) curve analysis (BMI=30.50-31.50 kg/m^2 in women and BMI=28.50 - 29.50 kg/m^2 in men) had both poor sensitivity (<0.63) and poor specificity (0.62), with an unacceptably high level of overall misclassification (>80). Furthermore, this study reported that despite a significant increase in odds ratio of hypertension and diabetes from BMI values as low as 21-23, this did not improve on the diagnostic performance of BMI measurements. BMI however, is the most common method used for obesity assessment among dietitians in Saudi Arabia (87%) (Almajwal, Williams et al. 2009). Studies in Arab adults provided WC cut-off points for metabolic diseases ranging from 22.9 to 31.5 in women and 22.6 to 30 in men (Table 1.3-3). Table 1.3-3 illustrates the cut-off points for BMI based on sensitivity being equal to specificity among Arab ethnic groups.

1.3.2.2 Waist Circumference (WC)

Even though BMI has been used widely in research and clinical practice, WC is a marginally better indicator of total body fat than BMI (Lean ME 1996) and that chronic health risks are predicted better by WC than by BMI (Pouliot, Despres et al. 1994; Lean, Han et al. 1995; Lean ME 1996).

Lean and Han (1995) (Lean, Han et al. 1995; Lean and Han 2002) defined WC action levels ("Action level 1" and "Action level 2") which have been adopted by the Scottish Intercollegiate Guidelines Network (SIGN 1996; SIGN 2010), and more widely by the NCEPATP-III (2001) (NIH 2001) and WHO (1998) (WHO 2000; WHO 2008). The authors determined by cross tabulation between variables two action levels for WC for weight management to identify most subjects with a BMI>25 (action level 1) and >30 (action level 2). The "action level 1" (with 80 cm for women and 94 cm for men) was intended as a first warning which individuals need to take action to prevent further weight gain (**Table** 1.3-1). The "action level 2" (with 88 cm for women and 102 cm for men) was intended as a warning which meant that individuals should demand professional help to achieve sustained weight/waist loss. However, it should be borne in mind that these cut-off values were derived by corresponding these action levels with BMI categories, which are questionable.

Zhu et al. (2004) suggested combining WC with BMI to predict the metabolic risks more efficiently than by BMI alone (Zhu, Heshka et al. 2004). This suggestion was adopted by different clinical guidelines (e.g. the National Institute for Health and Clinical Excellence (NICE), NHLBI Obesity Education Initiative (NIH-NHLBI), and Scottish Intercollegiate Guidelines Network (SIGN)) as health-risk scores through categorical combinations of BMI and WC as shown in **Table** 1.3-1 (NIH-NHLBI 2000; NHS-NICE 2006; SIGN 2010; NHMRC 2013).

Table 1.3-1: Body mass index and waist circumference cut-offs for health promotion and risk classification (Lean, Han et al. 1995; NIH 2001; Lean and Han 2002; WHO 2008).

Classification	Risk of co-morbidities* Caucasian			Risk of co-morbidities Asian		
	BMI (kg/m^2)	Waist circumference (cm)		BMI (kg/m^2)	Waist circumference (cm)	
		Men 94-102 Women 80-88**	Men >102 Women>88***		Men<90 Women <80	Men ≥90 Women ≥80
Normal weight	18.5 – 24.9	–	–	18.5 – 22.9	Average	Increased
Overweight	25.0 – 29.9	Increased	High	23.0 – 24.9	Increased	Moderate
Obese						
Class I	30.0 – 34.9	High	Very high			
Class II	35.0 – 39.9	Very high	Very high	25.0 – 29.9	Moderate	Severe
Class III	≥ 40.0	Extremely high	Extremely high	≥ 30.0	Severe	Very severe

* Disease risk for T2DM, hypertension, and cardiovascular disease

** Action level 1: for individuals to take personal steps to control weight/waist gain

*** Action level 2: professional input is required to achieve sustained weight/waist loss.

However, several studies are in disagreement (Janssen, Katzmarzyk et al. 2004; Lee, Huxley et al. 2008). Lee and colleagues (2008) conducted a meta-analysis of 10 studies including 88,514 individuals, to determine which of the four indices (BMI, WC, WHR and WHtR) is the best predictor of major cardiovascular risk factors (hypertension, T2DM and dyslipidaemia) (Lee, Huxley et al. 2008). The study results showed that combinations of BMI and WC, WHR, or WHtR, did not increase the discriminatory capability of BMI for hypertension, T2DM and dyslipidaemia in this group of multi-ethnic adults. Also, the study found that BMI was the poorest discriminator for cardiovascular risk factors. Combining body mass index with any measure does not improve upon its discriminatory capability (Lee, Huxley et al. 2008).

Janssen et al.(2004) conducted a study using the data of 14,924 adult individuals from the third National Health and Nutrition Examination Survey (NHANES III) in the United States (Janssen, Katzmarzyk et al. 2004). This study found that WC and not BMI explained obesity related health risk. Overweight (BMI 25-29.9 kg/m^2) and obese (BMI$\geq$30 kg/m^2) subjects were more likely to have hypertension, dyslipidaemia, and the metabolic syndrome than were normal weight subjects (BMI< 25 kg/m^2). However, after adjustment for WC category (normal or high (WC values $\geq$102 and $\geq$88 cm for men and women, respectively)), the odds of comorbidity reduced but remained higher in overweight and obese subjects than in normal-weight subjects. After adjustment for WC as a continuous variable, the likelihood of the metabolic syndrome, hypertension and dyslipidaemia was similar in both BMI and WC. When WC and BMI were used as continuous variables in the same regression model, WC alone was a significant predictor of comorbidity (the metabolic syndrome, hypertension and dyslipidaemia).

SA still uses the conventional reference cut-off points for BMI and WC which were derived from data based on European Caucasian populations (MOH 2014). These cut-off points have been adopted by the International Diabetes Federation (IDF) (Alberti, Zimmet et al. 2007) and the World Health Organization (WHO) (WHO 2008), and IDF recommends that researchers from Eastern Mediterranean and the Middle Eastern (Arab) populations utilise European cut-points for BMI and WC measurements for both genders until more ethnic-specific data is available.

These action levels of WC and BMI conventional cut-off points were derived from data on European Caucasian populations; and several studies have documented that Asians have higher morbidity than Caucasians at lower cut-off points for BMI (WHO 2000;

Snehalatha, Viswanathan et al. 2003; Vikram, Pandey et al. 2003; Razak, Anand et al. 2007) and WC (Snehalatha, Viswanathan et al. 2003; Vikram, Pandey et al. 2003; Collaboration 2007; Diaz, Mainous et al. 2007; Huxley, James et al. 2008). Since the reference BMI limits against which WC sensitivity and specificity profile were calculated do not apply to non-Caucasian populations including Asians, certain reference limits were predicted based on health outcomes and these anthropometric measures (WHO 2008). For example, reference cut-off points for BMI and WC were predicted and applied for Asians and Pacific Islanders. Studies in Arabs adults provided WC cut-off points for metabolic diseases ranged from 84.5 to 99 for women and from 78.5 to 102 for men (Table 1.3-4). Table 1.3-4 illustrates the cut-off points for WC based on sensitivity being equal to specificity among Arab ethic groups.

1.3.2.3 Waist to hip ratio (WHR)

Various ratios which include WC (waist-hip ratio (WHR), and waist-height ratio (WHtR)) have been used and evaluated in several studies (Molarius and Seidell 1998). WHR is an inexpensive indicator of body fat distribution for adult men and women (Huxley, Mendis et al. 2010). However, some studies found that WHR is less predictive of total body fat or visceral fat (Ross, Leger et al. 1992; González, Bellido et al. 2007).

The relationship between WHR and metabolic diseases performs consistently for most ethnic groups including Arabs (Al-Lawati and Jousilahti 2008; Huxley, Mendis et al. 2010). In 2007, a meta-analysis on WC and WHR as predictors of cardiovascular (CVD) events from prospective studies (15 articles (n=258,114 participants, 4,355 CVD events)) found that increased WC or WHR were related to an increased risk of cardiovascular events in men and women (Relative risk: 1.02 (95% CI: 1.01 to 1.03) for WC and (RR: 1.05 (95% CI: 1.04 to 1.07)) for WHR (De Koning, Merchant et al. 2007). WHO Expert Consultation Report (2008) recommended health professionals to use waist circumference and waist-hip ratio (WHO 2008). However, the North American Association for the study of obesity has stated that "the measurement of waist-to hip ratio provides no advantage over waist circumference alone" (NIH-NHLBI 2000). It has been claimed that the interpretation of WHR outcomes is difficult, especially, with the opposing relationships of WC and WHR with cardiovascular risk and metabolic outcomes (Peeters, Tanamas et al. 2016). Studies in Arabs adults provided WHR cut-off points for metabolic diseases ranged from 0.81 to 0.98 for women and from 0.89 to 0.96

for men (Table 1.3-5). Table 1.3-5 illustrates the cut-off points for WHR based on sensitivity being equal to specificity among Arab ethic groups.

1.3.2.4 Waist to height ratio (WHtR)

WHtR is also an inexpensive indicator of body fat distribution for adult men and women (Ashwell, Cole et al. 1996; González, Bellido et al. 2007). A recent meta-analysis in 2012 suggested that WHtR proved to be significantly better than BMI and WC in the prediction of all health outcomes including T2DM, hypertension, and CVD ($P < 0.005$) in both men and women (Ashwell, Gunn et al. 2012). Also, Lee and colleagues (2008) conducted a meta-analysis involving 10 studies of 88,514 individuals, to determine which of the four indices (BMI, WC, WHR and WHtR) was the best predictor of major cardiovascular risk factors (hypertension, T2DM and dyslipidaemia (Lee, Huxley et al. 2008). The study results showed that WHtR was the best discriminator for hypertension, diabetes, and dyslipidaemia in both sexes. Furthermore, a meta-analysis from the Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Asia Study (DECODA) was conducted to examine the strength of association between BMI, WC, WHR and WHtR to predict T2DM (Nyamdorj 2008). This study involved data from 16 cross-sectional studies. This study found a slightly stronger association between T2DM and WHtR in both men and women than BMI, WC, WHR. Ashwell and Gibson (2014) proposed a primary screening tool to use WHtR as a health promotion tool for all ethnic groups, suggesting that WC should be less than half (<0.5) of body height (Ashwell and Gibson 2014). Studies in Arabs adults provided WHtR cut-off points for metabolic diseases ranged from 0.50 to 0.61 for men and women (Table 1.3-6). Table 1.3-6 illustrated the cut-off points for WHtR based on sensitivity being equal to specificity among Arab ethic groups.

Table 1.3-2: Body composition classifications

Category	Women	Men
BMI		
Non-obese (kg/m^2)	18.5-24.9	18.5-24.9
Overweight (kg/m^2)	25-29.9	25-29.9
Obese (kg/m^2)	≥30	≥30
WC		
Normal WC (cm)	<80	<94
Risk I WC (cm)	80-88	94-102
Risk II WC (cm)	>88	>102
WHR		
High risk WHR	≥0.85	≥0.90
WHtR		
High risk WHtR	≥0.5	≥0.5

BMI: body mass index; WC: waist circumference; WHR: Waist to hip ratio; WHtR: waist to height ratio.

It has been suggested that the prediction of body composition (e.g.WC and BMI) cut-off points in clinical and public health settings should be based on the associations between the anthropometric data and health outcomes such as T2DM, hypertension, and dyslipidemia rather than to associations with body fat (WHO 2008). This is because the risk prediction is more straightforward if based on health outcomes. Ethnic and racial differences have also been observed between body (visceral) fat and metabolic risk factors (Snehalatha, Viswanathan et al. 2003; Vikram, Pandey et al. 2003; Misra, Wasir et al. 2005).

The optimal sensitivity and specificity using different body composition cut-off values to predict the presence of metabolic disease are used by implementing receiver operating characteristic curve (ROC) analysis. A greater area under the curve (AUC) indicates a better predictive capability. AUC=1.0 indicates perfect discrimination, and AUC<0.5 indicates that the test performs no better than chance (noninformative). To find out the optimal body composition cut-off points (e.g. WC and BMI), the shortest distance between any point on the curve and the top left corner on the y-axis is determined. Distance is estimated at each one-half unit of BC measures according to the following equation (Weng, Liu et al. 2006; Sung, Yu et al. 2007; Almajwal, Al-Baghli et al. 2009; Zeng, He et al. 2014):

$$\text{Distance in ROC} = \sqrt{(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2}$$

Table 1.3-3: Diagnostic performance of body mass index (BMI) in predicting health morbidities using optimal BMI cut-off values as defined by authors, based on the shortest distance in ROC curves in Arab adults.

Health Risks	Country	Age	Gender	Sample size (n)	Cut-off	Sensitivity	Specificity	AUC	Comments
(Assaad-Khalil, Mikhail et al. 2015)	Egypt	18-80	♀ ♂	1642 1567	- -	- -	- -	0.619 0.610	Presence of at least two other components of the metabolic syndrome according to IDF.
(Chedid, Gannagé-Yared et al. 2009) *	Lebanon	18-30	♀ ♂	180 201	27.5 27.5	95 95	89 89	0.95 0.95	Presence of at least two other components of the metabolic syndrome according to IDF
(Bener, Yousafzai et al. 2013)	Qatar	>20	♀ ♂	794 758	28.4-30 28-30	73.7-66.4 58-38.5	64.8-67.1 52.9-66.7	0.70 0.56	Presence of at least two other components of the metabolic syndrome according to IDF.
(Al-Odat, Ahmad et al. 2012)	Jordan	20–85	♀ ♂	288 212	30.3 28.4	59 61.2	74.2 59.1	0.67 0.59	Presence of at least two other components of the metabolic syndrome according to IDF.
(Al-Lawati and Jousilahti 2008)	Oman	≥20	♀ ♂	725 695	26.8 23.2	46.8 71.0	76.5 53.7	0.66 0.65	Prevalent CVD risk was defined as the presence of at least two of the following three risk factors: hyperglycaemia, hypertension and dyslipidaemia
(Al-Lawati, Barakat et al. 2008)	Oman	≥20	♀ ♂	725 695	22.9 22.6	84.2 80.3	45.1 37.3	0.639 0.601	The Framingham risk score (Anderson, WOLSON et al. 1991)
(Bouguerra, Alberti et al. 2007)	Tunisia	≥20	♀ ♂	2191 1244	27 24	55-66 52-67	62-74 63-69	0.64-0.71 0.63-0.70	Any presence of high blood pressure, hyperglycaemia, high blood cholesterol and hypertriglyceridaemia
(Almajwal, Al-Baghli et al. 2009)	Saudi Arabia	≥30	♀ ♂	95,905 99,946	30.5 28.5	0.63 0.58	0.58 0.56	0.640 0.594	Presence of T2DM or hypertension
(Almajwal, Al-Baghli et al. 2009)	Saudi Arabia	≥30	♀ ♂	95,905 99,946	31.5 29.5	0.61 0.55	0.59 0.62	0.643 0.618	Presence of T2DM and hypertension
(Almajwal, Al-Baghli et al. 2009)	Saudi Arabia	≥30	♀ ♂	95,905 99,946	31.5 28.5	0.58 0.55	0.61 0.54	0.618 0.566	Presence of T2DM
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀ ♂	6293 6693	26.1 25.4	66.3 66	47.4 53.9	0.59 0.63	Presence of T2DM [$]
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀ ♂	6293 6693	26.5 24.9	71.7 78.1	51.9 51.9	0.65 0.70	Presence of hypertension [£]
(El Din, Zaki et al. 2014)	Egypt	20-75	♀ ♂	2670 2880	30.1 28	69.1 62.8	60.7 59.9	0.678 0.664	Presence of hypertension [£]
(Almajwal, Al-Baghli et al. 2009)	Saudi Arabia		♀ ♂	95,905 99,946	31.5 29	0.60 0.59	0.62 0.58	0.645 0.625	Presence of hypertension [£]

AUC: Area under curve; BMI: Body mass index; CFBG: Capillary Fasting Blood Glucose; CRBG: Capillary Random Blood Glucose; FPG: Fasting Plasma Glucose; IDF: The International Diabetes Federation 2005; MetS: Metabolic syndrome; RFs: cardiometabolic risk factors.

According to IDF (Alberti, Zimmet et al. 2006), a participant has the MetS if WC ≥94 cm in men and ≥80 cm in women) plus any two of these risk factors: (a) FPG ≥ 100mg/dL (5.6mmol/L) or previously diagnosed impaired fasting glucose (b) blood pressure ≥130/85mmHg or treatment for hypertension; (c) Triglyceride ≥ 150mg/dL (1.7mmol/L); (d) HDL Cholesterol: Men < 40mg/dL (1.03mmol/L);Women < 50mg/dL (1.29mmol/L) or treatment for low HDL.

* The analysis were performed with combined data of men and women.

[$] FPG≥126 mg/dL on two occasion or symptoms of diabetes and a casual plasma glucose ≥200 mg/d (11.1 mmol/L) and/or diagnosed with diabetes.

[£] Blood pressure ≥140/90mmHg and/or diagnosed with hypertension.

CFBG was ≥126 mg/dl (≥7.0 mmol/l) or the CRBG was ≥200 mg/dl (≥11.0 mmol/l) and/or diagnosed with diabetes.

Table 1.3-4: Diagnostic performance of waist circumference (WC) in predicting health morbidities using optimal WC cut-off values based on the shortest distance in ROC curves in Arab adults.

Health Risks	Country	Age	Gender	Sample size (n)	Cut-off	Sensitivity	Specificity	AUC	Comments
(Assaad-Khalil, Mikhail et al. 2015)	Egypt	18-80	♀ ♂	1642 1567	96.25 100.5	71.8 59.1	55.4 69	0.683 0.693	Presence of at least two other components of the metabolic syndrome according to IDF.
(Bener, Yousafzai et al. 2013)	Qatar	>20	♀ ♂	794 758	91-88 99.5-102	86.5-94.4 81.6-75.9	64.7-53.2 63.9-67.3	0.81 0.78	Presence of at least two other components of the metabolic syndrome according to IDF.
(Al-Odat, Ahmad et al. 2012)	Jordan	20–85	♀ ♂	288 212	95.6 97.8	62.6 51.8	77.4 72.4	0.74 0.64	Presence of at least two other components of the metabolic syndrome according to IDF.
(Chedid, Gannagé-Yared et al. 2009)	Lebanon	18-30	♀ ♂	180 201	91 99.5	100 87	98 90	0.99 0.92	Presence of at least two other components of the metabolic syndrome according to IDF
(Mansour, Al-Hassan et al. 2007)	Iraq	≥18	♀ ♂	300 700	99 97	70 70	45 50	- -	Presence of at least two other components of the metabolic syndrome according to IDF.
(Ibrahim, Elamragy et al. 2011)	Egypt	≥25	♀ ♂	1332 981	91.5 93.5	- -	- -	0.697 0.78	Presence of RFs (diabetes mellitus, decrease in HDL-C and increase in LDL-C, triglycerides and left ventricular mass index by echocardiography) among Normotensives
(Ibrahim, Elamragy et al. 2011)	Egypt	≥25	♀ ♂	1332 981	92.5 93.5	- -	- -	0.63 0.668	Presence of RFs (diabetes mellitus, decrease in HDL-C and increase in LDL-C, triglycerides and left ventricular mass index by echocardiography) among Hypertensives
(Al-Lawati and Jousilahti 2008)	Oman	≥20	♀ ♂	725 695	84.5 80	71.9 65.2	61.6 66.7	0.71 0.70	Prevalent CVD risk was defined as the presence of at least two of the following three risk factors: hyperglycaemia, hypertension and dyslipidaemia
(Al-Lawati, Barakat et al. 2008)	Oman	≥20	♀ ♂	725 695	84.5 78.5	89.5 83.8	52.8 50.1	0.727 0.710	The Framingham risk score (Anderson, WOLSON et al. 1991)
(Bouguerra, Alberti et al. 2007)	Tunisia	≥20	♀ ♂	2191 1244	85 85	55-76 52-71	67-78 63-70	0.65-0.76 0.64-0.72	Any presence of high blood pressure, hyperglycaemia, high blood cholesterol and hypertriglyceridaemia
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀ ♂	6293 6693	91 90	79.6 79.5	47.2 49.4	0.67 0.69	Presence of T2DM [$]
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀ ♂	6293 6693	95 95	73.2 74.2	58.4 64.3	0.71 0.75	Presence of hypertension [£]
El Din AMS et al 2014 **(El Din, Zaki et al. 2014)**	Egypt	20-75	♀ ♂	2670 2880	87.8 95.8	80.9 71.9	48.6 51.9	0.693 0.681	Presence of hypertension [£]

AUC: Area under curve; WC: waist circumference; FPG: Fasting Plasma Glucose; IDF: The International Diabetes Federation 2005; MetS: Metabolic syndrome; RFs: cardiometabolic risk factors.
According to IDF (Alberti, Zimmet et al. 2006), a participant has the MetS if WC ≥94 cm in men and ≥80 cm in women) plus any two of these risk factors: (a) FPG ≥ 100mg/dL (5.6mmol/L) or previously diagnosed impaired fasting glucose (b) blood pressure ≥130/85mmHg or treatment for hypertension; (c) Triglyceride ≥ 150mg/dL (1.7mmol/L); (d) HDL Cholesterol:Men < 40mg/dL (1.03mmol/L);Women < 50mg/dL (1.29mmol/L) or treatment for low HDL.
[$] FPG≥126 mg/dL on two occasion or symptoms of diabetes and a casual plasma glucose ≥200 mg/dL.
[£] Blood pressure ≥140/90mmHg and/or diagnosed.

Table 1.3-5: Diagnostic performance of waist to hip ratio (WHR) in predicting health morbidities using optimal WHR cut-off values based on the shortest distance in ROC curves in Arab adults.

Health Risks	Country	Age	Gender	Sample size (n)	Cut-off	Sensitivity	Specificity	AUC	Comments
(Assaad-Khalil, Mikhail et al. 2015)	Egypt	18-80	♀	1642	-	-	-	0.619	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	1567	-	-	-	0.610	
(Bener, Yousafzai et al. 2013)	Qatar	>20	♀	794	0.88	75.4	71.5	0.75	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	758	0.90	70.1	69.9	0.75	
(Al-Odat, Ahmad et al. 2012)	Jordan	20–85	♀	288	0.84	62.1	77.4	0.76	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	212	0.89	44.7	90.6	0.71	
(Al-Lawati and Jousilahti 2008)	Oman	≥20	♀	725	0.91	67.2	73.7	0.76	Presence of CVD risk was defined as the presence of at least two of the following three risk factors: hyperglycaemia, hypertension and dyslipidaemia
			♂	695	0.91	58	71.6	0.68	
(Al-Lawati, Barakat et al. 2008)	Oman	≥20	♀	725	0.98	68.4	86.1	0.80	Presence of CVD risk using the Framingham risk score (Anderson, WOLSON et al. 1991)
			♂	695	0.96	60.7	80.6	0.77	
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀	6293	0.91	71.5	63.4	0.73	Presence of T2DM [$]
			♂	6693	0.92	76.9	60.5	0.74	
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀	6293	0.91	66.3	63.3	0.70	Presence of hypertension [£]
			♂	6693	0.92	75.3	60.4	0.73	
(El Din, Zaki et al. 2014)	Egypt	20-75	♀	2670	0.81	65.3	53.4	0.62	Presence of hypertension [£]
			♂	2880	0.92	64.6	55.8	0.64	

AUC: Area under curve; WHR: waist to hip ratio; FPG: Fasting Plasma Glucose; IDF: The International Diabetes Federation 2005; MetS: Metabolic syndrome; RFs: cardiometabolic risk factors; According to IDF (Alberti, Zimmet et al. 2006), a participant has the MetS if WC ≥94 cm in men and ≥80 cm in women) plus any two of these risk factors: (a) FPG ≥ 100mg/dL (5.6mmol/L) or previously diagnosed impaired fasting glucose (b) blood pressure ≥130/85mmHg or treatment for hypertension; (c) Triglyceride ≥ 150mg/dL (1.7mmol/L); (d) HDL Cholesterol: Men < 40mg/dL (1.03mmol/L);Women < 50mg/dL (1.29mmol/L) or treatment for low HDL.

[$] FPG≥126 mg/dL on two occasion or symptoms of diabetes and a casual plasma glucose ≥200 mg/dL.

[£] Blood pressure ≥140/90mmHg and/or diagnosed.

Table 1.3-6: Diagnostic performance of waist to height ratio (WHtR) in predicting health morbidities using optimal WHtR cut-off values based on the shortest distance in ROC curves in Arab adults.

Health Risks	Country	Age	Gender	Sample size (n)	Cut-off	Sensitivity	Specificity	AUC	Comments
(Assaad-Khalil, Mikhail et al. 2015)	Egypt	18-80	♀	1642	-	-	-	0.631	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	1567	-	-	-	0.674	
(Bener, Yousafzai et al. 2013)	Qatar	>20	♀	794	0.63-0.50	77.6-96.1	71.5-20.1	0.79	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	758	0.58-0.50	75.1-96.6	64.8-24.5	0.74	
(Al-Odat, Ahmad et al. 2012)	Jordan	20–85	♀	288	0.61	60.5	78.7	0.75	Presence of at least two other components of the metabolic syndrome according to IDF.
			♂	212	0.61	69.4	58.3	0.67	
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀	6293	0.56	82.6	45.1	0.68	Presence of T2DM [$]
			♂	6693	0.52	82.2	48.4	0.70	
(Mansour and Al-Jazairi 2007)	Iraq	30-62	♀	6293	0.59	78.6	54	0.73	Presence of hypertension [£]
			♂	6693	0.55	75.6	63.5	0.76	
(El Din, Zaki et al. 2014)	Egypt	20-75	♀	2670	0.56	61.4	58.9	0.61	Presence of hypertension [£]
			♂	2880	0.57	59.7	55.8	0.58	

AUC: Area under curve; WHR: waist to height ratio; FPG: Fasting Plasma Glucose; IDF: The International Diabetes Federation 2005; MetS: Metabolic syndrome; RFs: cardiometabolic risk factors; According to IDF (Alberti, Zimmet et al. 2006), a participant has the MetS if WC ≥94 cm in men and ≥80 cm in women) plus any two of these risk factors: (a) FPG ≥ 100mg/dL (5.6mmol/L) or previously diagnosed impaired fasting glucose (b) blood pressure ≥130/85mmHg or treatment for hypertension; (c) Triglyceride ≥ 150mg/dL (1.7mmol/L); (d) HDL Cholesterol: Men < 40mg/dL (1.03mmol/L);Women < 50mg/dL (1.29mmol/L) or treatment for low HDL.

[$] FPG≥126 mg/dL on two occasion or symptoms of diabetes and a casual plasma glucose ≥200 mg/dL.

[£] Blood pressure ≥140/90mmHg and/or diagnosed.

1.3.3 Derived equations

1.3.3.1 Percentage of Body fat (%BF) and Total Adipose Tissue Mass (TATM)

The body composition variables including Total Adipose Tissue Mass (TATM), skeletal muscle mass (SMM) and total body fat percent (%BF) are estimated using simple anthropometric and demographic measures.

1.3.3.1.1 Body fat Percent (%BF)

In 1991, Deurenberg et al (Deurenberg, Weststrate et al. 1991) developed a prediction equation (E1) based on simple anthropometric variables (age, BMI and sex) using densitometry measurements to estimate total body fat percentage; this equation has high correlations with Under-Water Weighing measured total body fat (R^2=0.79, SEE= 41% BF%).

$$(\mathrm{E1}) = (1.2\ \mathrm{BMI}) + (0.23\ \mathrm{Age}) - (10.8\ \mathrm{Sex}) - 5.4$$

Lean et al. (Lean, Han et al. 1996) developed regression equations (E2, E3) from waist circumference (WC) adjusted for age to predict total body fat. These equations were derived from body density measured by underwater weighing in 63 men and 84 women. Furthermore, they were tested and validated among independent validation group (146 men and 238 women) aged 18-83 years and obtained in a different population. These equations had the most robust prediction (R^2=0.69 for men, R^2=0.75 for women) (Lean, Han et al. 1996) against skin-fold measurements published by (Durnin and Womersley 1974), and found that WC provided almost identical predictive power.

$$(\mathrm{E2})(\mathrm{male}) = (0.567\ \mathrm{waist}) + (0.101\ \mathrm{age}) - 31.8$$

$$(\mathrm{E3})(\mathrm{female}) = (0.439\ \mathrm{waist}) + (0.221\ \mathrm{age}) - 9.4$$

The WHO and others / organisations have different thresholds to categorise individuals against %BF (Table 1.3-7).

Table 1.3-7: Body Fat percentage (%BF) classifications

	WHO 2004[a]		AACE/ACE		Oreopoulos et al	
Category	Women	Men	Women	Men	**Women**	**Men**
Non-obese (%)	<35	<22	-	-	<30	<20
Overweight (%)	35-40.9	22-27.9	-	-	30-37.9	20-24.9
Obese (%)	≥41	≥28	≥35	≥25	≥38	≥25

%BF: Body Fat percentage
[a] Based on WHO technical report in 2004 (WHO Expert Consultation 2004).
[b] Based on AACE/ACE technical report in 1998 (Dickey, Bartuska et al. 1998) recommendation.
[c] Based on Oreopoulos et al 2011 (Ho-Pham, Campbell et al. 2011) findings.
AACE/ACE: American Association of Clinical Endocrinologists /American College of Endocrinology; WHO: World Health Organization.

1.3.3.1.2 Total Adipose Tissue Mass (TATM)

Al-Gindan et al (2015) developed new prediction equations (E4, E5) using simple anthropometric variables to estimate Total Adipose Tissue Mass (TATM) (Al-Gindan, Hankey et al. 2015). These equations were derived from magnetic resonance imaging (MRI) measurements in 194 men and 222 women aged 18-88 years. These equations were validated among separate validation groups (94 men and 110 women) aged 18-86 years and high correlations were shown with the validation groups (validation: R^2 =0.84, CV=13%, SEE=3.0 kg). These equations correlated strongly with published anthropometric prediction equations, based on MRI and CT-scans (R^2=0.70–0.82). The estimated Total Adipose Tissue Mass (TATM) gave a good prediction power with published prediction equations for total body fat based on UWW (R^2= 0.7–0.8), with mean bias 2.5-4.9 kg. It has been assumed that the proportion by weight of the lipid fraction in adipose tissue is 80% (Snyder WS CM 1975; Sohlstrom, Wahlund et al. 1993; Wang, Zhu et al. 2003; Al-Gindan, Hankey et al. 2015). Therefore, the TATM outputs should be multiplied by 0.8 to generate Total Adipose Tissue Fat Mass (TATFM) (Snyder WS CM 1975; Sohlstrom, Wahlund et al. 1993; Wang, Zhu et al. 2003).

$$(\text{E4})(\text{male}) = -12.8 + 0.198\ \text{Body Weight (kg)} + 0.478\ \text{Waist (cm)} - 0.147\ \text{Height (cm)}$$

$$(\text{E5})(\text{female}) = 24.5 + 0.789\ \text{Body Weight (kg)} + 0.0786\ \text{Age (y)} - 0.342\ \text{Height (cm)}$$

1.3.3.2 Skeletal Muscle mass (SMM)

Al-Gindan et al., (2014) developed equations (E6, E7) to estimate skeletal muscle mass (SMM) among adult men and women using regression analysis of simple anthropometric and demographic data (Al-Gindan, Hankey et al. 2014). These equations were derived from magnetic resonance imaging (MRI) measurements in 196 men and 227 women aged 18-81 years and were validated among separate validation groups (92 men and 105 women) aged 19-83 years. They had good prediction power with these validation groups (validation: R^2 =0.79, SEE=2.7 kg in men; R^2 =0.59, SEE=2.1 kg in women). However, the anthropometry predicts SMM better in men than in women since this predictor explains the greatest percentage of variation in SMM from MRI.

(**E6**) $\text{SM (male)} = 39.5 + 0.665\ \text{Body Weight (kg)} - 0.185\ \text{Waist (cm)} - 0.418\ \text{Hip (cm)} - 0.08\ \text{Age (y)}$

(**E7**) $\text{SM (female)} = 2.89 + 0.255\ \text{Body Weight (kg)} - 0.175\ \text{Hip (cm)} - 0.038\ \text{Age (y)} + 0.118\ \text{Height (cm)}$

Meanwhile, Lee et al., (2000) (Lee, Wang et al. 2000) developed an equation (E8) to estimate SMM using simple anthropometric and demographic measures. This equation was developed and cross-validated in non-obese adults (n=244, BMI < 30 kg/m^2) and aged ≥20 years. It gave a good prediction power with validation groups (R^2 = 0.79, P <0.0001, SEE = 3.0 kg).

(**E8**) $\text{SM (Kg)} = 0.244 * \text{body weight (kg)} + 7.80 * \text{height (m)} - 0.098 * \text{age (y)} + 6.6 * \text{sex} + \text{race} - 3.3$

(Sex = 0 for female and 1 for male, race = -1.2 for Asian, 1.4 for African American, and 0 for white and Hispanic).

Baumgartner et al., (1998) recommended generating Skeletal Muscle Mass Index (SMI) by dividing the skeletal muscle mass (kg) by height (m) squared (muscle mass (kg)/height $(m)^2$) (Baumgartner, Koehler et al. 1998). The SMI outputs (kg/m^2) are compared with the SMM cut-offs (kg/m^2) to assess the low SMM situation for each subject (Chien, Huang et al. 2008). The SMI is defined according to different cut-offs from different ethnic groups as presented in **Table** 1.3-8. The SMI (SMM/square

height(m^2)) is used to define low muscle mass using cut-off points (**Table** 1.3-8). Low muscle mass used to be defined as SMI less than 2 standard deviations (SD) below the mean of population. However, a low skeletal muscle mass (less than 2 SD cut-off points) showed low clinical usefulness because of the very low prevalence determined by this definition (Kim, Joh et al. 2014). Furthermore, SMM (kg) to height (m^2) is highly correlated with body mass index (BMI) and may identify mostly thin people as having low muscle mass (Kim, Park et al. 2014). Therefore, this method (SMM/square height (m^2)) may have limited power to identify low muscle mass in obese people. Weight-adjusted SMM can be used to overcome this limitation. Kim et al found that muscle mass (kg) to fat mass (kg) ratio was significantly associated with metabolic syndrome (Odds Ratio: 5.43, 95% Confidence Interval 2.56–13.34) and brachial-ankle pulse wave velocity (baPWV) (R^2 =0.57) (Kim, Park et al. 2011). The authors suggested that the muscle mass/fat mass ratio is a new index of sarcopenic obesity.

Some studies found that the percentage of skeletal muscle mass to body weight (%SMM) was negatively predicting the metabolic risks in adults. %SMM was calculated for each subject by dividing the SMM (kg) by body weight (kg) and multiply the output by 100 as described by Janssen et al., 2002 (Janssen, Heymsfield et al. 2002) and Kim et al., 2009 (Kim, Yang et al. 2009). Park and Yoon (2013) among the Korean population reported that %SMM was negatively associated with high triglycerides (Odds Ratio: 0.77; 95% Confidence Interval: 0.61-0.97), High BP (OR:0.72; CI:0.61-0.86), and development of metabolic syndrome (OR: 0.51; CI: 0.40-0.65) (Park and Yoon 2013). In contrast, the authors found that SMI (kg/m^2) was positively associated with High TG (OR: 1.40; CI: 1.08-1.82), High BP (OR: 1.31; CI: 1.09-1.57), and development of metabolic syndrome (OR: 2.18; CI: 1.63-2.92) which raise a question regarding the use of SMI in predicting low muscle mass.

Table 1.3-8: Skeletal Muscle Mass Cut-offs (kg/m^2) based on gender and ethnic groups.

Code	Reference	Method	Sample Size	SMM cut offs (kg/m^2)		Reference group defined
				Male	Female	
A	Chien *et al*., (2008) (Chien, Huang et al. 2008)	BIA[a]	41	<8.87	<6.42	Taiwanese (aged 22–90)
B	Janssen *et al*., (2004) (Janssen, Heymsfield et al. 2002; Janssen, Baumgartner et al. 2004)	BIA[a]	4,449	Severe: ≤8.50; Moderate: 8.51–10.75; Normal: ≥10.76	Severe: ≤5.75; Moderate: 5.76–6.75; Normal: ≥6.76	NHANES III data on older (≥60 years)
C	Baumgartner *et al*., (1998) (Rosetta Study) (Baumgartner, Koehler et al. 1998)	DXA (ALM)	199/883	<7.26	<5.45	Elderly Hispanic and non-Hispanic white men and women
D	Delmonico *et al*., (2007) (Delmonico, Harris et al. 2007)	DXA	2,976	<7.25	<5.67	Elderly Black and white; Pennsylvania
E	Newman et al., (2003) (Newman, Kupelian et al. 2003)[£]	DXA	2,984	<7.23	<5.67	Elderly Black and white (aged 70-79); Pennsylvania
F	Kelly *et al*., 2009 (Kelly, Wilson et al. 2009); (Bijlsma, Meskers et al. 2013)*	DXA (ALM)	1195	<6.19	<4.73	NHANES subjects Whites Americans aged ≥20
G	Kelly *et al*., 2009 (Kelly, Wilson et al. 2009)[$]	DXA (ALM)	1195	<6.54	<4.89	Non-Hispanic Whites, Non-Hispanic Blacks, and Mexican Americans aged ≥20
H	Kim *et al*., 2009 (Kim, Yang et al. 2009; Kim, Park et al. 2014)	DXA (ALM)	526	7.40	5.14	Korean population; These levels Less than two s.d. below the sex-specific normal mean for the young reference group

[a] Validated against MRI; BIA: Bioelectrical Impedance Analysis; DXA: dual energy X-ray absorptiometry; MRI: magnetic resonance imaging; NHANES III: Third National Health and Nutrition Examination Survey; ASMM: Appendicular skeletal muscle mass; ALM: Appendicular lean mass; * According to Bijlsma *et al.*, (2013) (Bijlsma, Meskers et al. 2013); [$] Our own calculation based on less than 2 standard deviations below the adult (aged 20-40 years) mean for all three ethnic groups as recommended by European Working Group of Sarcopenia in Older Persons (EWGSOP) (Cruz-Jentoft, Baeyens et al. 2010). [£] These levels were adopted by the International Working Group on Sarcopenia (IWGS)(Fielding, Vellas et al. 2011).

1.3.3.2.1 Low muscle mass and non-communicable diseases (NCDs)

Excess body fat increases pro-inflammatory cytokines and non-esterified fatty acids, which leads to the development of the metabolic diseases including insulin resistance (section 1.2.3.1.1). Several studies have shown strong associations between poor skeletal muscle mass (low muscle mass and poor strength) and NCDs (Table 1.3-9). Muscle is one of the main sites of insulin action, and fat and glucose oxidation (Stump, Henriksen et al. 2006; Han and Lean 2015). It handles from 75% to 95% of all insulin mediated glucose disposal (Stump, Henriksen et al. 2006).

T2DM and metabolic syndrome are associated with a relative reduction of type I muscle fibres (red muscle) (Stump, Henriksen et al. 2006; Han and Lean 2015). Particularly, reduction in skeletal muscle mass (SMM) leads to early onset of insulin resistance due to decreased muscle glycogen synthesis (Petersen, Dufour et al. 2007). As a result, atherogenic dyslipidemia is promoted by diverting energy derived from dietary carbohydrates away from muscle glycogen synthesis into increased hepatic de novo lipogenesis (Petersen, Dufour et al. 2007). Consequently, insulin resistance reduces the ability of insulin to decrease central aortic pressure which leads to premature stiffening of large arteries; and to develop of pulse pressure related complications and systolic hypertension (Choi, Lee et al. 2004). As people age, skeletal muscle decreases and fat mass may be preserved or even increased in people with low muscle mass (Gallagher, Visser et al. 1997; Janssen, Heymsfield et al. 2000; Cesari, Kritchevsky et al. 2005; Vlassopoulos, Combet et al. 2013).

Low body muscle mass (SMM) is associated with cardiovascular risk factors including arterial stiffness which may contribute to hypertension (Table 1.3-9) (Ferreira, Snijder et al. 2004; Sampaio, Sampaio et al. 2014). Also, Kim et al 2014 found that the risk of low muscle mass was approximately 2 to 4 folds higher in older adults with T2DM, even after adjusting for age, body mass index, current smoking and other risk factors (using SMI and %SMM) (Kim, Park et al. 2014).

Moreover, Leenders et al (2013) found that leg lean mass and appendicular skeletal muscle mass (kg) were significantly lower in older men (19.1 ±0.3 and 25.9 ±0.4 kg, respectively) with T2DM compared with normoglycemic controls (19.7 ±0.3 and 26.7 ±0.5 kg, respectively) (Leenders, Verdijk et al. 2013).

Muscle mass strength (skeletal muscle fitness) is inversely associated with cardiovascular disease, dyslipidaemia, hypertension, T2DM, metabolic syndrome, obesity as well as premature death (Artero, Lee et al. 2012; Leenders, Verdijk et al. 2013). The concurrence of both obesity and low SM has been reported to increase the risk of metabolic impairment and physical disability more than either low SM or obesity alone (Baumgartner 2000; Dominguez and Barbagallo 2007; Kim, Yang et al. 2009; Lim, Kim et al. 2010; Anoop, Misra et al. 2014). This condition is called sarcopenic obesity by Heber et al. in 1996 (Heber, Ingles et al. 1996). Kim et al found that muscle mass (kg) to fat mass (kg) ratio was positively significantly associated with blood pressure, glucose,

lipid profiles and brachial-ankle pulse wave velocity (baPWV) and been considered muscle mass/fat mass ratio as a new index of sarcopenic obesity (Kim, Park et al. 2011).

Table 1.3-9: Evidence table for association between diabetes status and hypertension, and low muscle mass defined by various indices (SMI (kg/m^2), SMM (kg) and %SMM)

Reference	Study type	Country	Age	Gender	Sample size (n)	Comments
(Kim, Kim et al. 2015)	CSS	Korea	19-39	M/F	5,300	In the non-obese subjects (<25 kg/m^2), the prevalence of MetS, high waist circumference, high triglycerides, and high BP was significantly greater in the low muscle mass group (<1 SD below the mean) than in the high muscle mass group.
(Anoop, Misra et al. 2014)	CSS	North India	53.8 ± 10.0	M/F	168	Low fat free mass is associated with arterial stiffening in Asian Indians with T2DM (using PWV)
(Kim, Park et al. 2014)	CSS	Korea	≥65	M/F	414	The risk of low muscle mass was approximately two- to fourfold higher in older adults with T2DM, even after adjusting for age, body mass index, current smoking and other risk factors (using SMI and %SMM).
(Sampaio, Sampaio et al. 2014)	CSS	Japan	≥65	M/F	175	Higher CAVI was positively associated with low SMI in older adults
(Leenders, Verdijk et al. 2013)	CSS	Netherlands	≥65	M/F	92	Leg lean mass and appendicular skeletal muscle mass (kg) were significantly lower in older men with T2DM compared with normoglycemic controls.
(Park and Yoon 2013)	CSS	Korea	20-75	M/F	838	SMM%: Negative association with High TG, Dysglycemia, High BP, Development of MetS.
						MFR: Negative association with High TG, Dysglycemia, High BP, Development of MetS.
						SMM (kg): positive association with High TG, Dysglycemia, High BP, Development of MetS.
						SMI: positive association with High TG, Dysglycemia, High BP, Development of MetS
(Abbatecola, Chiodini et al. 2012)	CSS (longitudinal)	USA (black & white)	70–79	M/F	1136	A positive association exists between PWV and age-related muscle mass decline using SMI, lean mass in arms, legs and skeletal muscle mass (over 6 year follow-up).
(Kohara, Ochi et al. 2012)	CSS	Japan	67.2±8.8	M/F	1024	Thigh muscle cross-sectional area was negatively associated with brachial-ankle PWV in men.
(Srikanthan and Karlamangla 2011) (NHANES III)	CSS	USA	≥20	M/F	13,644	The highest quintile of SMI (the ratio of total SMM to total body weight) and the ratio of total skeletal muscle mass (estimated by bioelectrical impedance) were associated with improved insulin sensitivity and lower risk of transitional/pre- or overt diabetes mellitus.
(Atlantis, Martin et al. 2009)	CSS	Australia	35-81	M	1195	Odds for present IDF MetS increased for lower muscle mass (Whole-body LM (%)). Significant PAR% due to lowest muscle mass was 31% for the IDF MetS.
(Ferreira, Snijder et al. 2004)	CSS (longitudinal)	Netherlands	36.5 ±0.6	M/F	336	Peripheral lean mass was inversely associated with stiffness of the carotido-femoral segment (over 23 year follow-up).

BP: blood pressure; CAVI: cardio-ankle vascular index; MFR: Muscle mass to body fat ratio; MetS: Metabolic syndrome; NHANES III: The Third National Health and Nutrition Examination Survey; SMI: Skeletal muscle mass index; SMM: Skeletal muscle mass; PAR%: Population attributable risk (PAR%); PWV: Pulse wave velocity; SD: standard deviation; CSS: Cross-sectional study.

1.4 Nutritional prevention and management of NCDs

Although the primary causes have not been fully elucidated, many of the risk factors associated with NCDs are lifestyle related and thus, modifiable (WHO/FAO 2003). NCDs can be prevented early (WHO 2003). Appropriate lifestyle modifications such as diet, physical activity and weight loss have been recognised to be similar, or even more effective, than medical interventions in preventing or delaying the onset of NCDs in high risk people (Goldman and Cook 1984; Tuomilehto, Lindström et al. 2001; Group 2002; Appel, Champagne et al. 2003; Molitch, Fujimoto et al. 2003; Elmer, Obarzanek et al. 2006; Beaglehole, Bonita et al. 2011).

In 2012, a meta-analysis on 8 randomized controlled trials were conducted to evaluate the effect of lifestyle modifications (including dietary and physical activity modifications) on resolution of metabolic syndrome (MetS) and improvement of the values of MetS components (Yamaoka and Tango 2012). This meta-analysis reported that the relative proportion of subjects with resolved MetS in the lifestyle modification group was approximately 2.0 (95% CI 1.5 to 2.7) times greater in the modification group compared with the control group. The authors found also that the lifestyle modification significantly reduced mean values for Systolic BP by -6.4 mmHg (95% CI -9.7 to -3.2), Diastolic BP by -3.3 mmHg (95% CI -5.2 to -1.4), triglycerides by -12.0 mg/dl (95% CI -22.2 to -1.7), WC by -2.7 cm (95% CI -4.6 to -0.9), and fasting blood glucose by -11.5 mg/dl (95% CI -22.4 to -0.6). In 2007, a meta-analysis of 80 weight-loss clinical trials with a minimum 1-year follow-up found a mean weight loss of 5% to 9% was observed during the first 6 months from interventions involving a reduced-energy diet and/or weight-loss medications with weight plateaus at approximately 6 months (Franz, VanWormer et al. 2007). Also, it found that in studies extending to 48 months, a mean 3% to 6% of weight loss was maintained with none of the groups experiencing weight regain to baseline. However, it found that advice-only and exercise-alone groups had minimal weight loss at any time point.

WHO has recommended tobacco control, salt reduction, improved diets and physical activity, reduction in hazardous alcohol intake, and essential drugs as a top priority for tackling NCDs and has considered this a public health target (Beaglehole, Bonita et al. 2011). However, these targets will not be achieved without fully elucidating the factors affecting the behavioural change such as knowledge, perceptions and factors influencing food choices and food behaviours amongst the community.

1.4.1 The role of dietary modification in protecting against NCDs

1.4.1.1 Salt reduction

As discussed earlier (Section **1.2.3.2**), reducing salt intake for long term and less than 6 grams per day (<100 mmol salt per day) lowers the blood pressure and subsequently reduces the occurrence of cardiovascular diseases (CVDs) in general population including normotensive and hypertensive populations (He, Markandu et al. 2005; Cook, Cutler et al. 2007; He, Li et al. 2013; Johnson, Raj et al. 2015). Based on this body of evidence, national and international authorities have launched recommendations to reduce daily sodium intake to reduce blood pressure and risk of cardiovascular disease, stroke and coronary heart disease in adults.

The WHO strongly recommends that adults should not consume more than 5 g of salt per day (2 g sodium per day) (WHO 2007). In SA, this recommended level was adopted in the "Dietary Guidelines for Saudis: Healthy Food Palm" in 2012 (MOH 2012), and the national "Diet and Physical Activity Strategy (DPAS)" in 2014 (MOH 2014). In the United Kingdom, the Scientific Advisory Committee on Nutrition (SACN), in 2003, made a recommendation to reduce the average salt intake of the population to <6 g per day (2.3 g per day) (SACN 2003). In the United States, the 2015 Dietary Guidelines for Americans recommended a reduction of daily salt intake to 6 g salt per day (2.3 g sodium per day) and further reduction in salt intake to 3.8 g salt per day (1.5 g sodium per day) among individuals who are aged >51 years and those of any age who are African American or have diabetes, hypertension, or chronic kidney disease (USDA 2015) (Table 1.4-1).

Table 1.4-1: Recommendations for reduction of salt (sodium) Intake for general population.

Guideline	Sodium (Na)	Salt (NaCl)	Country
	(g/day)	(g/day)	
USDA (USDA 2015; DeSalvo, Olson et al. 2016)	< 2.3	< 6	USA
WHO (WHO 2007; WHO 2012)	<2	< 5	WHO
SACN (SACN 2003)	< 2.3	< 6	UK

WHO: World Health Organization; SACN: Scientific Advisory Committee on Nutrition; UK: United Kingdom; USA: USDA: United States of America; USDA: United States Department of Agriculture;

1.4.2 Factors influencing food choices, behavior and nutrition

1.4.2.1 Social and psychosocial determinants

Different reviews identified several determinants affecting food choices including social determinants such as education, marital status, having children and family peers; psychosocial determinants such as attitudes, beliefs, intention, self-efficacy, social support, motivation and knowledge; economic determinants such as cost and income; physical determinants such as accessibility, availability, cooking skills, living area and time; and biological determinants such as age, food properties (e.g. satiety, palatability) and gender (Sørensen, Møller et al. 2003; EUFIC 2005; Kamphuis, Giskes et al. 2006; Shaikh, Yaroch et al. 2008; Engler-Stringer 2010; Guillaumie, Godin et al. 2010; Krølner, Rasmussen et al. 2011; Mayén, Marques-Vidal et al. 2014; Higgs 2015).

1.4.2.1.1 Psychosocial determinants

There are many models that have been used to explore the psychosocial determinants of healthy lifestyle including healthy eating. The Theory Planned Behaviour (TPB), the Health Belief Model, the Theory of Reasoned Action and the Social Cognitive Theory, and Trans Theoretical Model are amongst the most commonly used models (EUFIC 2005).

The theory of Planned Behaviour (Ajzen 1988; Ajzen 1991) is one of social-psychological models frequently used to examine factors influencing behaviours and behavioural intensions (Ajzen 1991). This theory was considered to be one of the more relevant theories to design evidence-based interventions (Ajzen 2011; Ajzen 2015). It identifies these factors via the consideration of seven main constructs: socio-demographic, attitudes towards behaviour (ATT), subjective norms (SN), perceived behavioural control (PBC) (or self-efficacy), actual barriers to behaviour, intentions, and behaviours. The TPB model assumes that ATT, SN, and PBC lead to the foundation of a behavioural intention, and that intention is anticipated to be the direct former of behaviour (Figure 1.4-1). Consequently, behavioural intention occupies the motivational factors that influence behaviour, for example, to eat nutritionally balanced diet. Ajzen (2011) also has argued that other factors such as socio-demographic characteristics or a personal nature, are expected to indirectly influence intentions and behaviour by affecting the intention's determinants ATT, SN and PBC (Ajzen 2011). A schematic representation of the theory is shown in Figure 1.4-1.

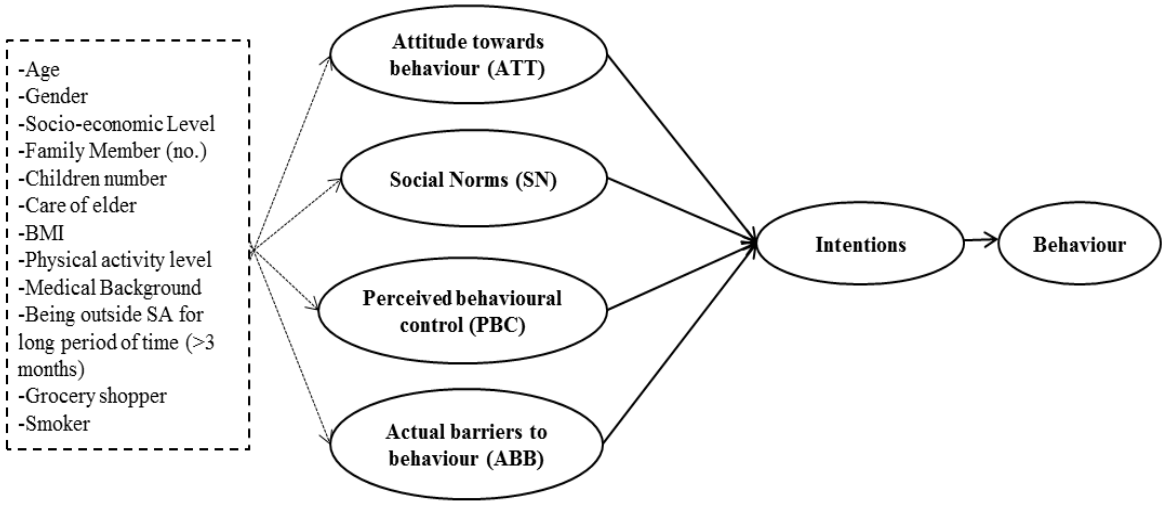


Figure 1.4-1: The theory of planned behaviour (TPB) model - adapted from (Conner and Sparks 2005).

Understanding the determinants that induce behaviours and behavioural intensions towards healthier eating practices in adults will enhance the effectiveness of nutritional education interventions and food and nutrition policies in the prevention and mitigation of NCDs. Although many studies examine certain aspects of lifestyle and dietary behaviours amongst the Saudi population, the vast majority of these studies did not assess the influencing factors on food choices and food behaviours.

- Attitude towards the behaviour (ATT)

Intention is assumed to be determined by "behavioural beliefs" which refers to the perceived positive or negative consequences of performing the behaviour and the subjective values or evaluations of these consequences. Consequently, behavioural beliefs that are readily accessible in memory lead to the formation of a positive or negative attitude toward the behaviour (ATT) (Ajzen 2015).

- Subjective norms (SN)

Intention is assumed also to be determined by perceived behaviours and expectations of important referent individuals or groups, combined with the person's motivation to comply with these referents. These considerations are called "normative beliefs", and these normative beliefs are readily accessible in memory to produce "subjective norm" or perceived social pressure with respect to perform the behaviour. Therefore, "subjective norms" are a perceived social pressure to engage or not to engage in behaviour toward a more balanced diet (Ajzen 2015).

- Perceived behavioural control (PBC) (Self efficacy)

The perceived presence of factors that can influence a person's ability to perform the behaviour is called "control beliefs". These factors to facilitate or interfere with behavioural performance have a perceived power to produce a certain level of "perceived behavioural control" or as called "self-efficacy" (Bandura 1977) in relation to the behaviour (Ajzen 2015).

- Actual barriers to behaviour (ABB)

Actual barriers to behaviour (ABB) refer to objective barriers that influence whether or not a person can do certain behaviours, rather than the respondents' beliefs about barriers (Conner and Sparks 2005; d'Ardenne, McManus et al. 2011). In addition, actual barriers can control behaviour regardless of intention (e.g. level of knowledge toward the behaviour, lack of time or costs) (Conner and Sparks 2005).

In a recent systematic review and meta-analysis (2015), found TPB variables (ATT, SN and PBC) had medium to large associations with intention and behaviour (McDermott, Oliver et al. 2015). The authors found that the attitudes towards the behaviour had the strongest association with intention (ATT, r = 0.54) followed by perceived behavioural control (PBC, r = 0.42) and subjective norm (SN, r = 0.37). However, the authors stated that the associations between TPB key variables and behaviour were significantly lower both for choosing and avoiding nutritionally balanced diet; and they strongly suggest that researchers should carefully consider the nature of the behaviour being exhibited prior to selecting the theory (McDermott, Oliver et al. 2015). In 2011, a meta-analysis found that the TPB model provide strong predictions of intention and behaviour across a range of health behaviours (McEachan, Conner et al. 2011). The authors found that physical activity and dietary behaviours were better predicted by the model. In addition, Guillaumie et al., (2010) investigated the efficacy of these psychosocial different models in predicting fruit and vegetable consumption, the authors reported that the Theory of Planned Behaviour, as well as the Social Cognitive Theory are the preferable models to predict fruit and vegetable consumption in adults (Guillaumie, Godin et al. 2010).

1.4.2.2 Nutrition and health guidelines in SA

Nutrition and health guidelines (NHG) aimed at optimising the community health by promoting healthy eating and lifestyles (Willett 2013). Khan (2000) developed dietary recommendations, goals and guidelines for optimising health in SA, and it was expected

that these dietary recommendations and goals would be achieved by 2005 (Khan 2000). However, looking at the results of recent national surveys (Table 1.1-1) none of these recommendations were achieved. The "Dietary Guidelines for Saudis: Healthy Food Palm" in 2012 (MOH 2012), and the national "Diet and Physical Activity Strategy (DPAS)" in 2014 (MOH 2014) were introduced by the Ministry of Health (MOH) in SA to improve the quality of the Saudi lifestyle toward diet and physical activity. However, none of these guidelines has national dietary targets and goals to be achieved by a stated time and hence evaluated. Furthermore, SA developed a country cooperation strategy (CCS) with WHO (2012–2016) aimed at addressing the country's health priorities and challenges, including nutritional and dietary issues (WHO 2013).

As a result of the CCS, the Regional Office of Eastern Mediterranean in WHO (WHO/EMRO) organised and developed a consultation with the goal of establishing strategic interventions regarding the reduction of dietary salt and fat (including trans fats) in the Eastern Mediterranean Region (WHO/EMRO 2013). In the latter report, it was suggested that the national salt consumption should be reduced by 30% by 2025. The WHO/EMRO (2013) also proposed various work plans aimed at tackling these issues, namely: changing public behaviours through public awareness and education campaigns; establishing food and nutrition policies, including pricing policies; reformulating food products, and; improving research in this field.

1.5 Assessing dietary intake

Epidemiological studies demonstrate significant associations between dietary habits and chronic diseases such as obesity, cardiovascular diseases, hypertension, T2DM and cancer (WHO/FAO 2003; Wild 2004; Bingham 2007; Dodd 2008; Kastorini 2009; Koning 2011). In SA, there is increasing trend of fast food use (Naeem 2012; ALFaris, Al-Tamimi et al. 2015). ALFaris et al. showed that nearly 25% of adolescent girls and young adult girls consumed fast food twice or more weekly and nearly 56% of them consumed fast food daily. Burgers were the main kinds of fast food meals (70%) usually consumed by the study participants, followed by pizza (33%) and French fries (30%) (ALFaris, Al-Tamimi et al. 2015). However, there are no national dietary surveys to give more accurate details. Reliable information on actual levels of consumed foods has to be generated through representative consumption surveys (WHO/FAO 2003). Therefore, dietary assessment methods can be used to collect the dietary consumption data at the national, household or

the individual level and also at long-term and short-term stages (Block 1989; Rutishauser 2005; Bingham 2007; FAO 2008; Thompson 2013).

There are different methods been developed, implemented, and evaluated in a number of countries such as United Kingdom, some European Countries and United States of America for assessing dietary intake and nutritional status at a national and individual levels (Lester I H 1994; Jerome 1997; Ministry of Health 2003; Resano-Pérez 2003; Ashwell 2005; Ministry of Health 2006). The Food Frequency Questionnaire (FFQ), 24 Hour diet recall, and Dietary Record are the most commonly used methods in epidemiologic studies to assess long-term nutritional exposure to nutrients and its relation to some nutritional and health issues (Willett 1998; Rutishauser 2005; Rutishauser 2007; Thompson 2010; Sam 2012; Boeing 2013).

1.5.1 24-hour diet recall

The 24-Hour diet recall is interviewer administered, so literacy of the respondent is not required (Baranowski 2013). During the interview, the subject is asked to recall and report all the foods and beverages consumed in the preceding 24-hours or preceding day (Thompson 2013). The interview also can be done by phone (Posner, Borman et al. 1982; Casey, Goolsby et al. 1999) or computerized system (Slimani, Deharveng et al. 1999; Raper, Perloff et al. 2004; Subar, Thompson et al. 2007; Moshfegh, Rhodes et al. 2008). However, this method needs well trained dieticians and multiple interviews to reflect the usual dietary intake which is potentially increasing the cost, time, logistical, and personnel constraints (Baranowski 2013; Thompson 2013). This method also relies on subject's memory which is a source of error especially with people with minimum or impaired memory or cognitive functioning such as children and older people (Michael Nelson 2003; Thompson 2013). This limitation was minimised by developing a new multiple pass (steps) method to help the subject remember all consumed foods including additional foods (Conway, Ingwersen et al. 2003; Raper, Perloff et al. 2004).

1.5.2 Dietary Records

In the Dietary Record or diary method, the subjects are asked to record all consumed foods and beverages at the time that foods are eaten, to minimize reliance on memory for one or more days (Baranowski 2013; Thompson 2013). To represent the usual intake, the subjects need to record their diet for several days due to day-to-day variation. However, this may

lead the subjects to change their eating behaviour in order to ease the burden of recording, or as a response to increased awareness of their food choices through their participation for long time (Johnson 2002; Pattersen 2013). Moreover, literacy is required in this method which may limit its application in some population groups (Baranowski 2013; Thompson 2013). There is also evidence that subjects tend to under-report their energy intake when using this method which may distort the links between dietary data and the health risks (Hill and Davies 2001; Trabulsi and Schoeller 2001; Rennie, Coward et al. 2007).

1.5.3 Food Frequency Questionnaire (FFQ)

The Food Frequency Questionnaire (FFQ) is a commonly used instrument to evaluate long-term usual dietary intake and assess its relationship with chronic diseases (Margetts 1997; Willett 2012). FFQ is also considered to be one of the most practical methods used in epidemiological studies (Thompson 1994). Despite the low cost and ease of administration of this questionnaire, it suffers from random and systematic errors as other dietary intake assessment methods (Margetts 1997; Subar 2001; Westerterp 2002; Thompson 2010). However, these limitations can be minimised by using an accurate specific-population data such as selection of specific-population portion sizes; developing a representative food list based on other national studies (24-h method and Dietary Records); and creating a nutrient database based on national food composition tables; (Teufel 1997 ; Kroke A 1999; Cade 2002; Cade 2004; Subar 2004; Willett 2007; Dehghan 2012; Palmer 2012).

FFQ need to be developed and validated for specific populations because foods are culture-dependent (Cade 2002). The validity of the FFQ data can be assessed by comparing its outcomes with repeated dietary recalls, human body biomarkers, and/or total energy expenditure data (Nelson 1997; Kroke A 1999; Cade 2004; Gibson 2005; Serra-Majem 2009; Willett 2012). It is required to validate the estimated nutrients by FFQ against recovery biomarkers, for example potassium by urinary potassium, sodium by urinary sodium and protein by urinary nitrogen (Bingham 2003; Tasevska, Runswick et al. 2006; Munehiro, Tsutomu et al. 2012). The 24-hour urine collection is considered as a “gold standard” method to measure sodium intake, capturing 85-90% of consumed sodium (Schachter, Harper et al. 1980; Holbrook, Patterson et al. 1984; Shepherd, Farleigh et al. 1985; Bingham 1987; Elliott and Brown 2007; Bates, Thurnham et al. 2009; Van Dam and Hunter 2013). FFQ are considered as sufficiently valid when the correlation coefficients between FFQ and the reference method whether estimated dietary intake or human body

biomarker, is 0.50 and more (Willett 2012). Additionally, the Bland–Altman method should be implemented to determine if there is any systematic difference between the two methods (bias), and to what extent the two methods agree (limits of agreement) (Cade 2002).

Several FFQs were validated to assess salt intake in different countries apart from Saudi Arabia. Table **1.5-1** illustrates the reliability and validity of different FFQs against dietary assessment methods or 24-hour urinary collection method to assess daily salt intake.

Table 1.5-1: Comparison of validation results of FFQ against 24h dietary recall (MP24-HR), food records (FR), and 24h urinary excretion (UE) to assess salt (sodium) intake

Reference	Sample Size (n)	Items (n)	Valid Sample Size (n)	Age (years)	Crude-r			Energy-adjusted r			LOA (Lower-Upper)			Agree (%)	Adjacent (%)	Opposite	Sen (%)	Spec (%)	Kappa	Weighted Kappa	Comments
					24-HR	FR	UE	24-HR	FR	UE	24-HR	FR	UE								
(Jayawardena, Byrne et al. 2016)	77	85	77	≥18	-	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7-day weighed-intake dietary records (Sri Lanka)
(Freedman, Commins et al. 2015)	2265	-	2265	≥40	-	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	Pooled data, black, white/other, (United States)
(Gunes, Imeryuz et al. 2015)	120	229	120	30-70	0.38	-	-	0.29	-	-	-	-	-	38	56	6	-	-	-	0.29	Two MP24-HR and mean four FFQs Turkish adults
(Maruyama, Kokubo et al. 2015)	58	84	58	47-78	-	0.32-0.39	-	-	0.43-0.48	-	-	-	-	53-55	31-38	16-7	-	-	-	-	Urban, Japanese, middle-aged population
(Pereira, Bensenor et al. 2015)	15,105	114	8,257	35-74	-	-	0.1	-	-	-	-	-	-	23	35	42	-	-	-	0.18	12-hour urinary excretion
(Talegawkar, Tanaka et al. 2015)	468	110	468	26-95	-	-	-	-	0.27	-	-	-	-		72	28	-	-	-	-	3-d FR, Hispanic and non-Hispanic white (energy adjusted)
(Elorriaga, Irazola et al. 2015)	147	126	147	21-74	0.33	-	-	0.47	-	-	-	-	-	-	-	-	-	-	-	-	Three MP24-HR (Argentinan, Chile and Uruguay adults)
(Macedo-Ojeda, Vizmanos-Lamotte et al. 2013)	97	162	97	18-71	-	0.25	-	-	0.22	-	-	-	-		58	42	-	-	-	-	9-d FRs (men and women (Mexico))
(Dehghan, Ilow et al. 2012)	146	134	146	30-70	0.19-0.46	-	-	-	-	-	-	-	-	66-75	-	-	-	-	-	-	Four MP24-HDRs (Polish adults)
(Dehghan, del Cerro et al. 2012)	156	96	156	35-70	0.32-0.40	-	-	-	-	-	-	-	-	29-31	39-43	32-26	-	-	-	-	Four MP24-HDRs (Argentinian adults)
(Na and Lee 2012)	305	138	305	≥40	-	0.598	-	-	0.51	-	-	-	-	55	27	18	-	-	0.26	0.42 (0.34-0.49)	3-days FRs (Korean)
(Sam 2012)	132	147	132	30-59	-	0.36	-	-	0.27	-	-	49-290%	-	75	-	-	-	-	-	-	8-dWeight FRs and compare with previous studies
(Zhuang, Yuan et al. 2012)	207	86	207	30–75	0.34	-	-	0.32	-	-	-	-	-	37	37	26	-	-	-	0.2	Four MP24-HDRs
(Hong, Choi et al. 2010)	1478	85	85	33-70	-	0.417	-	-	-	-	-	-	-	-	-	-	-	-	0.22	0.34 (0.19-0.49)	3-days FRs (T2 DM Korean)
(Carithers, Talegawkar et al. 2009)	436	158	436	35-81	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	Four MP24-HDRs
(Ferreira-Sae, Gallani et al. 2009)	132	50	121	18-85	-	-	0.19£	-	-	-	-	-	-	-	-	-	-	-	-	-	24 H UE & 3-d FRs Low-income and low-literacy Brazilian hypertensive

*Continued overleaf

Reference	Sample Size (n)	Items (n)	Valid Sample Size (n)	Age (years)	Crude-r			Energy-adjusted r			LOA (Lower-Upper)			Agree (%)	Adjacent (%)	Opposite	Sen (%)	Spec (%)	Kappa	Weighted Kappa	Comments
					24-HR	FR	UE	24-HR	FR	UE	24-HR	FR	UE								
(Lassale, Guilbert et al. 2009)	74	174	74	31-60	-	-	0.35	-	-	-	-	-	-	31	53	16	-	-	-	0.31	Two 4-day Weight FRs (Australian women) (C-FFQ)
(Lassale, Guilbert et al. 2009)	74	174	74	31-60	-	0.69	-	-	-	-	-	63-215 %	-	37	55	8	-	-	-	0.55	Two 4-day WFR (Australian women) (C-FFQ)
(Charlton, Steyn et al. 2008)	324	42	324	20-65	0.75	-	0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	Repeated 24 H UE (multi-ethnic South African)
(Block, Wakimoto et al. 2006)	89	103	89	18-71	0.53	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	Three MP24-HDRs Low-income (Hispanic)
JACC Study 2005 (Date, Fukui et al. 2005)	110000	33	85	20-79	-	0.35	-	-	0.31	-	-	-	-	-	-	-	-	-	-	-	12-days weighed FRs
(George, Milani et al. 2004)	95	195	95	18-38	-	-	-	-	0.24	-	-	-	-	21	69	10	-	-	-	-	3-day FRs (College women - multi-ethnic Americans)
(George, Milani et al. 2004)	50	195	50	18-38	-	-	-	-	0.28	-	-	-	-	30	64	6	-	-	-	-	4-day FRs (low-income women - multi-ethnic Americans)
(Sasaki, Ishihara et al. 2003)	89	110	89	-	-	-	NS	-	-	NS	-	-	-	-	-	-	-	-	-	-	28-Days FRs & two 24-H UE (Japanese)
(Kabagambe, Baylin et al. 2001)	503	135	120	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	Seven MP24-HDRs & two FFQ (Hispanics)
EPIC-Norfolk 2001(McKeown, Day et al. 2001)	204	130	146	45-74	-	0.45-0.47	0.18-0.20	-	0.44-0.52	-	-	-	-	FR:34	FR:60	6	-	-	-	-	7-d FRs (European)
(Sasaki, Yanagibori et al. 1998)	223	110	223	-	-	-	NS	-	-	0.23$	-	-	-	-	-	-	-	-	-	-	Single 24-H UE(Japanese)
(Sasaki, Yanagibori et al. 1998)	47	110	47	38-69	-	0.41	-	-	0.3	-	-	-	-	30	66	4	-	-	-	-	3-day FRs (Japanese women)
(Männistö, Virtanen et al. 1996)	160	110	160	25-75	-	0.22	-	-	0.42	-	-	-	-		64	36	-	-	-	-	7-day FRs (Japanese women)

[$] Significant in women only.
[£] Significant correlation when the discretionary salt was added to the FFQ.
C-FFQ: computerised FFQ; K: Kappa; FFQ: food frequency questionnaire; MP24-HR: 24 H dietary recall; FR: food records; Sen: Sensitivity; Spec: Specificity; UE: 24-H urinary excretion; Valid: Validation; WK: Weight Kappa; LOA: Limit of Agreement.

Chapter Two

General Materials and Methods

2.1 Overview

This chapter outlines the general materials and methods used throughout this thesis. The thesis contains three main studies divided over six chapters (Chapter 3 to 8). This thesis was undertaken in the broad research area of nutritional assessment and management of NCDs in Saudi Arabia (SA) aiming to fill many gaps and answer various questions. Briefly, the first study examines the validity of salt intake using a newly developed FFQ and its relationship with hypertension among SA adults. The second study is a secondary data analysis examining the performance and reliability of body composition measures in predicting NCDs in a large sample in SA. The third study explores the factors impacted on the intention of people to adopt nutritionally balanced diet. Figure 2.1-1 shows the three studies which were carried out during this PhD and their relevant analyses. Methods specific to each study are described in detail in the relevant chapters.

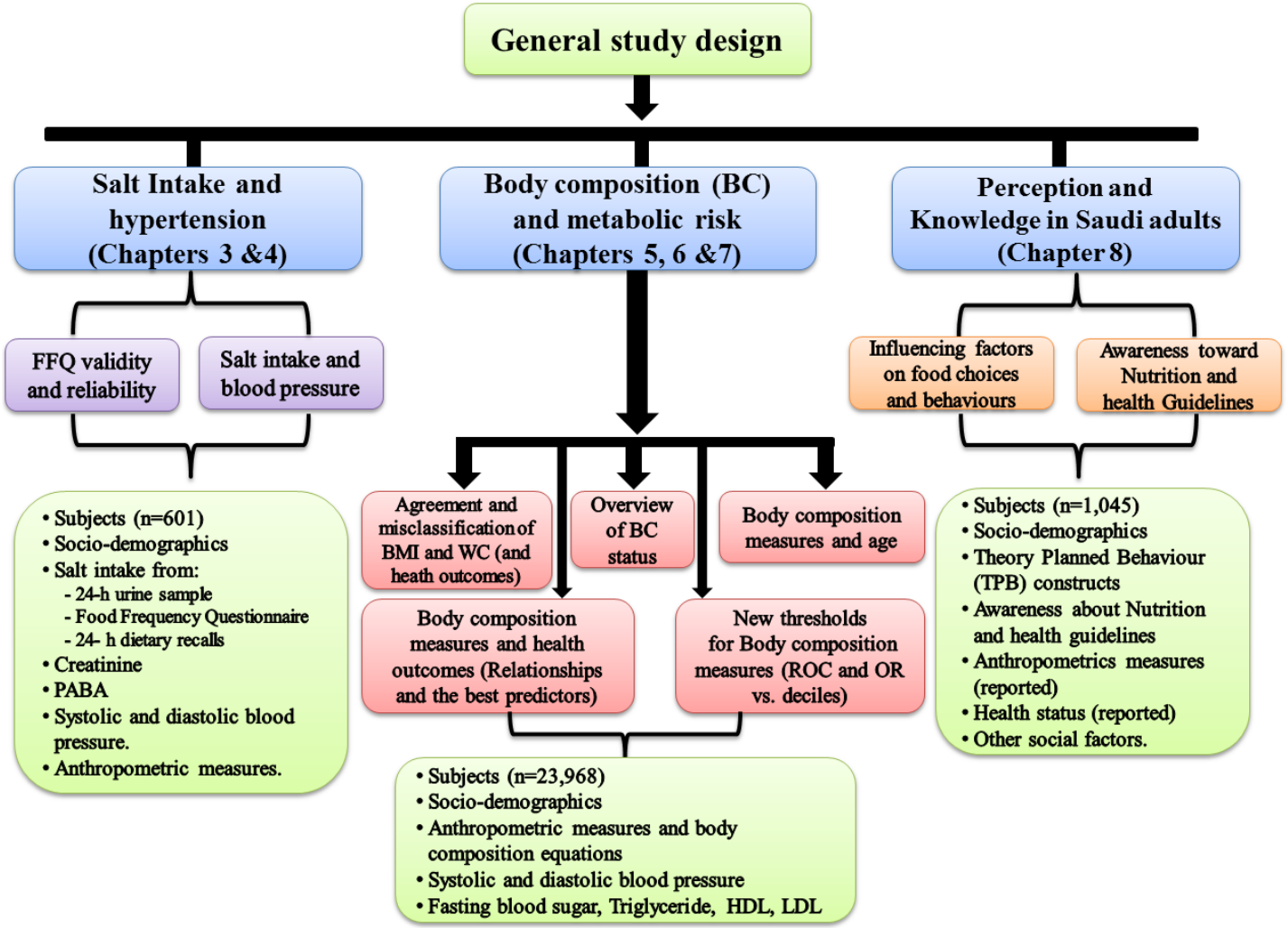


Figure 2.1-1: General study design and relevant analysis for studies 1, 2 and 3.

2.2 Dietary salt intake study

2.2.1 The study rationale

As reviewed in Chapter 1, there is a strong body of evidence supporting the association between chronically high sodium intake (in the form of salt – NaCl) and occurrence of hypertension (Meneton, Jeunemaitre et al. 2005; He and MacGregor 2009; Blaustein, Leenen et al. 2012; He and MacGregor 2015; Johnson, Raj et al. 2015) as a major influential factor to the development of CVDs such as stroke and heart diseases (He, Burnier et al. 2011; Soga and Pandey 2011). SA experiences a high prevalence of CVDs including hypertension (Al-Nozha 2004; Al-Nozha, Al-Mazrou et al. 2005). Several studies have assessed the relationship between dietary salt intake and CVDs, and the main dietary sources of salt in different countries around the world. However, salt intake has not been assessed in Saudi Arabia and the main dietary sources of salt have not been examined. Thus, salt intake in SA should be assessed through validated tools; and its relationship with hypertension should be assessed as well. Therefore, this study aims to answer the following research questions:

RQ1: Is the food frequency questionnaire a reliable and valid tool to assess salt intake in Saudi Arabia? (**Chapter 3**)

RQ2: Does salt intake vary with socio-economic characteristics; is salt intake related to blood pressure in SA; and what are the main sources of dietary salt in Saudi Arabia? (**Chapter 4**)

2.2.2 Study design and sampling

The study of the salt intake used a cross-sectional study design. This study was conducted in Riyadh city during October and November 2013 and included males and females aged 19 to 60 years. Subjects on kidney dialysis and pregnant women were excluded from this study. A FFQ was developed and pretested among participants similar to those who were included in the actual survey. The FFQ food list is culturally-based and expatriates have different eating patterns which may have affected the findings of this study (Amin, Al Sultan et al. 2014). Therefore, expatriates were not included in this study. The Kuwaiti Semi-Quantitative Food Frequency Questionnaire (Dehghan 2005) was used to design the present study questionnaire, as it is culturally relevant. Information describing Saudi food intakes is limited. Details of nutrient intakes from

broad food groups, (Al-Nozha M 1996) were collected in 1987 and published in 1996. More detailed food intake data from Saudi adults have not been published. Thus, 24-hour recalls from 19,598 men and women from all over SA (Al-Nozha M 1996) were used to derive the food lists for the Saudi Food Frequency Questionnaire whereas the Kuwaiti FFQ was used to design the main food groups of the present FFQ.

Repeated multiple pass 24-Hour dietary recalls (24-HDR) and urinary biomarkers for a sub-sample of the population were collected. The 24-HDR was carried out twice in non-consecutive days including weekends and to minimize the source of error of repeated food recalls, a standardization of interviewers was carried out to ensure that they trained dietitians on the proper ways to generate food intake using a multiple pass method. This was acquired using an interview similar to the USDA 5-Step Multiple (Conway, Ingwersen et al. 2003). If the participant was interviewed on the weekend the second interview was on a weekday and vice versa, by telephone. In every round of 24-HDR interview, each day was weighted appropriately to produce a synthetic week as the following equation (E2) (Liu, Wang et al. 2013):

$$\text{E2: Mean daily intake} = \frac{(\text{weekday} \times 5) + (\text{weekend} \times 2)}{7}$$

The two main stages to collect the dietary intake data are clarified in Figure 2.2-1**.** More details clarified in chapter 3.

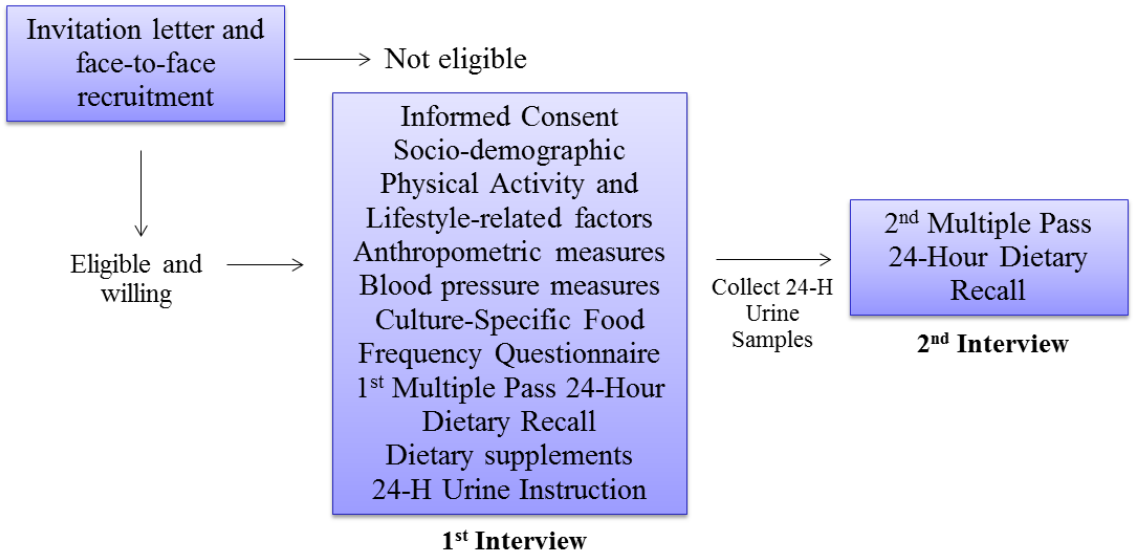


Figure 2.2-1: Study procedures.

2.2.3 Ethical considerations

The study was conducted in accordance with the guidelines laid down in the Declaration of Saudi National Committee of BioEthics (Appendix 1). All procedures were approved by the Saudi Food and Drug Authority Ethical Committee (SFDA-IRB). Each volunteer was given an information sheet and the chance to discuss their participation before they agreed to take part. They were asked to sign two copies of a consent form. One was kept by the volunteer and the other kept by the researcher. All volunteers were informed that they could stop their participation at any time.

2.2.4 Data Collection

The survey tools (FFQ, and 24-HDR, socio-demographic, and 24-hour urinary instructions and record forms) were designed to fulfil the objectives of this survey. The tools were translated into Arabic and were back-translated by an independent translator to ensure the accuracy of translation. The Arabic FFQ was pre-tested on 52 eligible respondents for wording and understanding of the questions, and necessary adjustments were made in FFQ in light of the pre-test. In addition, the draft Saudi-FFQ was distributed among three senior dietitians in the Saudi Food and Drug Authority and King Saud University with known expertise in dietary assessment for review and comments. The components of the survey tools are shown in Table 2.2-1**.**

Table 2.2-1: Variables assessed within the study

Category	*Variable*	*Measurement instrument*
Demographic characteristics	Age, sex, marital status, children, family members, Socio-economic status (education, income, occupation, health insurance)	Individual interview and interviewer-administered questionnaires at survey site
Medical history	Chronic health conditions and non-communicable diseases (hypertension, Type 2 Diabetes, High Triglyceride, High Cholesterol, Anemia, Osteomalacia, Heart Disease, Kidney Disease, Liver Disease, Stomach Ulcer, Cancer)	Interviewer-administered questionnaires at survey site
Lifestyle-related factors	Physical activity (Sedentary Lifestyle, light activity, moderate activity, high activity and very high activity).	Interviewer-administered questionnaires at survey site
	Usual diet (No special diet, Vegetarian, Weight reduction diet, Diabetic diet, Low salt diet, Low Fat/Cholesterol diet, and other special diets.	Interviewer-administered questionnaires at survey site
Dietary Intake	Food Frequency Questionnaire	Saudi Food Frequency Questionnaire
	Repeated 24-h dietary intake	Multiple Pass 24-Hour Dietary Recall
Physical measurements	Height	Stadiometers (Detecto, USA)
	Weight	Electronic scales (Seca, Germany)
	Waist and hip circumferences	Non-stretchable and pushbutton measuring tapes
	Blood pressure	Automatic sphygmomanometer (Omron M6 Comfort (HEM-7223-E), Japan)
Urine measurements (24- hour)	Sodium	Atomic absorption spectrophotometer (AA-6650, Shimadzu Co. Ltd., Japan)
	Potassium	Atomic absorption spectrophotometer (AA-6650, Shimadzu Co. Ltd., Japan)
	Creatinine	kinetic Jaffe´ technique
	Para-Amino Benzoic Acid	High performance liquid chromatography (HPLC)
	Nitrogen	Kjeldahl technique (Kjeltec 2300 analyser, Foss, DK)
Participants' Burden	To assess which dietary method the participants preferred (FFQ or MP24-HDR) and why? To assess whether the participants faced any difficulty in describing their food intake; describing the amount their food intake; or facing other difficulties during the survey. To assess whether the answers of the participants reflecting their real intake*	Interviewer-administered questionnaires at survey site

* Opinions of the dietitians who worked in the research field.

Three temporary investigation centres were built in large retail centres in areas of contrasting socio-economic status in Riyadh city. Each centre was divided to two investigation rooms for female and male participants. Each room was designed to ensure the privacy and comfort of the participants as well as investigators. Each room was fully equipped with the required research instruments as well as games for children who joined their parent in the investigation centres. For food portion sizes estimation, every room was equipped by household measures such as cups, spoons and Standardised Portioned Plates (SPP), and food models and printed visuals on the room wall. Stadiometers (DETECTO–8528-M063-O1, USA), electronic scales (SECA-813, Germany), non-stretchable and pushbutton measuring tapes, and Automatic sphygmomanometers (OMRON-HEM7223, Japan) were also provided. The study was conducted by the researcher with assistance of eleven trained dietitians.

A sub-sample (n=71) received verbal and written instructions on how to of collect the urine samples for 24 hours and how to use the Para-aminobenzoic acid (PABA) tablets. PABA was used to verify the completeness of the urine collections. Urine collections with <85% PABA recovery were considered in-complete and removed from further data analyses (Bingham 1983). Also, used was a urinary creatinine index (UCI) to verify the completeness of the urine collections: urinary creatinine excretion (UCE) (mg) adjusted for body weight (kg) and time (24 hours). Any level of UCI falling outside the range of 11–20 and 14–26 (mg/kg) for women and men respectively was excluded (Hristova EN 2001; Burtis and Ashwood 2012).

2.3 Body composition study

2.3.1 Study rationale

As discussed in the introduction (Section 1.3.2), the performance and accuracy of BMI is questionable in assessing obesity and consequently in assessing its relationship with NCDs, especially among non-Caucasian population. Therefore, it is important to assess the performance and accuracy of BMI and other alternative obesity measures in Saudi Arabia and its relationship with NCDs. Also, muscle mass (SMM) has been advocated as one of the factors linked with NCDs and its related risk factors, such as T2DM and hypertension, in some epidemiological studies. However, this factor has not been fully examined in non-Caucasian populations especially in Arab populations. Therefore, it is

important to assess the performance and accuracy of SMM in Saudi Arabia and its relationship with NCDs. Therefore, this study aimed to answer the following research questions:

RQ3: Are body composition measures influenced by age; does the body mass index agree with waist circumference for predicting NCDs; and does skeletal mass index represent the muscle mass status in the body? (**Chapter 5**)

RQ4: Are skeletal muscle mass indices better metrics to estimate the likelihood of having metabolic diseases? (**Chapter 6**)

RQ5: Is BMI alone or a combination of BMI and WC the better metric to estimate the likelihood of having metabolic diseases in Saudi Arabs? (**Chapter 7**)

2.3.2 Study design and sampling

This study was a secondary analysis of integrated data from the Saudi National Surveys (Saudi Health Information Survey (SHIS) and Saudi National Health Survey (SNHS)), the Riyadh Region Surveys (two), and the Riyadh Validation Survey (RVS). Both Saudi National Health Surveys sample the population using a multistage stratified cluster random sampling of private households, using a national sampling frame maintained and updated by the SA Census Bureau, to provide nationally representative data on health-related variables (WHO-STEPwise 2005; Memish, El Bcheraoui et al. 2014). Both Riyadh region surveys are the capital-wide Biomarker Screening in Riyadh region (BSR), a collaborative effort between the Biomarkers Research Program (BRP) of King Saud University (KSU) and the Ministry of Health in Riyadh, Kingdom of Saudi Arabia (RIYADH Cohort) (Al-Daghri, Al-Attas et al. 2011). Subjects were recruited randomly from their homes using the cluster sampling strategy and their information was taken from the existing database of more than 17,000 subjects in Riyadh region (Al-Daghri, Al-Attas et al. 2011). The RVS sampled the population at large retail centres in areas of contrasting socio-economic status in Riyadh city during October and November 2013 (Alkhalaf, Edwards et al. 2015).

In 2016, the SA Census Bureau revealed that nearly 11.6 million (36%; out of 31.7 million) non-Arab Saudis are living in Saudi Arabia from different ethnic groups such as

Indians, Pakistanis, Filipinos, etc. (MOEP 2016). However, Arab Saudi nationals only were included in the study.

2.3.3 Ethical considerations

All studies were conducted in accordance with the guidelines laid down in the Declaration of Saudi National Committee of BioEthics. All procedures were by the local Institutional Review Boards (IRB). All volunteers provided written informed consent to participate in the study.

2.3.4 Data Collection and analysis

This secondary data analysis included males and females aged 18 years and over. Both SHIS and SNHS included younger age group 15-17 years old. However, we excluded this age group from our analysis. Pregnant women and expatriates (through National ID) were also not included in this analysis. The data were accessed after taking permission from BRP program in King Saud University and the Ministry Of Health, Public Health Deputy Minster, General Directorate for Control of Genetic & Chronic Diseases, SA.

Subjects of all surveys were interviewed by a trained interviewer to collect information on anthropometric measure, socio-demographic factors, dietary habits, lifestyle (smoking, physical activity), and health conditions. Height, weight, waist and hip circumferences (WC, HC) were measured by trained professionals (WHO-STEPwise 2005; Al-Daghri, Al-Attas et al. 2011; Memish, El Bcheraoui et al. 2014; Alkhalaf, Edwards et al. 2015). All anthropometric measurements followed specified protocols using calibrated scales and non-stretchable plastic tapes. The body composition variables including Total Adipose Tissue Mass (TATM), skeletal muscle mass (SMM) and total body fat percent (%BF) were estimated using simple anthropometric and demographic measures. Consenting adults were asked to fast overnight (10-hour) before blood withdrawal. Blood samples were drawn, centrifuged and processed on the same day. Systolic and diastolic blood pressure was measured twice within 20 minutes using validated upper arm automatic sphygmomanometer.

Individual data sets of each survey were checked for consistency with previously published results. Then, all the samples were combined in one single dataset. The same collection methods and the same (or similar) sample design were used in all studies apart

from RVS which is a convenience sample. However, RVS provided similar anthropometric results compared with SHIS (weight: 75.5 vs. 75.6 kg; height: 163.4 vs. 163.3 cm; WC: 88 vs. 90.4 cm, respectively). Also, the RVS (84% and 16%) closely represents the adult population in SA (20-44 and 45-60 years, respectively) compared to the adult population Saudi census (80% and 20%, respectively) in 2010 (Ministry of Economy and Planning 2010). These indicate suitability of surveys data to be combined. Biologically implausible values for anthropometric measures were excluded using two steps (details described in Chapter 5, Section 5.2).

2.4 Knowledge and perceptions study

2.4.1 The study rationale

As explained earlier (Chapter 1, Section 1.4), appropriate lifestyle modifications such as diet, physical activity and weight loss have been recognised to be similar, or even more effective, than medical interventions in preventing or delaying the onset of NCDs in high risk people. Nutritional knowledge is one of the main influential factors to improve behaviour of healthy eating and lifestyle towards health and overall wellbeing (McCullough, Feskanich et al. 2002; Kolodinsky, Harvey-Berino et al. 2007). Although many studies examine certain aspects of lifestyle and dietary behaviours amongst the Saudi population (Epuru and AlMuqrn ; Bani and Hashim 1999; Khattab, Abolfotouh et al. 1999; Al-Rethaiaa, Fahmy et al. 2010; ALFaris, Al-Tamimi et al. 2015), the vast majority of these studies did not assess the influencing factors including knowledge on food choices and behaviours. Therefore, the hypothesis is that the lack of knowledge and awareness is affecting the population intention toward nutritionally balance diet. Thus, this study aimed to answer the following research questions:

RQ6: Are Saudi adults aware of the existing nutrition and health guidelines and does their awareness best predict the psychosocial constructs to eat a nutritionally balanced diet? (**Chapter 8**)

RQ7: Is nutritional knowledge the best predictor of intention to eat a nutritionally balanced diet among the psychosocial constructs using TPB? (**Chapter 8**)

2.4.2 Study design and sampling

A cross-sectional study was conducted on a sample of Saudi men and women aged 18 years and older. No expatriates were included in this study since they have different eating patterns which may influence the current study outcomes (Amin, Al Sultan et al. 2014). Internet use in SA has increased from 13% of the total population (3 million) in 2005 to 64% (19.6 million) in 2014 (Al-Tawil 2001; Al-Saggaf 2004; CITC 2014). In 2010, 93% of Saudi people aged 19 to 25 years, and 70% of people older than 45 years are using the internet (Simsim 2011). Therefore, participants of the study were recruited online via email, social media (Twitter and Facebook) and snowball recruitment, in December 2015 and January 2016.

The sample size of the study was calculated based on the records of the 2010 census (Ministry of Economy and Planning 2010). In a total of 13,226,393 Saudi adults in SA aged 18 years and over (6,521,284 women and 6,705,109 men), with absolute precision on either side of the proportion (the margin of error) of 5%, 95% confidence interval and variance in population of 50% (having sufficient nutritional knowledge), calculations resulted in a sample size of 384 individuals (Lwanga S and S 1991; Systems 2015). Since men have poorer knowledge than women regarding nutritionally balanced diets (Parmenter, Waller et al. 2000), a cluster effect of 2 was applied on the primarily sample size. Based on pretesting sample, the completion rate of the questionnaire was 42% (Section 3.2.4). Therefore, the final sample size is 1090 which is able to represent the Saudi population.

2.4.3 Ethical considerations

The study was conducted in accordance with the guidelines laid down in the Declaration of Helsinki. All subjects provided online informed consent to participate in the study. All procedures were approved by the University of Glasgow College of Medicine, Veterinary Medicine and Life Sciences (MVLS) Ethical Committee.

2.4.4 Data collection

The survey questionnaire was developed to answer the research questions above (RQ 6 and RQ 7). This questionnaire included question assessing the awareness of survey participants towards existing government policies and guidelines in Saudi Arabia. Also, this questionnaire assessed the knowledge of the Saudi adults regarding a nutritionally

balance diet. Our study considered the knowledge of a nutritionally balance diet as a perceived barrier which is one of the components of Theory of Planned Behaviour (TPB) model. The term "nutritionally balanced diet or healthy eating" has been defined in this study as being a diet low in fat and salt, and high in fruit and vegetable consumption, based on current dietary recommendations. The questionnaire included also questions regarding socio-demographics, physical activity, medical condition, health insurance, demographics, and self-reported anthropometric measurements (height, weight, and waist and hip circumferences). The study questionnaire was piloted in a community group (n=40) not involved in the main study to ensure that the content, flow and number of questions were appropriate for the aims of the study as well as identifying technical problems which might occur using proposed methods. Detailed information regarding components of the study questionnaire is shown in Chapter 8, section 3.2.3.

2.5 General statistical analysis

Detailed presentations of the statistical analysis performed for each study is presented in relevant chapters. First, all thesis data were initially tested for normality using the Kolmogorov-Smirnov test. Continuous variables were shown as median and interquartile range (IQR) or mean and standard deviation (SD) as appropriate. Differences in means or medians were assessed using the Student's T-test or ANOVA or the non-parametric equivalent tests. The Tukey post hoc test was applied in ANOVA tests. The Chi-Squared (χ^2) test was used to determine significant differences in proportions among categorical survey variables. Where the number of expected subjects in a cell was below five, Fisher's exact test was used.

Spearman's or Pearson correlations (as appropriate) were determined to see the relation between continuous variables (r ±1). Regression analysis (linear and logistic) was performed to explore potential relationships between study variables such as age and vs. salt intake; salt intake vs. blood pressure; age vs. body composition; and body composition vs. metabolic risks. The 95% confidence interval (95% CI) of correlation and regression outcomes was estimated. Kappa (k) analysis was performed (Sim and Wright 2005) to measure inter-tertile agreement between dietary methods. Statistical significance was set at $P<0.05$ except body composition chapters where Bonferroni correction test (p-value/n.of tests). All statistical tests were performed using the Statistical Package for Social Sciences (SPSS) software, version 21.0 for Windows (SPSS Inc., Chicago, IL, USA).

Chapter Three

Validation of a food frequency questionnaire specific for salt intake in Saudi Arabian adults, against urinary biomarker and multiple pass 24-hour dietary recalls

3.1 Introduction

In 2008, approximately 40% of adults aged 25 and above, worldwide, were diagnosed with hypertension, which is responsible for more than 9 million deaths annually (WHO 2013). The incidence of obesity and overweight has risen dramatically, not only in high-income countries, but also in low- and middle-income countries (Flegal, Kit et al. 2013). Obesity represents a worldwide public health challenge as populations increase their per capita caloric intake and adopt sedentary lifestyles (Omari 2007). Obesity and overweight are estimated to be responsible for more than 36 million deaths annually (63% of global deaths) (WHO 2014) and they are considered major contributors to the development of non-communicable diseases (NCDs) including hypertension (WHO 2008).

SA suffers from a high burden of NCDs such as cardiovascular diseases, hypertension and T2DM (Al-Nozha 2004; Al-Nozha 2004; Al-Nozha, Abdullah et al. 2007; Kilpi 2014). In 2005, the Saudi National Health Survey (SNHS) found a high prevalence of hypertension (26%) in SA (Al-Nozha, Al-Mazrou et al. 2005), while the more recent National Health Survey (SHIS) a prevalence of 15.2% (El Bcheraoui, Memish et al. 2014). There is a strong body of evidence supporting the association between chronically high sodium intake (in the form of salt - NaCl) and occurrence of hypertension (Meneton, Jeunemaitre et al. 2005; He and MacGregor 2009; Blaustein, Leenen et al. 2012; He and MacGregor 2015; Johnson, Raj et al. 2015), a major influential factor to the development of CVDs such as stroke and heart diseases (He, Burnier et al. 2011; Soga and Pandey 2011).

A meta-analysis of randomized trials Long term reduction of salt intake to less than 6g/d lowered blood pressure by 7/4 mmHg ($P<0.001$ for both SBP and DBP) in hypertensives and 3.6/1.7 mmHg in normotensive individuals (SBP: $P<0.001$; DBP: $P<0.05$); and reduced cardiovascular diseases such as stroke by 24% and ischaemic heart disease (IHD) by 18% (He and MacGregor 2002; He, Li et al. 2013).

There is dearth of information on habitual salt intake in SA apart from one study which is not representative of the general population (Alkhunaizi, Al Jishi et al. 2013), further confounded by inclusion of samples from potential kidney donors and patients who

underwent treatment for nephrolithiasis. It is important to better understand the relationship between diet, food consumption levels and patterns, and these emerging chronic diseases (Bingham 2007). This would allow the development and implementation of cost-effective interventions and preventive strategies in the community such as food fortification and nutrition education and awareness programmes, and lifestyle modification campaigns (West 2009). Reliable information on the actual levels of foods consumed should be generated through representative consumption surveys, using appropriate dietary assessment methods (WHO/FAO 2003).

Different methods have been developed, implemented, and evaluated in a number of countries (such as the UK, some European countries and the USA) to assess usual dietary intake and nutritional status at national levels (Lester I H 1994; Jerome 1997; Ministry of Health 2003; Resano-Pérez 2003; Ashwell 2005; Ministry of Health 2006). Food Frequency Questionnaires (FFQ), 24-hours diet recall, and dietary record are the most commonly used methods in epidemiological studies to assess long-term nutritional exposure to nutrients, and its relation to nutritional and health issues (Rutishauser 2007). However, it is important to develop more accurate and valid instruments to investigate the habitual food consumption of specific population because foods are culture-dependent.

The 24-Hours diet recall (24-HDR) is interviewer-administered, so is less dependent on the literacy of the respondent (Baranowski 2013). During the interview, the respondent is asked to recall and report all the foods and beverages consumed in the preceding 24-hours (Thompson 2013). The interview can be done by phone with valid data collection (Posner, Borman et al. 1982; Casey, Goolsby et al. 1999) or computerised system (Slimani, Deharveng et al. 1999; Raper, Perloff et al. 2004; Subar, Thompson et al. 2007; Moshfegh, Rhodes et al. 2008). However, this method needs well trained dietitians and multiple interviews to reflect the usual dietary intake increasing the cost, time, logistical, and personnel constraints especially in big national surveys (Baranowski 2013; Thompson 2013). This method also relies on the respondent's memory a source of error for diet recalls especially with people with minimum or impaired memory or cognitive functioning such as children and older people (Michael Nelson 2003; Thompson 2013). This limitation was minimised by developing a new multiple pass (steps) method to help subjects remember all consumed foods (Conway, Ingwersen et al. 2003; Raper, Perloff et al. 2004).

The Dietary Record or diary method requires subjects to record all consumed foods and beverages at the time that they are eaten for one or more days, to minimize reliance on memory (Baranowski 2013; Thompson 2013). To represent their current habitual intake subjects need to record their diet for several days (i.e. 2-7 days). A comparison of methods showed that a 7-day record (estimated record) showed the next highest correlation with biomarkers compared to a FFQ and a 24-HDR (Bingham, Gill et al. 1997). However, this may lead subjects to change their eating behaviour in order to ease the burden of recording, or as a response to increased awareness of their food choices through participation for long time (Johnson 2002; Pattersen 2013). Moreover, higher literacy levels are required from the subjects, limiting its application in some population groups (Baranowski 2013; Thompson 2013). There is also evidence that the subjects tend to under-report their energy intake when using this method, which may distort the links between dietary data and health risks (Hill and Davies 2001; Trabulsi and Schoeller 2001; Rennie, Coward et al. 2007).

The Food Frequency Questionnaire (FFQ) is a commonly used instrument for evaluation of long-term dietary intake, over a defined period in the past (usually 3-12 months), and to assess relationships with chronic disease (Margetts 1997; Willett 2012). FFQ is especially practical for epidemiological studies as it is easier to analyse automatically and cheaper (Thompson 1994). However, the method suffers from higher risk of random and systematic errors than other dietary intake assessment methods (Margetts 1997; Subar 2001; Westerterp 2002; Thompson 2010). These limitations can be reduced by selection of specific-population portion sizes; developing a representative food list based on other national studies (24-h method and Dietary Records); and creating a nutrient database based on national food composition tables (Teufel 1997 ; Kroke A 1999; Cade 2002; Cade 2004; Subar 2004; Willett 2007; Dehghan 2012; Palmer 2012).

FFQs need to be developed and validated for specific populations because foods are culture-specific (Cade 2002). The validity of the FFQ data outcomes can be assessed by against repeated dietary recalls, human biomarkers, and/ or total energy expenditure (Serra-Majem 2009; Willett 2012). Nutrients estimated by FFQ should be validated against recovery biomarkers, for example potassium by urinary potassium, sodium by urinary sodium and protein by urinary nitrogen (Bingham 2003; Tasevska, Runswick et al. 2006; Munehiro, Tsutomu et al. 2012). The 24-hour urine collection is considered a “gold standard” method

to measure sodium intake capturing 85-90% of consumed sodium (Bates, Thurnham et al. 2009; Van Dam and Hunter 2013). FFQ is considered as sufficiently valid when the correlation coefficients between FFQ and the reference method (whether estimated dietary intake or human body biomarker) is 0.50 and more (Willett 2012). However, correlation coefficients in method agreement studies can be misleading (Bunce 2009). The higher correlations typically depends on the range of measures being assessed, with wider ranges being assessed but not as a result of better agreement between the methods being assessed (Bland and Altman 1986; Bunce 2009). Alternatively, the Bland–Altman method (the limits of agreement (LoA) technique) should be implemented to determine if there is any systematic difference between the administration of FFQ and reference methods (bias), and to what extent the two administrations agree (limits of agreement) (Cade 2002). A few studies have characterized the performance of FFQ against validated biochemical measures of intake in Saudi Arabia but none for salt intake.

Information describing Saudi food intake is limited: data on energy and nutrient intakes from broad food groups were collected in 1987 by Al-Nozha, using a single 24h food recall (Al-Nozha M 1996). More detailed food intake data from the general population of Saudi adults at national level have not been published since, apart from one national study describing the food groups using a diet history method (Moradi-Lakeh, El Bcheraoui et al. 2016). Various small studies have been conducted on an irregular basis in SA, such as hospital-based which cannot be used as a proxy of general population. These studies did not represent the dietary behaviours or nutritional status of the population due to small sample size and targeted population. Some of these studies were conducted in SA using FFQs developed and validated among varied non-Saudi populations (Abalkhail 1998; Alamri F.A. 2014). To the knowledge of the researcher, there is no validated Saudi specific FFQ, apart from two semi-quantitative FFQs for the assessment of vitamin A (Alissa 2005) and, zinc, phytic acid and protein intake (Alsufiani, Yamani et al. 2014). Furthermore, there are no data on habitual salt intake in SA, apart from one study in the Eastern region which is not representative for the general population and did not find any relationship between 24-hour urinary sodium excretion and blood pressure (BP) (Alkhunaizi, Al et al. 2013). Traditionally, some of Saudi traditional foods are rich in salt such as lentil soup, fava beans (*foul medammes*), *shakshuka* omelettes, and chick pea dishes (Al-Nozha M 1996). Therefore, the research question to be raised in this chapter is:

- Is the food frequency questionnaire a reliable and valid tool to assess salt intake in Saudi Arabia?

3.2 Methodology and materials

3.2.1 Population

A cross-sectional study was conducted in males and females (19 to 60 years). Those on kidney dialysis and pregnant women were excluded. No expatriates were included in this study. Participants were selected using a 2 stratified cluster sampling procedure, male and female being the strata because they have different salt intake (Sauvageot, Alkerwi et al. 2013). The participants were recruited at large retail centres in areas of contrasting socio-economic status in Riyadh, during October and November 2013.

The sample size of the study was calculated based on the records of the 2010 census (Ministry of Economy and Planning 2010). There were a total of 1,903,190 adults in Riyadh city aged 19-60 years (969,075 men and 934,115 women). The absolute precision on either side of the proportion (the margin of error) was estimated at 0.05 (5%) whereas the level of confidence was based on 95% confidence interval. The variance in population was estimated to be 0.5 (50%). Our calculations resulted in a primary sample size of 384 individuals. The non-completion rate was 19% based on pilot study (Section 3.2.2.2.4). The percentage of mis-reporting using FFQ is 29% (Subar, Kipnis et al. 2003). The final sample size was calculated as 568.

A power analysis was performed to estimate the sample size required to detect a correlation between sodium intake for FFQ and 24HDR with correlation coefficient (R) = 0.10 (Block, Wakimoto et al. 2006) which is the lowest correlation coefficient level between these methods to satisfy the all scientific power needs. With 95% power, and α of 0.05, samples ranging from 99 subjects would be needed for this study. Overall underreporting of energy intake using 24-HDR was 73% (Novotny, Rumpler et al. 2003). Therefore, the final sample size for analysis was estimated to be 171 subjects. Also, the power analysis was performed to estimate the sample size required to detect a correlation between sodium urinary excretion and sodium intake for FFQ with an R ranging from 0.19 (McKeown, Day et al. 2001) which is the lowest R to satisfy the all the scientific power needs. With 95% power, and α of 0.05,

it was calculated that samples ranging from 48 subjects would be necessary for this study. The response rate of 24-h urine was reported to be 58% and the completion rate of urine samples using para-aminobenzoic acid (PABA) to verify the completeness of the urine collections among Scottish population were 25% (SCSR/FSA 2011). The final sample size for analysis was estimated to be 88 subjects.

Therefore, the sample sizes used in this study were n=171 to detect the relationship between sodium intake for FFQ and 24HDR, and n=88 to detect the relationship between sodium urinary excretion and sodium intake for FFQ.

The study was conducted in accordance with the guidelines laid down in the Declaration of Saudi National Committee of BioEthics (Appendix 1). All volunteers provided written informed consent to participate in the study (Appendix 2). All procedures were approved by the Saudi Food and Drug Authority Ethical Committee (SFDA-IRB).

3.2.2 Data collection

3.2.2.1 Socio-demographics and blood pressure

The socio-demographic information was collected from the participants. Systolic and diastolic blood pressures were measured twice within 20 minutes in sitting position. More details in **Chapter 2.**

3.2.2.2 Dietary data

Forty-nine dietitians (28 females and 16 males) attended a two-day workshop, covering the background and purpose of the study, the methodology and procedures. This comprised teaching and practical sessions designed to familiarise them with the rationale for the study, the methodology and fieldwork procedures. This included practical demonstration of how to accurately; collect the participants' socio-demographic and dietary intake data using the Saudi-Food Frequency questionnaire (FFQ) and Multiple Pass 24-Hour Dietary Recall methods (24-HDR); and to measure the participants' height, weight, waist and hip circumferences, and blood pressure. Also, it included a practical elucidation of the para-amino benzoic acid (PABA) tablets, urine collection containers and hats, urine containers,

Urine Collection Record sheet and Urine Collection Instructions' sheet that participants would use for collecting 24-hour urine samples. It was followed by one-day workshop to ensure that each trainee was shown the instrument of the survey and allowed to practise using it. All the investigators were provided with the study procedures manual which contained full details of data collection and processing procedures such as standardized anthropometric, physical, biological and dietary assessment procedures used throughout the study.

3.2.2.2.1 Saudi Food Frequency Questionnaire

The validity of a FFQ is highly dependent on precise portion size estimation, representative food list selection, and nutrient content assumptions for each food item on the list (Block 1989; Thompson 2013). The Kuwaiti Semi-Quantitative Food Frequency Questionnaire (Dehghan 2005) was used to design the present study questionnaire, as it is culturally relevant. Information describing Saudi food intakes is limited. Details of nutrient intakes from broad food groups, (Al-Nozha M 1996) were collected in 1987 and published in 1996. More detailed food intake data from Saudi adults have not been published. Thus, 24-hour recalls from 19,598 men and women from all over SA (Al-Nozha M 1996) were used to derive the food lists for the Saudi Food Frequency Questionnaire whereas the Kuwaiti FFQ was used to design the main food groups of the present FFQ.

The Saudi-FFQ includes 133 foods or food groups and 9 adjustment questions, and was designed to assess typical dietary habits over the previous year in Riyadh city population (

Table 3.2-1). The Saudi- FFQ was double translated, from English to Arabic and then from Arabic to English by different translators) (Appendix 3). Mean nutrient intake were estimated from the Saudi-FFQ using the product-sum method with following equation (E1)(Willett 2009; Jaceldo-Siegl, Knutsen et al. 2010):

E1: Daily nutrient intake=Σ[(reported consumption frequency of a food item; converted to times per day) ×

(portion size consumed of that food)×(amount of that nutrient in a standard serving size of that food)]

Table 3.2-1: Food categories and items in the Food Frequency Questionnaire

Food categories	Food items
Dairy Products	Milk; *Laban*; Cream Cheese; White cheese (Feta, Mozzarella and Spread Cheeses); Cheddar Cheese; Yogurt; *Labnah*; Ice cream; and *Quashta* (Cream)/*Gaymar*.
Fruits	Fresh Fruit Salad; Tinned Fruits (all kinds); Apple; Banana; Strawberry and Raspberries; Oranges and Mandarin; Grapefruit; Plums, Peaches /Nectarines, or Apricots; Dates: Dry dates (*Tammer*), Fresh Dates (*Ruttab*, refrigerated); Pears, Pineapple, Kiwi, Figs, or Cherries; Grapes; Olives; Dried Fruits (e.g. Figs, Apricots, Raisins, Peaches); Watermelon; Other Melons (e.g. Canteloupe, Galia or Honeydew); Mango; and Pomegranate.
Vegetables	Cabbage (fresh and cooked); Mixed Vegetable Salad (fresh); Mixed Vegetables (cooked); Cauliflower, Broccoli or Brussels sprouts (cooked); *Tabouleh*; Green leafy vegetables; (*Molokhia*, Spinach, Coriander), Okra & Green Beans; Peas (cooked)/ (*Bazelah*); Carrots; Tomatoes; Mushrooms; Leeks; Cucumber; Lettuce; Beetroots; Sweetcorn; Onion; Beans (Fava, Red, White and Soya beans), Lentils, Chickpeas (cooked); Baked beans; Boiled potatoes; Fried potatoes (French fries); and Potato crisps.
Meat, Fish and Eggs	Boiled Egg; Fried eggs, Scrambled eggs or Omelettes; Chicken or Turkey (boiled, grilled or fried); Lamb or Mutton as a sandwich or mixed dish (e.g. *Kabsah*, Stew, Casserole, Spaghetti, Lasagne etc.); Lamb or Mutton as a main dish (eg. Steak, roast, in gravy etc.); Beef as a sandwich or mixed dish (e.g. *Kabsah*, stew, casserole, Spaghetti, Lasagne etc.); Beef as a main dish (eg. Steak, roast, in gravy etc.); Camel Meat cubes; Burgers (beef burger or Chicken Burger); Fried fish; Grilled or steamed fish; Canned tuna, Salmon, Mackerel, or Sardine; Prawn or Shrimps; Mussels, Oysters, Scallops or Cockles; and Organ meat (liver, brain, heart).
Mixed Dishes	Vegetable soup; Chicken soup with cream; Lentil soup; Oat meal Soup; *Jareesh* (*Gerish*), *Marqooq*, *Harees*, *Mataziz*, or *Qorsan*; *Saleeq*; *Marasia* (*Marassia*); *Aseeda* (*Asseda*); Rice (*Kabsah*, *Beriani*, *Bukhari* or *Mandi*) without meat; Rice with Vegetables (*Maqloobah*) without meat; *Kebbah*; *Mottabaque* w/ egg (*Muttabagh*); Stuffed vegetables (Vine leaves, Cabbage, Squash); Eggplant (Aubergine), Zucchini (Marrow) (cooked) (Mussakaah or Moussaka); and Lasagne.
Breads, Cereals and Starches	Breakfast cereals (corn flakes); White bread (*Samoli*, *Tabonah*, *Tannor*, Toast, Pita); Brown bread (*Samoli*, *Tabonah*, toast, Pita); *Tamees* or Irani bread with sesame; Pasta Spaghetti and Macaroni; Dates Biscuits; and Other Biscuits and crackers.
Beverages, Juices and Drinks	Regular Coffee and Instant coffee (e.g. Nescafe); Arabic Coffee; Coffee Whiteners e.g. Coffee-mate; Regular fizzy soft drink (e.g. Cola, lemonade, etc.); Low calorie (diet) fizzy soft drink; (e.g. Cola, lemonade, etc.); Black Tea; Green tea; Fruit squash or cordial; Hot chocolate/ Cocoa drinks; Horlicks/ Ovaltine/ Nesquik/ Milo; Mineral water (not in other drinks) (*Sehha*); Tap water (not in other drinks); Pure fruit juice (orange, apple,etc.); and Energy drinks.
Sweet Baked Goods	Cream caramel; *Halawah Tahinah* (Tahini); Doughnuts; *Basbousah* and *Konafah*; *Mohallabiah*; *Klijah* & *Lugimat Al-Ghadi* (*Lugimat*); Cake; Arabic sweets *Baklawa*; Chocolate; Honey; Jam; and Mayonnaise.
Seeds and Nuts	Almond; Cashew nuts; Peanut; Pistachio; Walnut; Hazelnuts; Pecan nuts; Chestnuts; Mixed nuts; Seeds (Sunflower, Melon, Sesame seeds); Peanut butter
Fats, Oils (Spread on bread)	Butter; margarine; or other spread or oil on bread
Sugar	added to drinks and on cereals or deserts

3.2.2.2.2 Multiple Pass 24-Hour Dietary Recall (24-HDR)

Participants completed the interview administered and repeated Multiple Pass 24-Hour Dietary Recall (24-HDR) lists. The 24-HDR was carried out twice in non-consecutive days including weekends and to minimize the source of error of repeated food recalls, a standardization of interviewers was carried out to ensure that they trained dietitians on the proper ways to generate food intake using a multiple pass method. This was acquired using an interview similar to the USDA 5-Step Multiple (Conway, Ingwersen et al. 2003). This

includes five steps; Quick List, Forgotten Foods, Time and Occasions, Detailed Description of consumed food, and Review the recalled information. In Step one a quick list of foods and beverages consumed were collected. In step two, a review was made into foods that have been documented as frequently forgotten, such as milk with coffee or cereal. The time and occasion for the consumed foods were acquired in step three. In step 4, a description of foods and the amounts of consumed foods were obtained. Step 5 contains probes into completeness of the food recall. If the participant were interviewed in weekend day the second interview was in weekday and vice versa by telephone. In every round of 24-HDR interview, each day was weighted appropriately to produce a synthetic week as the following equation (E2) (Liu, Wang et al. 2013):

$$\text{E2: Mean daily intake} = \frac{(\text{weekday} \times 5) + (\text{weekend} \times 2)}{7}$$

Fast food and hot takeaway meals contain more added salt, therefore eating fast food seems to have an adverse effect on diet quality (Rasmussen, Lassen et al. 2010; Jaworowska, Blackham et al. 2012). So, the participants been asked how frequently they eat from restaurants and takeaways.

3.2.2.2.3 Dietary data analysis

The FFQ and the 24-HDR were coded manually for calculations of total energy, energy-yielding nutrients, minerals and vitamins, and food items. A dietary analysis database was developed especially to fulfil the objectives of present study using data from the Saudi food composition tables (Al-Nozha M 1996; KFSH&RC 2002). If any data on food composition did not exist, the Food composition tables for Arab Gulf countries (Gulfoods) (Musaiger 2012) or the McCance and Widdowson's Composition of Foods (Paul and Southgate 1991) were used to generate the alternative food composition variables. During the interview, participants were asked choose their portion sizes using household measures (e.g., cups, plates or spoons), and food models, Standardised Portioned Plate (SPP) (for food composite or mixed foods) and printed visuals to estimate portion sizes of consumed foods.

3.2.2.2.4 The FFQ pre-testing

The first version of the culture-specific Food Frequency Questionnaire (FFQ) was tested among 52 Saudi students aged 19-60 years old living in the city of Glasgow, United Kingdom and Saudi citizens living in Riyadh city, Saudi Arabia. All the participants in this pretest were similar to those who were included in the actual survey. The draft Saudi FFQ was distributed among three senior dietitians with known expertise in dietary assessment to review and comment. Each subject was asked to answer all questions provided. The subjects were instructed to report on the following; questions difficulty, ambiguity, time taken, and the appropriateness and accuracy of the portion size measures. Subjects were also were instructed to report on the completeness of the food list, wording, sequence, form and layout of the FFQ. The completion rate of the subjects was also tested (81%) (Quigley 1997; Teufel 1997; O'Leary 2005; SA McNaughton 2005; Malhotra 2006; McNaughton 2007). The Pre-testing comments and suggestions are illustrated in Table 3.2-2.

Table 3.2-2: Pre-Testing Comments and suggestions

Pre-test criteria	***Comments and Suggestions***
Structure	Horizontal instead of vertical, frequency options should be in all pages, missed frequency squares (6.3 & 6.8), Rearrange the food items as the natural groups.
Frequency Options	Rearrange the Frequency options to start from day to month instead of month to day.
Repeated (Duplicated) food items	Meat, grapes, pears.
Food items Should be added	*Shaborah* (Rusk), Energy Drinks, brown sugar, corn sugar, green tea, weight reduction foods, soya milk, special dietary use formula, artificial sweeteners, sports foods, *Ghurabah*, *Barazeq*, Jelly, and Fish and *Homourr* (mixed dish).
Shortening the FFQ	The FFQ is so long, it should be shorten.
Portion sizes	It is difficult to estimate and mach some portion size measures with the targeted food item e.g.1 cup potatoes & meat in grams. It has been suggested to use table spoon instead of cup in butter portion; and *shawarma* portion size is missed.
Other suggestions	Use traditional names, *queeker* instead of oat meal soup and Pepsi or Coca Cola instead of cola.

3.2.2.3 Urine collection (24 hours)

A sub-sample received verbal and written instructions on how to of collect the urine samples for 24 hours (Appendix 4). Subjects were provided a container prefilled with 10g boric acid to collect urine. Urine samples were collected in an opaque container to prevent degradation of para-aminobenzoic acid compounds) and then stored in an insulated bag with ice. No incentives were provided to the participants.

Para-aminobenzoic acid (PABA) was used to verify the completeness of the urine collections (Bingham 1983). Subjects received verbal and written instructions on how to use para-aminobenzoic acid (PABA) tablets (PABAcheck; Glostrup Apotek, Glostrup, Denmark). Urine collections with <85% PABA recovery were considered in-complete and removed from further data analyses (Bingham 1983).

Also, we used a urinary creatinine index (UCI) to verify the completeness of the urine collections which is urinary creatinine excretion (UCE) (mg) adjusted for body weight (kg) and time (24 hours) as the following equation. Any level of UCI falling outside the range of 11–20 and 14–26 (mg/kg) for women and men respectively was excluded (Hristova EN 2001; Burtis and Ashwood 2012). This approach for identifying the completeness of 24-Hour urine collection has been used in some previous studies (Malekshah, Kimiagar et al. 2006). The urine volume was recorded and urine aliquoted to three parts (50mls) each and immediately stored at –80°C until analyses of nitrogen, PABA, potassium and sodium were made.

$$\text{E3: UCI (mg/kg)} = \text{UCE (mg)/body weight (kg) X 24}$$

The urinary creatinine was determined by the kinetic Jaffé technique developed by Bartels and Böhmer (1971) (Bartels and Böhmer 1971). The concentration of sodium in urine was determined by atomic absorption spectrometry using an AA-6650 atomic absorption spectrophotometer (Shimadzu Corp., Kyoto, Japan). The median daily salt intake (NaCl) from urinary sodium (Na) excretion was estimated by the following equation (Dickinson BD 2007) considering that the most of the sodium in the diet is ingested in the form of sodium chloride (Elliott and Brown 2007); and the most ingested sodium is excreted via the kidneys (Dahl 1958).

$$\text{E4: Nacl (g/day)} = \text{(Na (mmol/day)x 58.5)/1000}$$

3.2.3 Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) software, version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). Normality of variables was tested using the Shapiro-Wilk test. Continuous variables were shown as median and

interquartile range (IQR) using descriptive statistics. The validity of the FFQ intake was assessed in terms of its ability to rank individuals according to estimate levels of nutrient intake. Thus, the differences in median intake of dietary components between the FFQ and each of the two other tools (24-HDR and 24-Hour urine excretions) were examined by using the Wilcoxon test to compare differences of continuous variables. Statistical significance was set at $p<0.05$. Spearman's correlation was performed to assess the relation between the FFQ and each of the two other tools (24-HDR and urinary sodium). Correlations were found to be moderate between 0.4 and 0.7 (Willett 2012). Validity coefficients were also calculated between the unknown true salt intake and the intake estimated from the FFQ, 24-HDR and urinary excretion (Figure 3.3-2) using the Triangulation method (Triad) (Ocke and Kaaks 1997; Yokota, Miyazaki et al. 2010) as implemented by others (McNaughton, Marks et al. 2004; Combet and Lean 2014). Bootstrap sampling was used to construct confidence intervals (CI) around the validity coefficients (Yokota, Miyazaki et al. 2010). A total of n=1,000 bootstrap of study sample to assess the validity coefficients between FFQ, and urinary excretions and 24-HDR (Efron 1987).

The Bland Altman method (Bland and Altman 1986) was used to evaluate the agreement between the FFQ, and 24-HDR and 24-Hour urine excretions which plots the individual differences between the two measurements against the mean of the measurements. Linear regression analysis was performed to test for the presence of proportional bias on the study variables. Linear and Quadratic weighted kappa (k) values (Sim and Wright 2005) were calculated to measure inter-tertile agreement between FFQ, and 24-HDRand 24-Hour urine excretions. The values obtained for k were interpreted according to the cut-off points proposed by Landis and Koch (1977) (Landis and Koch 1977); thus, values of less than 0.21 indicate poor agreement, 0.21 to 0.40 fair agreement, 0.41 to 0.60 moderate agreement, 0.61 to 0.80 substantial agreement, and greater than 0.80 almost perfect agreement. Also, the salt scores were cross-classified into tertiles to evaluate the ability of both methods to classify individuals similarly in broad categories of salt intake. Tertiles were defined for both assessment methods and urinary salt outputs separately. The overall percentage of individuals classified into same, adjacent or extreme (i.e. classified from one extreme category to the other extreme category of intake) tertiles was calculated.

Subjects were categorised as having high or normal sodium (salt) intake according to a threshold of 2g sodium/day (equivalent to 5g salt/day) (WHO/FAO 2003). The sensitivity and specificity of the FFQ to identify respondents meeting or failing to meet recommended salt intakes (<5g salt/day) was also calculated against food recalls and urinary salt as gold standard methods, based on Dietary Guidelines for Saudis (MOH 2012) adapted from the WHO (WHO/FAO 2003). Sensitivity was defined as the proportion of subjects with an intake above the recommended level (5g salt per day), as defined by both the FFQ and the gold standard method (true positive), over the sum of all cases defined positive by the gold standard method. Specificity was defined as the proportion of subjects with an intake below the recommended level (5g salt per day), as defined by both the FFQ and the gold standard method (true negative), over the sum of all cases defined negative by the gold standard method. A post-hoc test was used using the G-power software to obtain the sample size and effect size to determine what the power was in the study.

3.3 Results

3.3.1.1 Study participants

A total of 601 individuals (336 women (56%) and 265 men (44%)) participated in the study, representing an overall completion rate of 78% (77% in women and 86% in men). Seventy (9.4%) participants withdrew during the 1st interview and 70 (9.4%) withdrew during the 2nd interview. Five (0.7%) participants were excluded from the analysis because they did not fulfil the inclusion criteria (subjects on kidney dialysis and pregnant women were excluded). All completed the FFQ and repeated 24-HDR (Figure 3.3-1). However, due to the time constraints, not all the 24-HDR forms were computed. A random selection of two-hundred and thirteen (n=213/601, 35%) participants was computed for 24-HDR. A sub-sample of 71 subjects (24 males, 47 females, median age 38, IQR 25-45) provided urine samples, 49 of which (18 males, 31 females) provided complete 24-h urine collections (creatinine index falling inside the range of 11–20 and 14–26 mg/kg body weight/ day for women and men, respectively) (Table 3.3-3). Urinary creatinine index (UCI) was used instead of PABA, as most the study subjects were not complying with the instructions on how to use the PABA tablets. Eighteen (25.4%) subjects did not comply in taking PABA tablets at all and seven subjects (10%) did not fill the record on whether they had taken the

tablets or not. Sixteen subjects (22%) did not return the urine collection records back, so, the PABA tablets intake for them was unknown. For this reason, it was decided to verify the completeness of the urine collections by using the UCI.

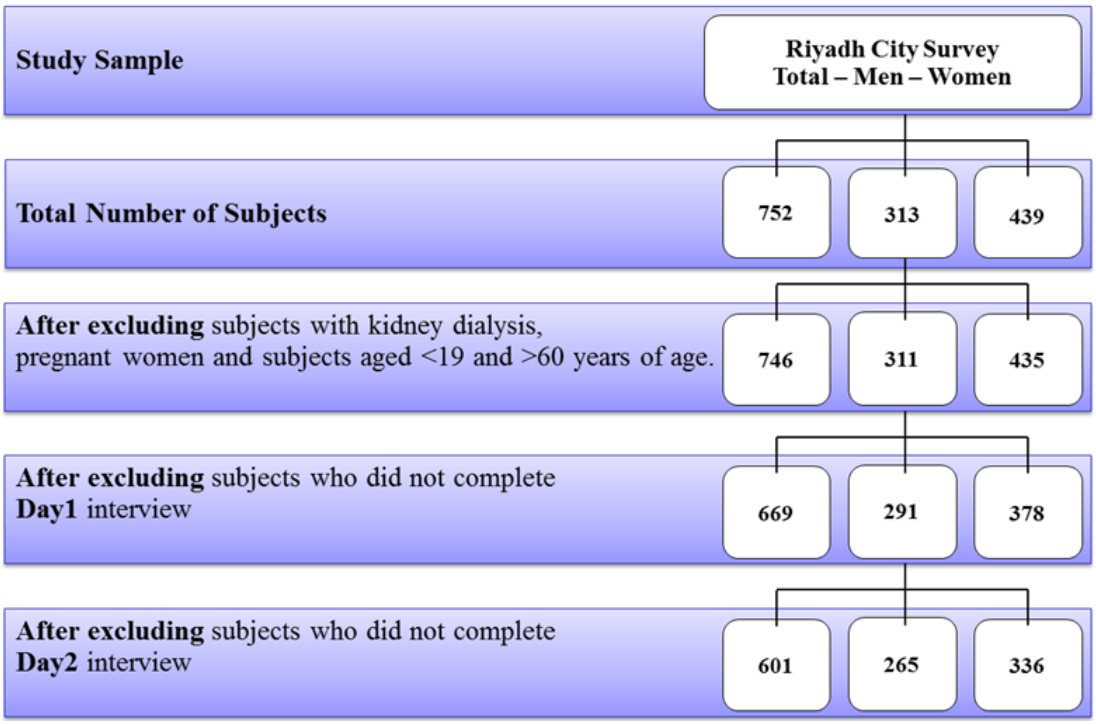


Figure 3.3-1: Study sample derivation

Subjects were excluded if their energy intake from Saudi-FFQ (3.3% (n=20)) or 24-hour recall (3.3% (n=7)) was below 500 kcal or above 5,000 kcal (Willett 1998). Four participants who provided 24-HDR and one who provided urine sample were considered implausible after excluding participants with implausible FFQ. Therefore, the final sample for analysis was n=581 for Saudi-FFQ, n=202 for 24-HDR and n=48 for 24 hour urinary samples. A post-hoc calculation of the final number of collected 24-HDR (n=202) using G-power software showed that the dietary salt data of the present study achieved a power of 99%. This calculation based lowest correlation coefficient level between these methods; r=0.10 (Block, Wakimoto et al. 2006). Also, the post-hoc calculation of the final number of collected urine samples (n=48) using G-power software showed that the urinary salt data of the present study achieved a power of 83%. The sample size was enough to estimate the validation and current salt intake patterns. Characteristics of the study population are

summarized in Table 3.3-1. The overall median age of participants was 29 (IQR 24-38) - 28 for females (IQR 23-28) and 30 for males, (IQR - 25-38)). Fifty-two percent of those participants were aged between 19-29 years and 25% between 30-39 years. The majority of participants were married (n=322, 55%). Most participants (59%) were educated to college level or higher; however, personal income was low (<42,000 SR/ year, equivalent to minimum wage) for nearly half (45%), potentially due to the proportion of females not in paid occupation in SA. Approximately half were employed (58%). Most participants (57%) had medium socioeconomic status.

Table 3.3-1: Characteristics of study participants (n=581)

Characteristics	***All (581) n. (%)***	***Female (n=330) n.(%)***	***Male (n=251) n. (%)***	***p*** [c]
Age (year)				
19-29	302 (52)	182 (55)	120 (48)	
30-39	146 (25)	70 (21)	76 (30)	
40-49	76 (13)	40 (12)	36 (14)	
50-60	57 (10)	38 (12)	19 (8)	
Total	581	330 (57)	251 (43)	
Median Age (IQR)	29 (24-38)	28 (23-28)	30 (25-38)	0.146
Education				0.001
None or elementary	36 (6.0)	30 (9)	6.0 (2)	
Intermediate or secondary	202 (35)	104 (32)	98 (39)	
College or higher	341 (59)	195 (59)	146 (58)	
Marital Status				<0.0001
Never Married	227 (39)	137 (42)	90 (36)	
Married	322 (55)	162 (49)	160 (64)	
Divorced	26.0 (5)	25 (8)	1 (0.4)	
Widowed	6.0 (1)	6 (2)	0 (0.0)	
Income [a]				<0.0001
<42,000	257 (45)	209 (64)	48 (20)	
42,000 - 100,000	176 (31)	76 (23)	100 (41)	
>100,000	139 (24)	42 (13)	97 (40)	
Occupational status				<0.0001
Employed	334 (58)	135 (41)	199 (79)	
Student	114 (20)	79 (24)	35 (14)	
Household (Stay at Home)	87 (15)	87 (26)	0 (0)	
Unemployed	29 (5)	23 (7)	6 (2)	
Retired	17 (3)	6 (2)	11 (4)	
Socio-economic Status				<0.0001
Low (2-3)	138 (24)	106 (32)	32 (13)	
Medium (4-5)	330 (57)	189 (57)	141 (56)	
High (6)	111 (19)	34 (10)	77 (31)	

[a] IQR: Interquartile range; [b] In Saudi Riyals (SR) per year; [c] Value was significantly different between males and females (P <0.05) bases on chi square and Man-Whitney analysis.

3.3.1.2 Estimated salt intake

Table 3.3-2 shows the results of daily sodium (salt) intake and urinary sodium (salt) excretions obtained from the Saudi-FFQ, repeated MP-24-Hour Dietary Recalls (24-HDRs) and 24-hour urinary excretions. The median sodium intake using FFQ was 8.7 g salt/24 h (IQR 5.8-11.9 salt/24 h). Intake estimated by FFQ was different between genders (p=0.001), with male participants consuming 3,626 mg/24 h (2,655-4,915 mg/day) equivalent to 9.2 g salt/day (IQR 6.7-12.4 g/day), higher than that of the female participants, 3,253 mg /day (IQR 2,106-4,598 mg/day) equivalent to 8.3 g salt/day (IQR 5.3-11.7 g/day). The median salt intake using repeated MP-24-Hour Dietary Recalls was 5.6 g salt/24 h (IQR 3.5-8.2 salt/24 h). The median salt intake of male participants using 24-HDR was 6.3 g salt/day (IQR 4.1 -9.9 g/day) which was particularly higher than that of the female participants, 4.5 g salt/day (IQR 2.5-7.4 g/day) (p<0.0001). The median urinary salt output was 7.7 g salt/24 h (IQR 5.3-9.9). The median urinary salt of male participants was 9.2 g salt/day (IQR 5.6-10.7 g/day) which was higher than that of female participants, 7.1 g salt/day (IQR 5.1-9.7 g/day) but not statistically significant (p=0.195).

Table 3.3-2: Comparison of medians (IQR) of intake and urinary excretions of energy, macro- and micronutrients obtained from the Saudi-FFQ (n=581), repeated MP-24-Hour Dietary Recalls (24-HDRs) (n=206) and 24-hour urinary excretions (n=48) among Riyadh city adults, Saudi Arabia.

Nutrients	Saudi-FFQ (n=581)		Repeated 24-HDR(n=202)		24-Hour Urinary excretion (n=48)	
	Median	***IQR***	**Median**	***IQR***	**Median**	***IQR***
All						
Sodium (mg)	3457[$]	(2298-4696)	2217[$£]	(1380-3261)	3,036[#]	(2,069-3,897)
Salt (g/day)	8.7[$]	(5.8-11.9)	5.6[$£]	(3.5-8.2)	7.8[#]	(5.3-9.9)
Male						
Sodium (mg)	3626	2655-4915	2463	1635-3904	3,632	(2,213-4,215)
Salt (g/day)	9.2	6.7-12.4	6.3	4.1-9.9	9.2	5.6-10.7
Female						
Sodium (mg)	3,253	2,106-4,598	1773	993-2887	2,809	1,988-3,825
Salt (g/day)	8.3	5.3-11.7	4.5	2.5-7.4	7.1	5.1-9.7

IQR: Interquartile range; FFQ: food frequency questionnaire; 24-HDRs: Multiple pass 24-Hour Dietary Recalls.
[$] Value was significantly different between males and females (p <0.05) bases on Mann-Whitney analysis.
[£] Value was significantly different between FFQ and 24-HDR (p <0.05) bases on Wilcoxon analysis.
[#] Value was significantly different between FFQ and Urinary excretion (p <0.05) bases on Wilcoxon analysis.

Table 3.3-3 shows the results of daily urinary sodium (salt), PABA (mg/day), PABA recovery (%), creatinine (mg/day) and urine volume (ml/day) obtained from the 24-hour urinary excretions. There was a difference between male and female subjects in urinary

creatinine concentration in PABA and UCI group ($p<0.05$). There were no significant differences between the sodium output from completed samples using UCI and completed samples using PABA ($p>0.05$).

Table 3.3-3: Comparison of medians (IQR) of sodium from the 24-hour urinary excretions (n=71) among Riyadh city adults, Saudi Arabia.

Nutrients	All urinary samples		PABA≥85%		Urinary Creatinine Index (11–20 (♀) and 14–26 (♂) (mg/kg))	
	(n=71)		(n=23)		(n=49)	
	Median	*IQR*	Median	*IQR*	Median	*IQR*
All						
Sodium (mg/day)	2904	1988-3955	3366	2561-3879[$]	3036	2069-3,897
Salt (g/day)	7.4	5.1-10.1	8.6	6.5-9.9[$]	7.7	5.3-9.9
PABA (mg/day)	130	87-197	230	188-317	138	88-205
PABA (%)	65.2	37.3-93.6	109.6	93.6-132.3	66.1	41.1-94.7
Creatinine (mg/day)	1227	1018-1573[$]	1337	1153-1820[$]	1211	1022-1529[$]
Volume (ml)	1450	995-2080	1710	1195-2320	1465	1095-2067[£]
Male						
Sodium (mg/day)	3632	2288-4092	3898	3880-4450	3632	2213-4,215
Salt (g/day)	9.2	5.8-10.4	9.9	9.1-11.3	9.2	5.6-10.7
PABA (mg/day)	102.5	63.3-210.5	227.5	194.8-323	127	71.5-217.5
PABA (%)	69	29.6-95.3	113.4	94.2-134.7	73.3	35.4-99.3
Creatinine (mg/day)	1795	1180-2033	1959	1397-2222	1795	1230-1988
Volume (ml)	1495	1105-2188	1930	1435-2453	1605	1330-2220[£]
Female						
Sodium (mg/day)	2586	1878-3855	2809	2444-3428	2809	1988-3,825
Salt (g/day)	6.6	4.8-9.8	7.1	6.2-8.7	7.1	5.1-9.7
PABA (mg/day)	136	88-197	242	169-315	138	90-205
PABA (%)	64.2	39.6-87.1	105.5	87.1-132.3	61	42.8-87.1
Creatinine (mg/day)	1103	877-1337	1289	1097-1453	1103	911-1252
Volume (ml)	1320	970-2050	1710	1105-2320	1260	1000-2005[£]

IQR: Interquartile range; PABA: Para-aminobenzoic acid (PABA recovery ≥85%); UCI: urinary creatinine index (UCI: 11–20 and 14–26 (mg/kg) for women and men respectively).
[$] Value was significantly different between males and females ($p<0.05$) bases on Mann-Whitney analysis.
[£] Value was significantly different between UCI and PABA ($p<0.05$) bases on Wilcoxon Signed Ranks Test.

3.3.1.3 Relative validity of FFQ

The estimated salt intake from FFQ was higher than the salt from food recall ($p<0.0001$) and from 24-h urinary outputs ($p<0.0001$) (Table 3.3-4). However, salt intake (g/day) assessed by the FFQ was low but significantly correlated with the salt intake assessed by 24-HDR ($r_s=0.403$, $p<0.0001$). Salt intake (g/day) assessed by the FFQ was moderately correlated with the urinary excretion of salt ($rs=0.501$, $p<0.0001$). Table 3.3-4 shows the results of all

Spearman's correlation coefficients for the FFQ and food recall, and FFQ and 24-h urinary outputs.

Using the triad method, the validity coefficients were calculated for each of the three measurements (FFQ, 24-HDRand Urinary salt) and the true 'unknown' salt value, according to equations (1) to (3) outlined below (where Q is the salt defined by FFQ; D is the salt defined by 24-HDR; U is the salt defined by biological (urinary) marker; and S is the "true unknown salt intake") (Yokota, Miyazaki et al. 2010) (Figure 3.3-2).

(1) $$\rho QS = \sqrt{\frac{rQD * rQU}{rDU}}$$

(2) $$\rho DS = \sqrt{\frac{rQD * rDU}{rQU}}$$

(3) $$\rho US = \sqrt{\frac{rDU * rQU}{rQD}}$$

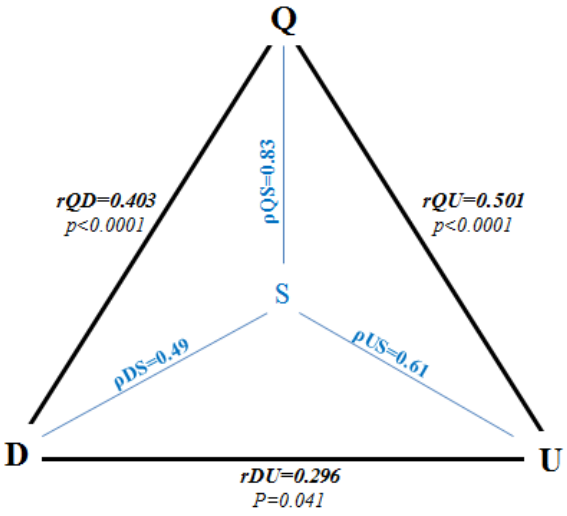


Figure 3.3-2: Graphical representation of the Triads method used to estimate the validity coefficient between the true salt intake (S), at the centre, and the intakes estimated by the Saudi-FFQ (Q), 24-HDR(D) and urinary salt (U) among Riyadh city adults, Saudi Arabia. The relationships between each two estimation method is denoted by the correlation coefficient r (rQU, rQD, rDU) outside the triangle, whereas validity coefficients between each estimate and the true intake S are shown inside the triangle (ρQS, ρDS, ρUS) (Yokota, Miyazaki et al. 2010).

Table 3.3-4: Spearman's correlation (95% CI) between salt (Na) obtained from the Saudi-FFQ (n=581), repeated multiple pass 24-Hour Dietary Recalls (24-HDRs) (n=206) and 24-hour urinary excretions (n=48) among Riyadh city adults, Saudi Arabia.

Nutrients	Saudi-FFQ vs. 24-HDR (n=202)				Saudi-FFQ vs. 24-Hour Urinary excretion (n=48)			
	R_S	*P-value*	95% CI (percentage)	LOA	R_S	*P-value**	95% CI (percentage)	LOA
Crude								
Salt (g/day)	0.403	<0.0001*	0.326-0.616	(-5.4), (12.2)	0.501	<0.0001*	0.303-0.936	(-10.1)-5.5
Sodium (mg/day)	0.403	<0.0001*	0.326-0.616	(-2,160)- (4,880)	0.501	<0.0001*	0.303-0.936	(-4,040)-(2,200)
Energy-adjusted								
Salt (g/day)	0.310	<0.0001*	0.178-0.446	-	0.402	0.005*	0.143-0.759	-
Sodium (mg/day)	0.310	<0.0001*	0.178-0.446	-	0.402	0.005*	0.143-0.759	-

* Correlation is significant at the <0.05 level;
CI: Confidence interval; LOA: Limits of agreement.

Table 3.3-5: Spearman's correlation coefficient (95% bootstrap CI) between salt (Na) obtained from the Saudi-FFQ (n=581), repeated multiple pass 24-Hour Dietary Recalls (24-HDRs) (n=206) and 24-hour urinary excretions (n=48) among Riyadh city adults, Saudi Arabia.

Nutrients	Saudi-FFQ vs. 24-HDR (n=202)				Saudi-FFQ vs. 24-Hour Urinary excretion (n=48)			
	R_S	*P-value*	95% CI (percentage)	LOA	R_S	*P-value**	95% CI (percentage)	LOA
Crude								
Salt (g/day)	0.403	<0.0001*	0.282-0.518	(-5.4), (12.2)	0.501	<0.0001*	0.206-0.699	(-10.1)-5.5
Sodium (mg/day)	0.403	<0.0001*	0.282-0.518	(-2,160)-(4,880)	0.501	<0.0001*	0.206-0.699	(-4,040)-(2,200)
Energy-adjusted								
Salt (g/day)	0.310	<0.0001*	0.186-0.425	-	0.402	0.005*	0.126-0.614	-
Sodium (mg/day)	0.310	<0.0001*	0.186-0.425	-	0.402	0.005*	0.166-0.614	-

* Correlation is significant at the <0.05 level;
CI: Confidence interval; LOA: Limits of agreement.

3.3.1.4 Relative reliability of FFQ

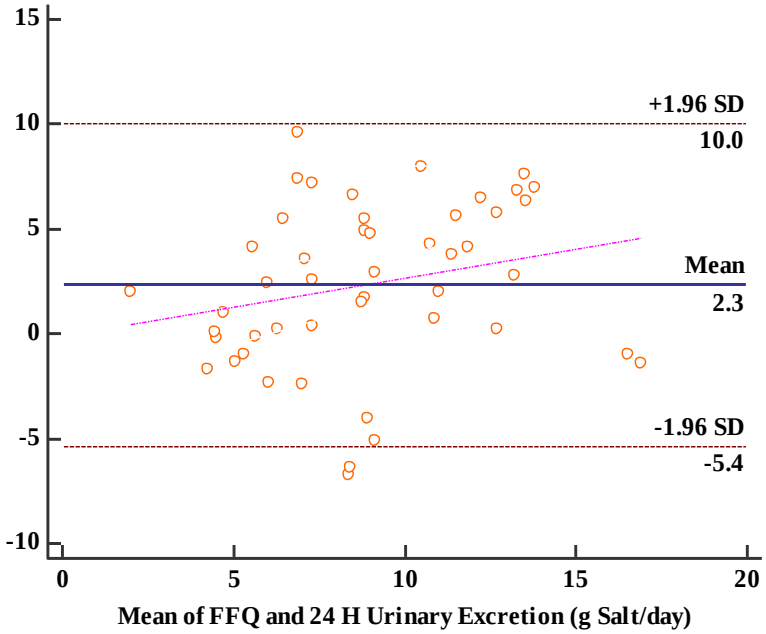
The biases between FFQ and 24-HDR, and FFQ and urinary excretion were relatively moderate (3.1 and 2.3 g salt/day, respectively) as shown graphically using Bland–Altman plots (Figure 3.3-3), although with wide limits of agreement (LOA) (-5.2 and 11.4 g salt/day, and -5.4 and 10.0 g salt/day, respectively).

Classification of salt intake into the same, adjacent and extreme tertiles of intake, derived from the Saudi-FFQ, 24-HDRand 24-Hour Urinary excretion are shown in Table 3.3-6 and Table 3.3-7. The Saudi-FFQ and Urinary excretion classified half (n=25 (52%) of the subjects into same tertiles and 33% (n=16) into adjacent tertiles for salt intake. Nearly 85% (n=41) of the subjects were classified in the same or adjacent tertiles between these two methods. Gross misclassification (the percentage of individuals in the opposite thirds) for salt intake between both methods was 15% (n=7).

Furthermore, the Saudi-FFQ and 24-HDR classified half (n=91 (45%) of the subjects into same tertiles and 37% (n=74) into adjacent tertiles for salt intake. Nearly 82% (n=159) of the subjects were classified in the same or adjacent tertiles between these two methods. Gross misclassification (the percentage of individuals in the opposite thirds) for salt intake between both methods was 18% (n=37).

The weighed Kappa statistic test (quadratic weights) was 0.37 (95% CI 0.11-0.63; p=0.009) between Saudi-FFQ and 24-Hour Urinary excretion, indicative of fair agreement between the two methods, and 0.36 (95% CI 0.23-0.49; p<0.0001) between Saudi-FFQ and 24-HDR, indicating fair agreement.

(a)



(b)

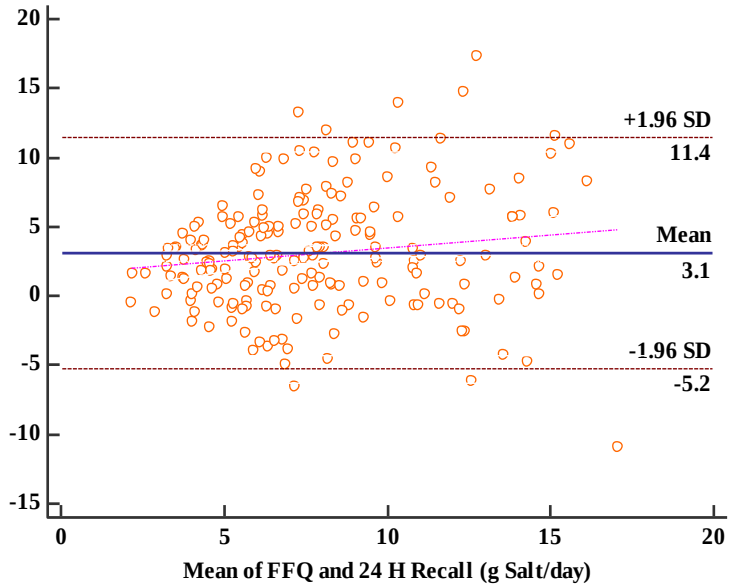


Figure 3.3-3: Bland-Altman plots showing the bias between the food frequency questionnaire (FFQ) and urinary salt (a) (n=48) and FFQ and 24-H Recall (b) (n=202) from Saudi adults.

Table 3.3-6: Tertile salt intake classification comparing the Saudi-FFQ with 24-hour urinary excretions (n=48) and the Saudi-FFQ with repeated 24-Hour Dietary Recalls (24-HDR) (n=202) among Riyadh city adults, Saudi Arabia.

Agreement	FFQ vs. Urine (n=48)		FFQ vs. 24HDRs (n=202)	
	N	%	N	%
Same tertiles	25	52	91	45
Adjacent tertiles	16	33	74	37
Extreme tertiles (gross misclassification)	7	15	37	18
Same + adjacent tertiles	41	85	165	82

Table 3.3-7: Tertile salt intake from the Saudi-FFQ (n=581), repeated MP-24-Hour Dietary Recalls (24-HDRs) (n=206), and 24-hour urinary excretions (n=48) among Riyadh city adults, Saudi Arabia.

	FFQ (n=581)	**24-HDR(n=202)**	**24-Hour Urinary excretion (n=48)**
Tertile1 (g/day)	4.9 (1.9-7.0)	3.1 (0.7-4.0)	4.5 (1.0-6.0)
Tertile2 (g/day)	8.7 (7.0-10.8)	5.6 (4.1-7.1)	7.7 (6.0-10)
Tertile3 (g/day)	13.5 (10.8-22.4)	9.9 (7.2-22.5)	10.9 (10.0-18.0)

The ability of Saudi-FFQ was examined to identify respondents whose dietary intake did not meet the dietary recommendations for salt (sodium). Using 24-HDR as the gold standard measurement, with a threshold of 5 g/day to classify salt intake as high, the FFQ had a sensitivity of 68% and specificity of 60%. The false positive rate (FPR) and false negative rate (FNR) were 0.10 and 0.45, respectively, with misclassification rate equals to 0.73. In addition, using urinary salt as the gold-standard measurement, the FFQ had a sensitivity of 55% and a specificity of 90%. The FPR and FNR was 0.40 and 0.32, respectively, with misclassification rate equals to 0.55. Table 3.3-8 illustrates the prevalence of people with high salt intake (≥5 g salt/day) from the different methods used in this study.

Table 3.3-8: The prevalence of subjects with high salt intake (g/day) from the Saudi-FFQ (n=581), repeated multiple pass 24-hour Dietary Recalls (24-HDRs) (202), and 24-hour urinary excretions (n=48) among Riyadh city adults, Saudi Arabia.

Salt Assessment method (g/day)	All		Women		Men		p-value [a]
	N	%	N	%	N	%	
FFQ (n=581)	477	82	262	79	215	86	0.051
24-HDR (n=202)	114	56	47	46	67	67	0.003
Urinary salt excretion (n=48)	38	79	23	77	15	83	0.582

[a] Value was significantly different between women and men (P <0.05) bases on chi square analysis (χ^2).

3.4 Discussion

In the present study, the reliability and validity of FFQ to assess habitual salt intake was evaluated using repeated multiple pass 24-hour dietary recalls (24-HDR) and 24-hour urinary biomarkers for a sub-sample of the population. This study recruited 581 participants (subsamples: 202 for 24-HDR and 48 for 24-H urinary excretions), which satisfied the relevant sample size and it had a larger sample size than that of previous studies (Dehghan, del Cerro et al. 2012; Elorriaga, Irazola et al. 2015; Gunes, Imeryuz et al. 2015). The results show that the FFQ provides moderate reliability for ranking individuals by salt intake, and thus can be considered a useful method for examining the relationship between salt and diseases such as high blood pressure or cardiovascular diseases.

A number of FFQs have been developed and used for the last several years in SA to study the relationship between food and NCDs. Previous studies were conducted using FFQ developed and validated among different non-Saudi populations (Abalkhail 1998 (Abalkhail 1998); Al-Amri et al 2014 (Alamri F.A. 2014)). To the knowledge of the researcher, there is no FFQ suited to a Saudi population to assess salt intake.

Several studies were validated and used FFQ to assess sodium intake at population level (Table 3.4-1). Relatively weak (r=0.19) to moderate (r=0.41) validity was found in FFQ estimates for sodium (salt) intake compared to dietary recall method using correlation coefficient (Block, Wakimoto et al. 2006; Na and Lee 2012; Elorriaga, Irazola et al. 2015). A FFQ is considered as sufficiently valid when the correlation coefficients between FFQ and

the reference method (whether estimated dietary intake or human body biomarker) is 0.40 and more (Willett 2012).

In the present study, the relative validity of FFQ against both dietary 24-HDR and urinary excretion using Spearman's correlation coefficient was moderate (r=0.403 and r=0.501, respectively). Results shows that the correlation between the Saudi-FFQ and 24-hour urinary salt (r_s=0.501, p<0.0001) is higher than the correlation obtained from the Norfolk cohort (r=0.18 to 0.20) (McKeown, Day et al. 2001). Relative validity of this Saudi-FFQ against 24-HDR was moderate (r_s=0.403, p<0.0001) are consistent with the work of Gunes et al. in Turkey in which the crude and energy-adjusted correlation coefficients were 0.38 and 0.29, respectively (Gunes, Imeryuz et al. 2015). The 24-hour urine collection is considered the "gold standard" to measure sodium intake (Bingham 1987; Van Dam and Hunter 2013). For this reason, the validity between Saudi FFQ and 24-hour urinary salt is higher that the validity between Saudi-FFQ and 24-HDR.

The overall validity coefficient of the Saudi-FFQ (ρQS) was calculated using the method of triads was 0.83, indicating high validity of FFQ to assess salt intake. There are no studies to compare to in term of the validity coefficient of FFQ for estimation of salt (sodium) intake using the Triad method.

3.4.1.1 Reliability

The estimated median intake of salt using the Saudi-FFQ was significantly higher, compared with the median intake estimated with 24-HDRs and urinary excretion (Table 3.3-2). The moderate bias (3.1 and 2.3 g salt/day for 24-HDRs and urinary excretion, respectively) and large limits of agreement seen on the Bland-Altman plots, however, demonstrate that the FFQ is not an appropriate for determining the daily salt intake of individuals, although it is a useful tool for estimating daily salt intake at population or group level and appropriate for ranking intakes of this population. Thus, the Saudi-FFQ performed well against both urinary salt excretion and 24-HDR for classification of intakes to tertiles, with 85% and 82%, respectively, being classified to the same or adjacent tertile. These results are consistent (58-94%) with previous studies, where same or adjacent values for salt estimated by Saudi-FFQ ranges from 74 to 94% against 24-HDR and from 58 to 68% against 24-hour urinary

excretion (Lassale, Guilbert et al. 2009; Zhuang, Yuan et al. 2012; Gunes, Imeryuz et al. 2015). However, when look at the agreement in the same tertile, we found only 52 and 45% of participants classified in the same tertile based on salt intake from Saudi-FFQ against 24-hour urinary excretion and 24-HDR. Therefore, the Kappa analyses were performed.

In this study, the weighed Kappa statistic tests between FFQ and urinary salt excretion, and 24-HDR for salt were 0.37 and 0.36, indicating fair agreement. These results are better than other studies, where Kappa values for salt estimated by FFQ ranges from 0.2 to 0.29 against 24-HDR and from 0.18 to 0.31 against 24-hour urinary excretion (Lassale, Guilbert et al. 2009; Zhuang, Yuan et al. 2012; Gunes, Imeryuz et al. 2015). The lower levels of kappa could be as a result of small sample sizes of these studies.

Fifty-five percent of people with a salt intake greater than 5 g/day by urine excretion (i.e., who failed to meet dietary recommendations) were correctly identified by the FFQ. In addition, 68% of people with a salt intake of greater than 5 g/day by the recalls (i.e., who failed to meet dietary recommendations) were correctly identified by the FFQ. Sensitivity was moderate (55%), indicating that the FFQ only identified more than half the cases when salt intake was high. This is potentially a result of not including sauces, condiments and discretionary salt present in the FFQ. Another factor that may have affected the sensitivity of the FFQ is the low representation of subjects with salt intake <5 g /day in the validation sample (10/48 as defined by the urinary salt or 88/202 using food recalls). However, the specificity of the FFQ was high (90%) indicating a very good performance when identifying the subjects with normal levels of salt intake (<5g/day). The overall misclassification rate between FFQ and urinary excretion (0.55) was lower than the rate between FFQ and 24-HDR (0.73).

Table 3.4-1: Comparison of validation results of FFQ against 24 H dietary recall (24-HDR), food records (FR), and 24-H urinary excretion (UE) to assess salt (sodium) intake.

Reference	Sample Size (n)	Items (n)	Validation Sample Size (n)	Age (years)	Crude-r			Energy-adjusted r			LOA (Lower-Upper)			Agree (%)	Adja (%)	Sens (%)	Spec (%)	Kappa	W-Kappa	Comments
					24-HDR	FR	UE	24-HDR	FR	UE	24-HDR	FR	UE							
Present study2016 *	581	133	48	19-60	0.41	-	0.5	0.30	-	0.4	-	-	26%(-68-119%)	52	33	55	90	0.28 (0.08-0.48)	0.33 (0.11-0.55)	Single 24-H UE
Present study 2016 *	581	133	202	19-60	0.4	-	-	0.31	-	-	42%(--62-145)	-	-	45	37	68	60	0.25 (0.15-0.36)	0.30 (0.19-0.42)	Repeated 24-HDR
(Jayawardena, Byrne et al. 2016)	77	85	77	≥18	-	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	7-day weighed-intake dietary records (Sri Lanka)
(Freedman, Commins et al. 2015)	2265	-	2265	≥40	-	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	Pooled data, black, white/other, (United States)
(Gunes, Imeryuz et al. 2015)	120	229	120	30-70	0.38	-	-	0.29	-	-	-	-	-	38	56	-	-	-	0.29	Two 24-HDR and mean four FFQs Turkish adults
(Maruyama, Kokubo et al. 2015)	58	84	58	47-78	-	0.32-0.39	-	-	0.43-0.48	-	-	-	-	53-55	31-38	-	-	-	-	Urban, Japanese, middle-aged population
(Pereira, Bensenor et al. 2015)	15,105	114	8,257	35-74	-	-	0.1	-	-	-	-	-	-	23	35	-	-	-	0.18	12-hour urinary excretion (spot urine)
(Talegawkar, Tanaka et al. 2015)	468	110	468	26-95	-	-	-	-	0.27	-	-	-	-	72		-	-	-	-	3-d FR, Hispanic and non-Hispanic white (energy adjusted)
(Elorriaga, Irazola et al. 2015)	147	126	147	21-74	0.33	-	-	0.47	-	-	-	-	-	-	-	-	-	-	-	Three 24-HDR (Argentinan, Chile and Uruguay adults)
(Macedo-Ojeda, Vizmanos-Lamotte et al. 2013)	97	162	97	18-71	-	0.25	-	-	0.22	-	-	-	-	58		-	-	-	-	9-d FRs (men and women (Mexico))
(Dehghan, Ilow et al. 2012)	146	134	146	30-70	0.19-0.46	-	-	-	-	-	-	-	-	66-75	-	-	-	-	-	Four 24-HDR(Polish adults)
(Dehghan, del Cerro et al. 2012)	156	96	156	35-70	0.3-0.4	-	-	-	-	-	-	-	-	29-31	39-43	-	-	-	-	Four 24-HDR(Argentinian adults)

*Continued overleaf

Reference	Sample Size (n)	Items (n)	Validation Sample Size (n)	Age (years)	Crude-r			Energy-adjusted r			LOA (Lower-Upper)			Agree (%)	Adja (%)	Sens (%)	Spec (%)	Kappa	W-Kappa	Comments
					24-HDR	FR	UE	24-HDR	FR	UE	24-HDR	FR	UE							
(Na and Lee 2012)	305	138	305	≥40	-	0.598	-	-	0.51	-	-	-	-	55	27	-	-	0.26	0.42 (0.34-0.49)	3-days FRs (Korean)
(Sam 2012)	132	147	132	30-59	-	0.36	-	-	0.27	-	-	49-290 %	-	75		-	-	-	-	8-dWeight FRs and compare with previous studies
(Zhuang, Yuan et al. 2012)	207	86	207	30–75	0.34	-	-	0.32	-	-	-	-	-	37	37	-	-	-	0.2	Four 24-HDR
(Hong, Choi et al. 2010)	1478	85	85	33-70	-	0.417	-	-	-	-	-	-	-	-	-	-	-	0.22	0.34 (0.19-0.49)	3-days FRs (T2 DM Korean)
(Carithers, Talegawkar et al. 2009)	436	158	436	35-81	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	Four 24-HDRs
(Ferreira-Sae, Gallani et al. 2009)	132	50	121	18-85	-	-	0.19 £	-	-	-	-	-	-	-	-	-	-	-	-	24 H UE & 3-d FRs Low-income and low-literacy Brazilian hypertensive
(Lassale, Guilbert et al. 2009)	74	174	74	31-60	-	-	0.35	-	-	-	-	-	-	31	53	-	-	-	0.31	Two 4-day Weight FRs (Australian women) (C-FFQ)
(Lassale, Guilbert et al. 2009)	74	174	74	31-60	-	0.69	-	-	-	-	-	63-215 %	-	37	55	-	-	-	0.55	Two 4-day WFR (Australian women) (C-FFQ)
(Charlton, Steyn et al. 2008)	324	42	324	20-65	0.75	-	0.15	-	-	-	-	-	-	-	-	-	-	-	-	Repeated 24 H UE (multi-ethnic South African)
(Block, Wakimoto et al. 2006)	89	103	89	18-71	0.53	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	Three 24-HDRLow-income (Hispanic)
JACC study (Date, Fukui et al. 2005)	110 000	33	85	20-79	-	0.35	-	-	0.31	-	-	-	-	-	-	-	-	-	-	12-days weighed FRs
(George, Milani et al. 2004)	95	195	95	18-38	-	-	-	-	0.24	-	-	-	-	21	69	-	-	-	-	3-day FRs (College women - multi-ethnic Americans)
(George, Milani et al. 2004)	50	195	50	18-38	-	-	-	-	0.28	-	-	-	-	30	64	-	-	-	-	4-day FRs (low-income women - multi-ethnic Americans)

*Continued overleaf

Reference	Sample Size (n)	Items (n)	Validation Sample Size (n)	Age (years)	Crude-r			Energy-adjusted r			LOA (Lower-Upper)			Agree (%)	Adja (%)	Sens (%)	Spec (%)	Kappa	W-Kappa	Comments
					24-HDR	FR	UE	24-HDR	FR	UE	24-HDR	FR	UE							
(Sasaki, Ishihara et al. 2003)	89	110	89	-	-	-	NS	-	-	NS	-	-	-	-	-	-	-	-	-	28-Days FRs & two 24-H UE (Japanese)
(Kabagambe, Baylin et al. 2001)	503	135	120	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	Seven 24-HDR& two FFQ (Hispanics)
EPIC-Norfolk (McKeown, Day et al. 2001)	204	130	146	45-74	-	0.45 - 0.47	0.18 - 0.20	-	0.44 - 0.52	-	-	-	-	FR:34	FR:60	-	-	-	-	7-d FRs (European)
(Sasaki, Yanagibori et al. 1998)	223	110	223	-	-	-	NS	-	-	0.23$	-	-	-	-	-	-	-	-	-	Single 24-H UE(Japanese)
(Sasaki, Yanagibori et al. 1998)	47	110	47	38-69	-	0.41	-	-	0.3	-	-	-	-	30	66	-	-	-	-	3-day FRs (Japanese women)
(Männistö, Virtanen et al. 1996)	160	110	160	25-75	-	0.22	-	-	0.42	-	-	-	-	64		-	-	-	-	7-day FRs (Japanese women)

[$] Significant in women only.
[£] Significant correlation when the Discretionary salt were added to the FFQ.
C-FFQ: computerised FFQ; FFQ: food frequency questionnaire; 24-HDR: 24 H dietary recall; FR: food records; UE: 24-H urinary excretion; Sens: Sensitivity: Spec: Specificity; W-Kappa: Weight Kappa; Adja: Adjacent.

3.4.1.2 Strengths and limitations

The sample size per gender was quite enough to estimate evidences stated in area of actions. The sample size (n=581) affords a confidence interval (margin of error) of ±4% for data reported, at the 95% confidence level (CRS 2015). Also, the post-hoc calculation of the final number of collected urine samples (n=48) using G-power software showed that the urinary salt data of the present study achieved a power of 83%. This calculation based on the worst case scenario (r=0.19) (McKeown, Day et al. 2001). This study is the first study in validating an FFQ to assess salt intake using the Triad method which provide high correlation coefficient. The "Triad" approach assumes that random errors εU, εQ and εD, present in all three measurements (urinary, FFQ and 24-HDR, respectively), are independent considering that each measurement demonstrates a linear association with the true salt intake (S). As such, errors from the use of urinary biomarker should not be correlated with errors from the dietary measurements (FFQ and 24-HDR), and their sources should thus be distinct (Kaaks 1997). Very low or negative values can cause validity coefficients greater than 1 (Heywood case), which can happen when the product of the bi-variable correlation (e.g. rQD = 0.25 * rQU = 0.35) is greater than the third (rDU = 0.03). In the present study, negative values or values greater than 1.0 were not observed.

A relatively large number of food items (133 items) in Saudi-FFQ were used to assess intake of salt (sodium), since including too few items has been shown to cause an underestimation of intake using an FFQ (Cade 2002). Because the FFQ is culturally based, no expatriates were included in this study since they have different eating patterns which may have affected the findings of this study (Amin, Al Sultan et al. 2014).

The 24-hour urine sample could be collected in ~22 or 26 hours. However, the participants were provided with Urine Collection Records and Urine Collection Instructions. Only 68% of the participants completed the records successfully. Both para-aminobenzoic acid (PABA) and urinary creatinine index (UCI) were used to verify the completeness of urine sample. The participants did not comply with the instructions of PABA usage (e.g. timing). Therefore, the UCI was used for completeness verification. The differences were assessed between the subjects who have completed urine collection using PABA recovery (n=23; PABA recovery >85%) and UCI (n=49; 11–20 and 14–26 mg/kg body weight/day for

women and men, respectively). The analyses revealed no significant difference between both groups in sodium outputs ($p>0.05$). The hot climate in Saudi Arabia especially in summer months may result in large losses of water and salt in the sweat (Sawka and Pandolf 1990). Therefore, to avoid any significant sodium loss in the sweat, we conducted the study during the moderate climate seasons (November and December).

Excluding seasonings and oils such as mono-sodium glutamate (MSG) or butter to assess nutrient intake may have led to an underestimation of sodium intake (Na and Lee 2012). Care must be taken while interpreting dietary intake data that do not include seasonings and oils (e.g. butter) which is high in salt (Na and Lee 2012; Shim, Oh et al. 2014). Our FFQ considered seasonings and cooking oils and by conducting a more dish-based questionnaire. For example, food-based questions were calculated to include only bread, whereas the dish-based questionnaire was calculated to include bread with added oils (e.g. salty butter). However, in this study 36% of those using salt substitute are using mono-sodium glutamate as a salt substitute which is not true substitute. The patterns of MSG use are assessed in this study but not estimate the exact amount. However, Li et al (2015) (Li, Qin et al. 2015) found that in the Chinese population, the main source of salt intake was added salt (79%), followed by salty vegetables (14%), soy sauce (3%), MSG (2%) and other sauce (2%) using validated FFQ. Therefore, further questions regarding the amount of MSG and discretionary salt should be added to the questionnaire in future.

Data regarding longer-term dietary patterns are crucial to better understand diet and associated diseases (Cade 2002). So, a limitation that should be acknowledged is the lack of information on the reproducibility of the FFQ. Reproducibility is often evaluated by carrying out the FFQ in two (or more) time points in the same group of people. However, in this study, it was difficult to carry out the FFQ again due to the time constraints and lack of data entry capacity. When considering any extrapolation of the data obtained beyond the parameters of this study population, it important to consider that the participants recruited in this study were a convenience sample and may not be a representative sample of the whole Saudi population. Additionally, there are also region-specific dietary habits in SA. For example, Al-Numair et al (2005) (Al-Numair, Lewis et al. 2005) found that the intake of total n-3 fatty acids was twice as high among the coastal region residents than for the

internal residents in SA. Therefore, a random and stratified sampling technique should be applied on a national level to collect representative sample of the population.

FFQ responses can vary with season of administration in a manner consistent with dietary intake reported consumed during that season (Fowke, Schlundt et al. 2004). Seasonally consumed items, such as watermelon in summer, can be challenging as they may be consumed and be reported more frequently when in season but not out of season (Cade 2002). Seasonal differences of food intake were not discussed before in SA. However seasonally consumed items were considered in this study questionnaire, especially fruits (dates, watermelon etc.), since they are consumed more frequently when in season and then not at all out of season. Also, the use of single 24-h urine collection may not have accurately captured the urinary status of the volunteers, depending on day and season variation for salt intake. However, the strength of this validation study was its assessment of salt using three methods by applying the Triad technique (Yokota, Miyazaki et al. 2010).

The funnelling trend of the agreement between FFQ and 24-H Recall using Bland-Altman method, demands a transformation of the data (probably log-base10) should be acknowledged. Finally, assessing non-western diet including SA diet is difficult as the most consumed food is based on mixed dishes and sharing food from the same plate is common among the SA population. This lead to difficulty to assess the portion sizes of Saudi diet. However, in this study the mixed foods were estimated using a stanardised plate.

3.5 Conclusion

In conclusion, this 133-item FFQ developed specifically for the SA population had moderate relative validity and fair reliability, and therefore FFQ is capable of ranking people based on their estimated salt intake in SA population, and performed as well as other salt FFQ developed for other nations, which is useful in examining the relationships between diet and chronic disease including hypertension. At the same time it must be acknowledged that FFQ is poor at measuring absolute salt intakes relative to 24-HDR or 24-hour urine samples. Further efforts should be made to evaluate the reproducibility and reliability of the present FFQ. Furthermore, population interventions and health education are required to reduce

sodium intake in SA population. The quantitative and qualitative data provided in this study could be used to develop and implement strategies for salt intake reduction in SA.

Chapter Four

Salt intake and hypertension in Riyadh city

4.1 Introduction

Hypertension or elevated blood pressure (BP) is a condition in which the blood vessels have persistently raised pressure above certain threshold values (Giles, Materson et al. 2009). Nearly 40% of adults worldwide, aged 25 years and over, had been diagnosed with hypertension in 2008, a disease responsible for more than 9 million deaths annually (WHO 2013). Hypertension is an underlying factor in at least 51% of deaths due to stroke and 45% of deaths due to heart disease (WHO 2011; WHO 2013). In 2014, high-income countries had a lower prevalence of hypertension than other income groups (WHO 2011; WHO 2015). There is a strong body of evidence supporting the association between chronic high-sodium intake (in the form of salt (NaCl)) and hypertension (Meneton, Jeunemaitre et al. 2005; He and MacGregor 2009; Blaustein, Leenen et al. 2012; He and MacGregor 2015; Johnson, Raj et al. 2015), increasing the risk of cardiovascular diseases (He, Burnier et al. 2011; Soga and Pandey 2011). Reducing salt intake long-term to less than 6 grams per day was shown to lower the blood pressure and subsequently reduce the occurrence of cardiovascular diseases (He, Markandu et al. 2005; Cook, Cutler et al. 2007; He, Li et al. 2013). People with low levels of socio-economic status (SES) (i.e. occupation, education and income) have higher salt intake than more affluent counterpart (Purdy, Armstrong et al. 2002; Miyaki, Song et al. 2013; Ji and Cappuccio 2014). Also, Alkhunaizi AM et al (2013) found a negative correlation between sodium excretion and age in Saudi Arabia (SA) (Alkhunaizi, Al Jishi et al. 2013). Socioeconomic status and lifestyle (including dietary habits) have dramatically changed in SA over the last few decades; and there was no study which assessed the relationship between salt intake and SES (Alwan 1997; Khatib 2004).

It is important to better understand the relationship between diets, food consumption levels and patterns, and these emerging chronic diseases (Kroes R. 2002; WHO/FAO 2003; Bingham 2007). This allows the cost-effective interventions and preventive strategies in the community such as food fortification and nutrition education and awareness programmes, and lifestyle modification campaigns to be well planned, implemented, and evaluated (Alwan 1997; Jerome 1997; Bingham 2007; West 2009). Reliable information on actual levels of consumed foods has to be generated through representative consumption surveys (WHO/FAO 2003). There is a dearth of information on habitual salt intake in SA apart from one study in the Eastern region (8.1 g/day), not representative for the general population

(Alkhunaizi, Al Jishi et al. 2013). Some samples of potential kidney donors and patients who underwent work-up for nephrolithiasis were used in this study. The food frequency questionnaire (FFQ) is considered to be one of the most practical methods used in epidemiological studies to collect dietary intake, because of its low cost and ease of administration (Thompson 1994). However, the validity and reliability of FFQ needs to be tested (Margetts 1997; Subar 2001; Westerterp 2002; Thompson 2010).

Based on the findings of Chapter 3, the Saudi-FFQ is useful to classify an individual's intake into tertiles, facilitating the examination of relationships between diet and chronic disease including hypertension. Therefore, the study presented in this chapter aims to answer the following research question:

RQ: Does salt intake vary with socio-economic characteristics; is salt intake related to blood pressure intake in SA; and what are the main sources of dietary salt in Saudi Arabia?

4.2 Methodology and materials

4.2.1 Population

The study sample included males and females aged between 19 to 60 years. Those on kidney dialysis and pregnant women were excluded from this study. No expatriates were included in this study. The full population characteristics have been outlined in **Chapter 3**. The study was conducted during October and November 2013 in accordance with the guidelines laid down in the Declaration of Saudi National Committee of BioEthics (Appendix1). All volunteers provided written informed consent to participate in the study (Appendix2). All procedures were approved by the Saudi Food and Drug Authority Ethical Committee (SFDA-IRB).

4.2.2 Data collection

4.2.2.1 Socio-demographics

The socio-demographic information collected included: sex (male and female); age was divided into four categories: 19-29, 30-39, 40-49 and 50-60; c) occupational status:

employed student, staying at home, unemployed and retired; d) educational status was divided into low (illiterate or elementary), medium (intermediate or secondary) and high (college or higher); and e) economic status was divided into three categories of low (<42,000 SR/year); corresponds to the minimum wage placed by the Ministry of Labour in Saudi Arabia, medium (42,000 SR To 100,000 SR/year) and high (>100,000 SR/year). Scores were given as 1 for low, 2 for medium and 3 for high. Socio-economic status for each participant was calculated ranging between 2 and 6 scores. These scores were divided into three categories: low (2-3), medium (4-5) and high (6) base on previous studies were conducted in SA (Al-Numair 2006) (Appendix 5). There is no existing approach that has been used in SA, therefore it was decided to employ the socio-economic approach used by a researcher in SA (Al-Numair 2006).

4.2.2.2 Blood pressure

Systolic and diastolic blood pressures were measured twice in sitting position within 20 minutes using an automatic sphygmomanometer (OMRON M6 COMFORT (HEM-7223-E), Japan). The average of both readings was recorded. Hypertension was defined as a systolic blood pressure (SBP) of 140 mmHg or above, and/or diastolic blood pressure (DBP) of 90 mmHg or above (WHO/ISH 2003). Subjects who reported to have been diagnosed with hypertension by a physician were considered as having hypertension. However, subjects diagnosed with hypertension and subjects using antihypertensive drugs were considered as having hypertension as well.

4.2.2.3 Dietary data

A quantitative FFQ was developed using a food list of common foods and composite dishes consumed by Saudi adults from previously collected 24-hour dietary recall (Al-Nozha M 1996). The FFQ was pretested and finalized with 133 food items. A specific question was included regarding table salt use while eating and cooking. The participants were interviewed once to report their typical dietary habits over the previous year using Saudi-FFQ. The Saudi-FFQ was validated against repeated multiple pass 24-hour dietary recalls (24-HDR) and urinary biomarkers for a sub-sample of the population. More details are shown in **Chapter 3**.

4.2.3 Statistical analysis

Spearman's correlation was performed to assess the relation between estimated salt intake, and systolic (SBP) and diastolic blood pressure (DBP). Regression analysis (linear and logistic) was performed to explore potential relationships between study variables such as age and socio-economic versus salt intake; and salt intake vs. systolic and diastolic blood pressure. Also, the salt scores were cross-classified into tertiles to evaluate the relationship between blood pressure and salt intake. Tertiles of salt intake were defined. One-Way ANOVA test was used to assess the differences of blood pressure (mmHg) between the tertiles of salt intake. One-Way ANOVA test was used to assess the differences of salt intake (g/day) between the socio-demographic categories. Statistical significance was set at $p<0.05$.

Subjects were categorised as having high or normal sodium (salt) intake using a threshold of 2g sodium/day (equivalent to 5g salt/day) based on Dietary Guidelines for Saudis (MOH 2012) which is adopted from the WHO (WHO/FAO 2003). A post-hoc test was used using the G-power software to obtain the sample size and effect size to determine what the power was in the study and whether the study achieved the scientific power to assess the association between salt intake and blood pressure of study population.

4.3 Results

4.3.1.1 Study participants

A total of 601 individuals, 336 women (56%) and 265 men (44%), participated in the study, with an overall completion (first and second interview) rate of 78% (77% in women and 86% in men). Seventy (9%) participants withdrew during the 1st interview and 70 (9%) withdrew during the 2nd interview. Five (1%) participants were excluded from the analysis because they did not fulfil the inclusion criteria (subjects on kidney dialysis and pregnant women were excluded). More details are shown in **Chapter 3**. This sample size (n=581) affords a confidence interval (margin of error) of ±4% for data reported, at the 95% confidence level (CRS 2015).

Characteristics of the study population are summarized in Table 4.3-1 and Table 4.3-2. The overall median (IQR) age of participants was 29 (24-38). Fifty-two percent of those

participants were aged 19-29 years and 25% of aged 30-39 years. The majority of participants were married, 322 (55%). Most participants (59%) were educated to college level or higher, however, personal income was low (<42,000 SR/year, equivalent to minimum wage) for nearly half (45%), potentially due to the proportion of females with no paid occupation in SA. Approximately, 58% of the participants were employed. Also, most participants (57%) had a "medium" socioeconomic status.

Table 4.3-1: Characteristics of study participants (n=581).

Characteristics	***All (581)**** ***n (%)***	***Female (n=330)*** ***n (%)***	***Male (n=251)*** ***n (%)***	***p*** [b]
Age (year)				0.019
19-29	302 (52)	182 (55)	120 (48)	
30-39	146 (25)	70 (21)	76 (30)	
40-49	76 (13)	40 (12)	36 (14)	
50-60	57 (10)	38 (12)	19 (8)	
Total	581	330 (57)	251 (43)	
Median Age (IQR)	29 (24-38)	28 (23-28)	30 (25-38)	0.146
Education				0.001
None or elementary	36 (6.0)	30 (9)	6.0 (2)	
Intermediate or secondary	202 (35)	104 (32)	98 (39)	
College or higher	341 (59)	195 (59)	146 (58)	
Marital Status				<0.0001
Never Married	227 (39)	137 (42)	90 (36)	
Married	322 (55)	162 (49)	160 (64)	
Divorced	26.0 (5)	25 (8)	1 (0.4)	
Widowed	6.0 (1)	6 (2)	0 (0.0)	
Income [a]				<0.0001
<42,000	257 (45)	209 (64)	48 (20)	
42,000 - 100,000	176 (31)	76 (23)	100 (41)	
>100,000	139 (24)	42 (13)	97 (40)	
Occupational status				<0.0001
Employed	334 (58)	135 (41)	199 (79)	
Student	114 (20)	79 (24)	35 (14)	
Household (Stay at Home)	87 (15)	87 (26)	0 (0)	
Unemployed	29 (5)	23 (7)	6 (2)	
Retired	17 (3)	6 (2)	11 (4)	
Socio-economic Status				<0.0001
Low (2-3)	138 (24)	106 (32)	32 (13)	
Medium (4-5)	330 (57)	189 (57)	141 (56)	
High (6)	111 (19)	34 (10)	77 (31)	
SBP (median (IQR)- mmHg)	111 (102-121)	108 (99-120)	115 (107-123)	<0.0001
DBP (median (IQR)- mmHg)	77 (69-83)	76 (68-83)	78 (71-83)	0.066

[a] In Saudi Riyals (SR) per year; [b] Value was significantly different between males and females (P <0.05) bases on chi square (χ^2) and Man-Whitney analysis.
IQR: Interquartile range;
* This number after excluding participants with implausible energy intake.

Table 4.3-2: Socio-demographic scores of Riyadh study participants (n=579) who completed the first and second interviews.

Category	Whole Population [£]		Female		Male	
	n (%)	*median age (IQR)*	*n (%)*	*median age (IQR)*	*n (%)*	*median age (IQR)*
Low (2-3)	138 (24)	27.5 (21.8-43.3)	106 (32)	30 (22.8-45)	32 (13)	21.5 (20-31.3)
Medium (4-5)	330 (57)	28 (24-35)	189 (57)	26 (23-34)	141 (56)	29 (25-35)
High (6)	11 (19)	35.5 (27-44.3)	34 (10)	35 (25.5-44.3)	77 (31)	36 (29-44)
All	579	29 (24-38) [bc]	335 (55.9)	28 (23-38.3) [ac]	250 (43)	30 (25-38) [abc*]
***p*-value [$]**		<0.0001		<0.0001		<0.0001

[*] Value was significantly different in socio-economic factors between males and females (P <0.05) bases on chi square analysis (χ^2). [$] Value was significantly different in age between socio-economic factors (p <0.05) bases on One-Way ANOVA test; [a] Value was significantly in age different between Low and Medium Socio-economic status (p <0.05) bases on One-Way ANOVA test; [b] Value was significantly different in age between Low and High Socio-economic status (p<0.05) bases on One-Way ANOVA test; [c] Value was significantly different in age between Medium and High Socio-economic status (p<0.05) bases on One-Way ANOVA test; [£] two participants did not report their Socio-demographic information.

4.3.1.2 Estimated salt intake

The median sodium intake estimated using the FFQ was 3,457 mg/24 h (2,298-4,696 mg/24 h), equivalent to 8.7 g salt/24 h (IQR 5.8-11.9 salt/24 h). The median sodium intake of male participants using FFQ was 3,626 mg/24 h (2,655-4,915 mg/day) equivalent to 9.2 g salt/day (IQR 6.7-12.4 g/day) which was particularly high and higher than that of the female participants, 3,253 mg /day (IQR 2,106-4,598 mg/day) equivalent to 8.3 g salt/day (IQR 5.3-11.7 g/day). The magnitude of the difference of daily salt intake between women and men was statistically significant (p=0.001).

4.3.1.3 Salt intake patterns

Around 60% of the study population always added salt while cooking with a higher proportion of men (66%) than women (55%) (χ^2=8.6, p=0.003). Furthermore, 73% never add salt while eating – with a small difference between genders: women, 77%, and men, 69% (χ^2=4.029, p=0.045). Approximately half of the population (54%) ate at least one time per week from restaurants and takeaways (no difference between gender (p=0.073)). Furthermore, participants reporting using salt substitutes named mono-sodium glutamate (MSG) (36%) and sea salt (35.7%) as what they used instead, both high in sodium and not true substitutes. Surprisingly, the salt intake increased with reduction in attitude to add salt while cooking (p=0.015).

Table 4.3-3: Patterns of table salt use and salt amount in each component of salt use from the Saudi-FFQ (n=581) among Riyadh city adults, Saudi Arabia.

Salt Use	Never n (%)	Rarely n (%)	Sometimes n (%)	Usually n (%)	Always n (%)	p-value
Add salt while cooking	28 (5)	20 (3)	31 (5)	153 (26)	348 (60)	
FFQ (g salt/day)	11.0	10.1	8.8	8.7	8.4	0.015
Add salt while eating	426 (73)	23 (4)	51 (9)	22 (4)	58 (10)	
FFQ (g salt/day)	8.8	10.6	8.6	7.2	8.2	0.381

[a] Value was significantly different between women and men (P <0.05) bases on One-Way ANOVA test.

4.3.1.3.1 Salt intake and current health recommendations

Calculations were performed to identify respondents meeting or failing to meet recommended salt intakes (<5 g salt/day) based on "Dietary Guidelines for Saudis" (MOH 2012) which was adopted from the WHO (WHO/FAO 2003). Very few people (18%, n=104/581) met the national recommendation for salt intake (<5 g salt/day). There were no significant differences in high salt intake prevalence between genders. Salt intakes among Saudi adults using FFQ are about 0.8–7 g salt/day above current recommendations.

4.3.1.3.2 Sources of salt intake

The main dietary sources of salt are shown in Table 4.3-4. Surprisingly, the main sources of salt intake using Saudi-FFQ are *Vegetables* (41.9%; 1.8 g salt/day) followed by *Mixed Dishes* (18.6%; 0.8 g salt/day), *Sandwiches and Snacks* (0.5 g salt/day), *Breads, Cereals and Starches* (0.5 g salt/day), and *Meat, Fish and Eggs* group (0.5 g salt/day). Furthermore, 55% of the salt intake came from un-processed foods and 45% of salt intake came from processed foods. There are no differences between genders in term of having processed or unprocessed food. Processed foods were defined in this study as bread and cereals; savoury snacks and sweets, such as crisps; meat products, such as burger; canned meat and fish products, such as canned tuna; drinks, such as milk, *laban* or soft drinks; cheese products such as cream cheese or white cheese; fast foods such as pizza and *shawarma* (donner kebab).

Table 4.3-4: Sources of salt (g salt/day) intake based on Saudi-FFQ among Saudi adults in Riyadh city, Saudi Arabia (n=581).

Food Groups	Na (mg)					Salt (g)				
	Median	Q1	Q3	Mean	STDV.	Median	Q1	Q3	Mean	STDV.
Milks	4.8	0.0	29.1	22.7	50.6	0.0	0.0	0.1	0.1	0.1
Labans	0.0	0.0	6.9	12.5	34.1	0.0	0.0	0.0	0.0	0.1
Cream Cheese	0.0	0.0	19.4	20.9	49.0	0.0	0.0	0.0	0.1	0.1
White and Cheddar Cheese	20.5	0.0	71.0	69.5	145.4	0.1	0.0	0.2	0.2	0.4
Yogurt	10.7	0.0	46.1	31.5	64.9	0.0	0.0	0.1	0.1	0.2
Labnah	0.0	0.0	0.8	2.4	8.0	0.0	0.0	0.0	0.0	0.0
Ice cream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quashta* (Cream) /*Gaymar	0.0	0.0	0.1	1.1	3.4	0.0	0.0	0.0	0.0	0.0
Fruits:	22.8	1.6	105.7	134.9	318.7	0.1	0.0	0.3	0.3	0.8
Fruits without Olives	9.8	1.0	27.4	21.4	35.8	0.0	0.0	0.1	0.1	0.1
Olives	0.0	0.0	83.2	113.5	311.2	0.0	0.0	0.2	0.3	0.8
Vegetables	739.2	233.0	2122.9	1248.1	1433.4	1.8	0.6	5.3	3.1	3.6
Meat, Fish and Eggs	197.0	77.3	428.2	322.1	392.8	0.5	0.2	1.1	0.8	1.0
Mixed Dishes	321.6	147.5	608.9	442.1	459.6	0.8	0.4	1.5	1.1	1.1
Sandwiches and Snacks	214.7	82.7	479.5	340.1	362.8	0.5	0.2	1.2	0.9	0.9
Breads, Cereals and Starches	207.8	96.0	443.4	317.5	326.0	0.5	0.2	1.1	0.8	0.8
Beverages, Juices and Drinks	17.3	5.4	48.3	39.0	98.6	0.0	0.0	0.1	0.1	0.2
Sweets	11.5	1.2	34.6	27.7	46.1	0.0	0.0	0.1	0.1	0.1
Seeds and Nuts	0.8	0.0	5.6	6.4	14.5	0.0	0.0	0.0	0.0	0.0
Butter, Margarine or other Spread or Oil on bread	0.0	0.0	0.0	2.1	12.6	0.0	0.0	0.0	0.0	0.0

4.3.1.4 Socio-economic factors and salt intake

There was a difference of 2grams in salt intake (g/day) between socio-economic groups (Table 4.3-5**,** p=0.007). This was seen in particular in term of income levels (difference from low to high: 2grams, p=0.011) levels but not between education levels (p=0.262) or occupation levels (p=0.089).

Table 4.3-5: Salt intake (g/day) from the Saudi-FFQ (n=581) among socioeconomic groups in Riyadh city adults, Saudi Arabia (n=581).

Socio-economic	**Salt Intake**	***Income***	**Salt Intake**	***Education***	**Salt Intake**
n=579		*N=572*		*n=579*	
Low	7.9 (5.7-11.5)	**Low**	8.2 (5.6-10.9)	**Low**	**8.9 (5.7-12))**
Medium	8.7 (5.7-11.6)	**Medium**	8.6 (5.7-12.4)	**Medium**	**8.2 (5.6-11.7)**
High	9.9 (6.6-13.1)[a c]	**High**	9.9 (6.9-12.3)[b]	**High**	**8.8 (5.8-11.8)**
p-value*	0.007	**p-value***	0.011	**p-value***	0.262

[*] Value was significantly different between socio-economic factors (p <0.05) bases on One-Way ANOVA test; [a]Value was significantly different between Low and Medium status (p <0.05) bases on One-Way ANOVA test; [b] Value was significantly different between Low and High status (p<0.05) bases on One-Way ANOVA test; [c] Value was significantly different between Medium and High status (p<0.05) bases on One-Way ANOVA test.

4.3.1.5 Estimated and measured daily salt intake and blood pressure (without anti-hypertensive medication)

Spearman's correlations between daily salt intake estimated with the Saudi-FFQ, and systolic (SBP) and diastolic blood pressure (DBP) are shown in Figure 4.3-1**.** The results show a significant but weak relationship between daily salt intake from Saudi-FFQ and SBP (R_S=0.089, p=0.036) while the relationship between daily salt intake and DBP was not significant (R_S=0.021, p=0.617).

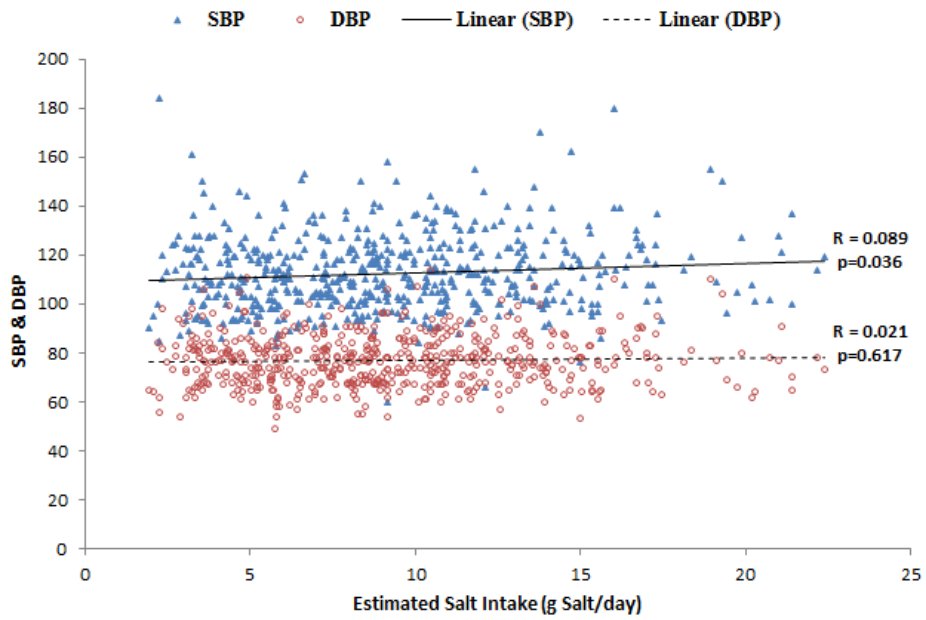


Figure 4.3-1: Correlation between estimated salt intake using FFQ, and the SBP and DBP (n=581).

Table 4.3-6 shows the linear regression analysis between blood pressure and salt intake, suggesting that the estimated salt intake is associated with SBP (p=0.013) but not with DBP (p=0.247). However, when the model was adjusted for age, WC and gender, the significance was lost in both SBP and DBP. The occurrence of hypertension was also not associated with salt intake from Saudi-FFQ (χ^2=0.064, p=0.969).

Table 4.3-6: Systolic and diastolic blood pressure associated with the increase of estimated salt intake (g salt/day) using Saudi-FFQ (n=581) among Saudi adults living in Riyadh city using multiple regression analysis

Coefficient:	B	SE	R Square	CI	t-value	p-value*
Estimated salt intake using FFQ-Crude						
SBP (mmHg)	0.38	0.153	0.011	0.08-0.68	2.50	0.013
DBP (mmHg)	0.120	0.104	0.002	-0.08-0.32	1.16	0.247
Estimated salt intake using FFQ-Adjusted £						
SBP (mmHg)£	0.084	0.146	0.154	-0.203-0.371	0.577	0.564
DBP (mmHg)£	-0.020	0.103	0.089	-0.222-0.182	-0.195	0.845

* Regression is significant at the <0.05 level;
£ Adjusted for WC, age and gender.
CI: Confidence Interval; SE: Standard error; B: coefficient estimate; SBP: systolic blood pressure; DBP: diastolic blood pressure; WC: Waist circumference.

4.4 Discussion

To the knowledge of the researcher, there is no precedent for developing an FFQ that suits a Saudi population to assess usual salt intake. The present study evaluated the relationship of salt intake on blood pressure and hypertension status on a Saudi adult population using the newly developed Saudi-FFQ. The effect of socio-economic characteristics on habitual salt intake and the dietary sources of salt were also tested. This study recruited 581 participants which satisfied the sample size requirements for representativeness, with a sample size larger than that of previous studies (Dehghan, del Cerro et al. 2012; Elorriaga, Irazola et al. 2015; Gunes, Imeryuz et al. 2015).

4.4.1.1 Estimated salt intake levels and patterns

The median estimated salt intake in this study is 8.7 g/day (IQR 5.8-11.9), with higher intake in men (9.2 g salt/day, IQR 6.7-12.4) than women (8.3 g salt/day, IQR 5.3-11.7). This difference between genders (male intake 11% higher than in women) mirrors that of the UK in 2011 (9.3 and 6.8 g/day in men and women, respectively) (Sadler 2012). However, salt intake in British men was nearly 27% higher than in women. The current intake of the Riyad population (8.7 g/day) is also similar to the intake of a South Indian population (estimated using a validated FFQ) at 8.5 g/day (Radhika, Sathya et al. 2007). However, it is substantially higher than previously estimated in the Saudi population: in 1987, Al-Nozha et al. (Al-Nozha M 1996) estimated sodium intake using a single 24hr food recall, with a mean intake of 2,454 mg/day, equivalent to 6.14 g salt/day; this is 42% lower than the current salt intake in this study.

Very few people (18%) in our study population met the national and WHO recommendation for salt intake (<5 g salt/day) (WHO/FAO 2003; MOH 2012). Salt intakes among Saudi adults are about 0.8–7 g salt/day above current recommendations. These findings are consistent with Trials of Hypertension Prevention (TOHP) findings, showing that only 10% of subjects were consuming <5.75 g salt/day (Cook, Appel et al. 2014).

Our findings are consistent with other Asian studies in term of salt addition behaviours. A majority of the study population always add salt while cooking and most never added salt while eating. In Chinese population, most dietary sodium (76%) was from discretionary salt added in home cooking (Anderson, Appel et al. 2010). In contrast, in

the UK, the contribution of salt added at the table or in home cooking to overall intake was 5% only (Anderson, Appel et al. 2010).

4.4.1.2 Estimated salt intake and socio-economic factors

Estimated salt intake was higher by 2 grams with individual income increase but not with education or occupation. However, these results are not in agreement with several other studies. In Japanese workers, education levels and household income were negatively associated with salt intake using self-administered diet history questionnaire (Miyaki, Song et al. 2013). In the UK, higher dietary sodium intake in people with the lowest educational and occupational levels was observed. The dietary sodium intake among those with no qualification was 5.7% (0.1%, 11.1%) higher than the reference group (Ji and Cappuccio 2014). Furthermore, in Northern Ireland a cross-sectional study (n=360) revealed that high discretionary salt usage and frequent consumption of processed foods among consumers of lower socio-economic status (Purdy, Armstrong et al. 2002).

4.4.1.3 Sources of estimated salt intake

It is also a practical tool to enable identification of sources of sodium with high intake and to inform public health interventions based on changing dietary practices, consumer education, and reformulation of processed foods (McLean 2014). Therefore, this study assessed the sources of high salt intake among the study population, with "Vegetables" (42%), followed by "Mixed dishes" (19%) the main dietary sources of salt.

Sources of salt in the diet differ among countries. The current study did not assess the amount of discretionary salt added to food at home in cooking and at table. However, the Saudi Food Composition Tables (SFCT) included "ready to eat" foods which contain discretionary salt in SFCT analyses (Al-Nozha M 1996).

In the INTERMAP study (International Study of macro and micro-nutrients and blood pressure) shows that the main source of salt in the Chinese diet was added salt during cooking (78%), followed by soy sauce (7%) (Zhou, Stamler et al. 2003; Anderson, Appel et al. 2010; Batcagan-Abueg, Lee et al. 2013). Li et al (2015) also found that in a Chinese population, the main source of salt intake was added salt (79%), followed by salty vegetables (14%), soy sauce (3%), MSG (2%) and other sauce (2%) (Li, Qin et al. 2015).

In the UK, the main source of dietary salt was breads, grains and cereals (34%), followed by red meats, poultry and eggs (20%) (Zhou, Stamler et al. 2003; Anderson, Appel et al.

2010). In the USA, the main source of dietary salt was added salt (29%), followed by breads, grains and cereals (29%), and red meats, poultry and eggs (19%) (Zhou, Stamler et al. 2003; Anderson, Appel et al. 2010).

The current study also shows that more than half of salt intake (55%) came from un-processed foods. In contrast, in the UK and USA excessive salt intake in modern diets in these countries is mainly came from commercial food processing (83% and 77%, respectively) (Sanchez-Castillo, Warrender et al. 1987; Mattes and Donnelly 1991; Anderson, Appel et al. 2010).

Seasonings, condiments and oils such as mono-sodium glutamate (MSG), margarines, soy and fish sauces, or butter are other sources of sodium in different populations (Batcagan-Abueg, Lee et al. 2013). The current study included questions regarding the amounts of margarines (0.01%), butter (0.01%) and mayonnaise (0.1%) in the FFQ. However, participants were not asked regarding the amount of MSG, dressings and sauces. Excluding seasonings and condiments during the assessment of nutrient intake may have lead to underestimation of sodium intake (Na and Lee 2012). In the USA, nearly 10% of daily salt came from gravies, seasonings, sauces, salad dressings (7.2%), and margarines (1.3%) (Anderson, Appel et al. 2010). In the Philippines, a high proportion of dietary sodium came from condiments such as soy sauce (14%) and fish sauce (1.4%) after added salt (58%) at the table or during cooking (Lee 2009). For this reason, the weak relationship between salt intake and BP may partly explained by not including some of these sources of sodium in the Saudi FFQ. However, the participants were asked regarding the type of salt substitutes they were using. Among those reported using salt substitutes, 36% of them used mono-sodium glutamate (MSG) and 36% used sea salt, both high in sodium and not true substitutes.

These findings raise a concern regarding the encouragement to increase vegetables intake without including advice regarding the risk of higher salt intake in SA. Also, these findings imply that focusing on traditional (local) and conventional (e.g. western food) diet is important.

In addition, updated consumer education, changes in the food environment and policies, and reformulation of processed and prepared foods to achieve the lowest possible sodium contents are also important as recommended in the recent WHO consultation report (WHO/EMRO 2013). These findings raised a concern regarding the encouragement to

increase intake of vegetables without including an advice regarding the risk of higher salt intake in SA.

4.4.1.4 Salt intake and blood pressure

This study revealed a weak but significant relationship between estimated salt intake and systolic blood pressure. Results showed that every 2g of measured salt increase is significantly associated with ≈ 0.8 mmHg (0.2-1.4 mmHg) increase in SBP. Antihypertensive drugs (including diuretics, beta blockers, Angiotensin-converting enzyme (ACE) inhibitors, Angiotensin II receptor blockers (ARBs), Calcium channel blockers, and renin inhibitors) may affect blood pressure and salt metabolism in the human body (Sciarretta, Palano et al. 2011; Thompson, Hu et al. 2011). However, the same results were observed even when subjects using antihypertensive were excluded ($p=0.034$). These results are consistent with several studies. In 2007, the CURES study (Chennai Urban Rural Epidemiology Study) recruited 26,001 participants aged 20 and more from South Indian Population (Radhika, Sathya et al. 2007). The study assessed the estimated salt intake using validated FFQ and found a significant increase of SBP and DBP with increasing salt intake ($p<0.0001$). The INTERMAP study which is cross-sectional epidemiologic study recruited 4,680 men and women aged 40-59 years from 17 diverse populations also agreed with the current study: every 1.0 g of urinary salt increase was significantly associated with 1.9 mmHg mm Hg (0.8-3.0 mm Hg) increase in SBP and 0.8 mm Hg (0.2-1.4 mm Hg) increase in DBP (Anderson, Appel et al. 2010). This strong relationship between salt intake and BP in INTERMAP may be explained by the salt intake estimation method, 24 hour urinary sodium output, which is considered as a "gold standard" method t (Van Dam and Hunter 2013).

The INTERSALT study, conducted in 1988 and re-analysed in 1996, assessed the association of salt intake using 24 hour urine samples and blood pressure in more than 10,000 subjects in 52 locations around the world (Elliott 1988; Elliott, Stamler et al. 1996). This study found a significant positive association between 24 hour urinary sodium excretion and blood pressure after adjustment for age, sex, BMI, and alcohol intake. It found that individual 24 hour urinary sodium excretion higher by 100 mmol (5.8 gram salt/day) was associated with SBP/DBP higher on average by 3/0 to 6/3 mm Hg within population (with and without BMI analyses); and associated with median SBP/DBP higher on average by 5-7/2-4 mm Hg across population (n=52).

The current study findings are in disagreement with those of Alkhunaizi et al. who did not find any significant relationship between urinary salt excretions, and SBP and DBP in eastern region of SA (Alkhunaizi, Al Jishi et al. 2013). One major limitation of that study was the small sample size and inclusion of potential kidney donors and patients who underwent work-up for nephrolithiasis.

Furthermore, as discussed in the introduction (Section1.2.3.2.1), the kidneys and hormones have a central role in maintaining sodium, water balance and blood pressure in human body through the renin-angiotensin system (RAS) (Guyton 1991; Lewis, Dirksen et al. 2014). Cells in the kidney release the enzyme called renin when blood volume or sodium levels in the body are low, or blood potassium is high. Renin converts angiotensinogen (produced in the liver) to the hormone angiotensin I. Then, an angiotensin-converting enzyme (found in the lungs) metabolizes angiotensin I into angiotensin II. This causes the blood vessels to be constricted and blood pressure increases due to the effect of the Angiotensin II. Also, Angiotensin II stimulates the release of aldosterone hormone (found in the adrenal glands). This causes the renal tubules to retain water and sodium and excrete potassium (Wilken and Juneja 2008; de Kloet, Krause et al. 2010). However, some factors such as kidney diseases, excess body fat and salt intake can affect this regulation, causing elevated blood pressure (hypertension). Antihypertensive drugs (including diuretics, beta blockers, Angiotensin-converting enzyme (ACE) inhibitors, Angiotensin II receptor blockers (ARBs), Calcium channel blockers, and renin inhibitors) are used to control blood pressure and salt metabolism in human body (Sciarretta, Palano et al. 2011; Thompson, Hu et al. 2011). In present study, subjects on kidney dialysis were not included in the study analysis.

4.4.1.5 Strengths and limitations

More details on strength and limitations of this study were discussed in details in Chapter 3. The sample size per each gender was quite enough to estimate evidences stated in area of actions. The sample size (n=581) affords a confidence interval (margin of error) of ±4% for data reported, at the 95% confidence level (CRS 2015). The current study also included questions regarding the amounts of margarines, butter, ketchup, and mayonnaise in the FFQ. However, participants were not asked regarding the amount of MSG, dressings and sauces which could lead to underestimating the salt intake in study population (more details discussed in section 3.4.1.1).

A causal relationship could not be drawn from this study as it is a cross-sectional study covering a snapshot of time which did not cover the seasoning differences in food intake; and did not assess the reproducibility of the FFQ (more details in Chapter 3). Even though there was no relationship between newly developed FFQ and blood pressure status, still it is a useful tool for a large population to assess their habitual dietary intake. It is also a practical tool to enable identification of sources of sodium with high intake and to inform public health interventions based on changing dietary practices, consumer education, and reformulation of processed foods (McLean 2014).

4.5 Conclusion

Data presented in this study indicate that most of Riyadh population consume an amount of salt higher than the recommended level (<5 g/d for salt). The main sources of dietary salt came from "vegetables" and un-processed foods. Socio-economic status, and particularly income, has a significant impact on salt intake. Data in present study also indicate a significant relationship between increase salt intake and blood pressure. Extensive data from prospective population studies indicate that such reduction in salt intake levels could substantially improve blood pressure levels and subsequently, reducing the major rates of cardiovascular diseases and mortality. Population interventions, including health education, are required to reduce sodium intake in this population. The quantitative and qualitative data provided in this study could be used to develop and implement strategies for salt intake reduction in Saudi Arabia.

Chapter Five

Body Composition Assessments from Surveys in Saudi Arabia: reliability, body size distributions and age

5.1 Introduction

National Health Surveys are conducted to estimate current and future disease burdens and costs in order to plan health care programmes. To do this, health surveys must be representative of the entire population, and must specifically include those at greatest health risk. The inclusion of appropriate anthropometric measurements to assess body composition in an epidemiological study is crucial (Gibson 2005), as long as these measurements are conducted by trained investigators with standardised techniques (WHO 2000; WHO 2008).

Obesity is usually described using the body mass index (BMI), with a BMI of 30 kg/m^2 or more defined as obese, and overweight defined as a BMI between 25 and 29.9 kg/m^2 (WHO 2014). However, BMI does not discriminate between body fat and muscle mass, which have opposite effects on health (Prentice and Jebb 2001; Vlassopoulos, Combet et al. 2013). Even though BMI has been used widely in research and clinical practice, WC is a marginally better indicator of total body fat compared to BMI (Lean, Han et al. 1996) and the chronic health risks are predicted better by WC than by BMI (Pouliot, Despres et al. 1994; Lean, Han et al. 1995). Although not recommended for individual assessment. BMI had a weak performance in predicting chronic health risks (T2DM and hypertension) among 197,681 Saudi adults in the east province of Saudi Arabia (Almajwal, Al-Baghli et al. 2009). This study reported that despite a significant increase in odds ratio of hypertension and diabetes from BMI values as low as 21-23, this did not improve the diagnostic performance of BMI measurements. Furthermore, this study highlights that the optimal BMI cut-offs using the receiver operating characteristic (ROC) curve analysis (BMI=30.50-31.50 kg/m^2 in women and BMI=28.50 - 29.50 kg/m^2 in men) had both low sensitivity and low specificity, with an unacceptably high level of type I and II errors (>80).

While NCDs are prevalent in SA, relatively few large scale studies have been performed there covering the reliability of body composition measures. Pooling primary data presents great advantages in nutritional epidemiology and can address the limitations faced in individual studies (Willett 2013). Therefore, it was aimed to integrate data obtained from different surveys in SA. The purpose of this chapter is to build a comprehensive picture of body composition (adiposity and muscle mass) in SA.

Therefore, the study presented in this chapter aims to meet five main objectives. Therefore, the questions to be raised are the following:

RQ1: Are body composition measures influenced by age?

RQ2: Does the body mass index agree with waist circumference for predicting adiposity?

RQ3: Does skeletal mass index represent the muscle mass status in the body?

5.2 Methodology and materials

5.2.2 Surveys and populations

This study is a secondary analysis of integrated data from the Saudi National Surveys (Saudi Health Information Survey (SHIS) and Saudi National Health Survey (SNHS)), the Riyadh Region Surveys (two), and the Riyadh Validation Survey (RVS). Both Saudi National Health Surveys sample the population using a multistage stratified cluster random sampling of private households with a national sampling frame maintained and updated by the SA Census Bureau, to provide nationally representative data on health-related variables (WHO-STEPwise 2005; Memish, El Bcheraoui et al. 2014). Both Riyadh region surveys are the capital-wide Biomarker Screening in Riyadh region (BSR), a collaborative effort between the Biomarkers Research Program (BRP) of King Saud University (KSU) and the Ministry of Health in Riyadh, Kingdom of Saudi Arabia (RIYADH Cohort) (Al-Daghri, Al-Attas et al. 2011). Subjects were recruited randomly from their homes using the cluster sampling strategy and their information was taken from the existing database of more than 17,000 subjects in Riyadh region (Al-Daghri, Al-Attas et al. 2011). The RVS sampled the population at large retail centres in areas of contrasting socio-economic status in Riyadh city during October and November 2013 (Alkhalaf, Edwards et al. 2015). This analysis included males and females aged 18 years and over. Both SHIS and SNHS included a younger age group 15-17 years old. However, this age group was excluded from the analysis.

Pregnant women and expatriates (through National ID) were also not included in this analysis. Although a reference for anthropometric measurements for the Arab population could not be identified, biologically implausible values for height and weight were excluded **1)** by trimming values below the 0.5 and above the 99.5 sex-specific percentiles using a 99% Winsorisation technique (Hastings Jr, Mosteller et al. 1947; Berentzen,

Jakobsen et al. 2011); **2)** and using reference levels of simple anthropometric measures as recommended by Das et al. and Tuan et al. (Das, Kinsinger et al. 2005; Tuan, Adair et al. 2008). Almost 6.5% (n = 1552) of the adults examined in these five surveys from 2004 to 2014 had a body-size measurement that was flagged as being biologically implausible on the basis of the values below the 0.5 and above the 99.5 sex-specific percentiles for each anthropometric measurement. Participants with missing socio-demographic values of (e.g., age or gender) were also excluded from this analysis (n=1337, 5.1%). The exclusion criteria were selected to reduce the impact of outliers on the associations. All the studies obtained written informed consent from the participants and were approved by the local Institutional Review Boards (IRB). Subjects of all surveys were interviewed by a trained interviewer to collect information on socio-demographic factors, dietary habits, lifestyle (smoking, physical activity), and health conditions.

5.2.3 Data collection

5.2.3.1 Anthropometric measures and body composition estimations

Height, weight, waist and hip circumferences (WC, HC) were measured by trained professionals, as detailed in the protocols of all regional and national surveys included (WHO-STEPwise 2005; Al-Daghri, Al-Attas et al. 2011; Memish, El Bcheraoui et al. 2014; Alkhalaf, Edwards et al. 2015). All anthropometric measurements followed specified protocols using calibrated scales and non-stretchable plastic tapes. Height measurements were recorded to the nearest 0.01 meter and carried out in the standing position, without shoes or head-covers, with the head in the Frankfort Plane position. Weight was measured with electronic scales with indoor clothing on without shoes, to the nearest 0.1 kg. WC and HC were measured using non-stretchable plastic tapes to the nearest 0.1 centimetre (cm). WC was measured in cm midway between the lower costal margin and iliac crest after an expiratory phase whilst HC was measured in cm at the greater trochanters. BMI was calculated as weight in kilograms divided by the square of height in meters (WHO 2014). From 23,968 participants in the five Saudi Surveys considered, 93% had data available for BMI, 88% for WC, and 52% for HC.

5.2.3.2 Anthropometric measures classifications

Standard BMI and WC cut-off values were used to calculate the prevalence of overweight and obesity in our sample (Lean, Han et al. 1995; WHO 2014). Based on the World Health Organization (WHO) recommended definitions for epidemiology, non-

obese (normal BMI) was defined as a BMI of 18.5-24.9 kg/m^2, overweight was defined as a BMI of 25-29.9 kg/m^2, and obese as a BMI of ≥30 kg/m^2 (WHO 2000; WHO 2014). Obesity was also defined according to gender-specific risk categories of waist circumference (WC) (Normal WC: WC<80 cm and WC<94 cm for female and male, respectively; Risk1: WC 80-88 cm, 94-102 cm for female and male, respectively; Risk 2: WC >88 cm, >102 cm for female and male, respectively) (Table 5.2-1) (Lean, Han et al. 1995; WHO 2008).

To assess the agreement and misclassification of overweight and obesity using BMI and WC measurements, BMI in combination with WC measurements were used to classify participants as [High-Risk Adiposity by BMI and WC], [High-Risk Adiposity by BMI only], and [High Risk Adiposity by WC only] based on the action levels first published by Lean et al (Lean, Han et al. 1995) and adopted internationally to diagnose metabolic syndrome. We also assessed the agreement and misclassification between BMI, WC, WHR and WHtR using a cross-tabulation technique. The adiposity high risk of waist to hip (WHR) was defined as a WHR≥0.85 for women and ≥0.90 for men (WHO 2008). The adiposity high risk of waist to height (WHtR) was defined as WHtR≥0.5 (Ashwell 2011; Ashwell and Gibson 2014) (**Table** 5.2-1).

Table 5.2-1: Body composition classifications

Category	Women	Men
BMI		
Non-obese (kg/m^2)	18.5-24.9	18.5-24.9
Overweight (kg/m^2)	25-29.9	25-29.9
Obese (kg/m^2)	≥30	≥30
WC		
Normal WC (cm)	<80	<94
Risk I WC (cm)	80-88	94-102
Risk II WC (cm)	>88	>102
WHR		
High risk WHR	≥0.85	≥0.90
WHtR		
High risk WHtR	≥0.5	≥0.5

BMI: body mass index; WC: waist circumference; WHR: Waist to hip ratio; WHtR: waist to height ratio.

5.2.3.3 Body composition estimations

Body composition variables, including Total Adipose Tissue Fat Mass (TATFM), skeletal muscle mass (SM) and total body fat percent (%BF), were estimated using simple anthropometric and demographic measures.

-Total Adipose Tissue Mass (TATM)

Firstly, we assessed the Total Adipose Tissue Mass (TATM) using Al-Gindan et al., 2015 equations (E1, E2). Then, the TATM outputs were multiplied by 0.8, assuming the proportion by weight of the lipid fraction in adipose tissue to be 80% (Snyder WS CM 1975; Sohlstrom, Wahlund et al. 1993; Wang, Zhu et al. 2003).

$$(\mathrm{E1})(\mathrm{male}) = -12.8 + 0.198\ \mathrm{Body\ Weight\ (kg)} + 0.478\ \mathrm{Waist\ (cm)} - 0.147\ \mathrm{Height\ (cm)}$$

$$(\mathrm{E2})(\mathrm{female}) = 24.5 + 0.789\ \mathrm{Body\ Weight\ (kg)} + 0.0786\ \mathrm{Age\ (y)} - 0.342\ \mathrm{Height\ (cm)}$$

-Body Fat Percent (%BF):

The total Body Fat Percent (%BF) was estimated using Lean et al., 1996 equations (E3, E4) using simple anthropometric and demographic measures (Lean, Han et al. 1996). These regression equations were calculated from body density measured by underwater weighing in 63 men and 84 women.

$$(\mathrm{E3})(\mathrm{male}) = (0.567\ \mathrm{waist}) + (0.101\ \mathrm{age}) - 31.8$$

$$(\mathrm{E4})(\mathrm{female}) = (0.439\ \mathrm{waist}) + (0.221\ \mathrm{age}) - 9.4$$

In 1991, Deurenberg et al. (Deurenberg, Weststrate et al. 1991) developed an prediction equation using simple anthropometric variables (age, BMI and sex) using densitometry measurements to estimate total body fat percentage this equation has high correlations with UWW-measured total body fat (R2=0.79, SEE= 41% BF%). Therefore, %BF of subjects in this study was estimated also using equation (E5) of Deurenberg et al. (1991) using simple anthropometric and demographic measures (Deurenberg, Weststrate et al. 1991).

$$(\mathrm{E5}) = (1.2\ \mathrm{BMI}) + (0.23\ \mathrm{Age}) - (10.8\ \mathrm{Sex}) - 5.4$$

-Skeletal Muscle Mass (SMM)

The skeletal muscle mass (SMM) of the study subjects was estimated using the Al-Gindan equations (E5, E6) (Al-Gindan, Hankey et al. 2014). The Lee equation (E7) was

used to estimate the SMM of the study population (Lee, Wang et al. 2000). Then, the muscle mass (kg) output was divided by height (m) squared to generate Skeletal Muscle Mass Index (SMI) (muscle mass (kg)/height (m^2)) (Baumgartner, Koehler et al. 1998). The SMI outputs (kg/m^2) were compared with the SM cut-offs (kg/m^2) to assess whether subjects would be categorised as having "low muscle mass" according to Chien et al. (Chien, Huang et al. 2008). However, SMI is highly correlated with BMI and may identify thinner people as having sarcopenia (Kim, Park et al. 2014). Thus, SMI may have limited power to identify low muscle mass in obese people and weight-adjusted SMM was used to solve this limitation (Kim, Park et al. 2011). Muscle mass (kg) to fat mass (kg) ratio (SMM/BF) is associated with WC, blood pressure, glucose, lipid profiles and brachial-ankle pulse wave velocity (baPWV) and the muscle mass/fat mass ratio is considered to be a new index of sarcopenic obesity (Kim, Park et al. 2011). Assuming percentage of skeletal muscle mass to body weight (%SMM) is potentially a good method to predict the metabolic risks in Saudi adults. %SMM can be calculated in this study for each subject by dividing the SMM (kg) by body weight (kg) and multiplying the output by 100, as described by Janssen et al. (Janssen, Heymsfield et al. 2002) and Kim et al. (Kim, Yang et al. 2009).

$$(\mathbf{E5})\text{SMM (male)} = 39.5 + 0.665\ \text{Body Weight (kg)} - 0.185\ \text{Waist (cm)} - 0.418\ \text{Hip (cm)} - 0.08\ \text{Age (y)}$$

$$(\mathbf{E6})\text{SMM (female)} = 2.89 + 0.255\ \text{Body Weight (kg)} - 0.175\ \text{Hip (cm)} - 0.038\ \text{Age (y)} + 0.118\ \text{Height (cm)}$$

$$(\mathbf{E7})\ \text{SMM (Kg)} = 0.244 * \text{body weight (kg)} + 7.80 * \text{height (m)} - 0.098 * \text{age (y)} + 6.6 * \text{sex} + \text{race} - 3.3$$

(Sex = 0 for female and 1 for male, race = -1.2 for Asian, 1.4 for African American, and 0 for white and Hispanic).

5.2.3.4 Statistical analysis

Data from the five surveys were combined into a single database. The body composition between males and females are different, and affected by increasing age (Marriott and Grumstrup-Scott 1992; Miller, MacDougall et al. 1993; Janssen, Heymsfield et al. 2000; Heymsfield 2005; Kirchengast 2010; Forbes 2011). Therefore, analyses were conducted

separately for men and women. Incomplete anthropometric data was considered as missing and coded as 999 in the SPSS program during the analysis.

Subjects were grouped into eight 10-year age bands, identified by the middle year from 25 (that is, ages 18–27) to 95 (ages 88–97) years. There were insufficient subjects older than 97 years to warrant being included in the age-bands analysis. The participants' age was cross-classified into tertiles to evaluate the relationship between body composition and age. A One-Way ANOVA test was used to determine differences between body composition variables and the tertiles of age. Spearman's correlations and regression analyses were performed to determine the relationship between body composition and age within each gender. Statistical significance was set at $p<0.05$.

5.3 Results

5.3.1 Survey Characteristics

The characteristics of the five surveys (2004–2014) under consideration are summarised in **Table** 5.3-1. A multistage stratified cluster random sampling technique was used in both SHIS and SNHS. However, a post-stratification was applied in SHIS to account for non-response and to reflect the general SA population. This standard methodology for creating sampling weights in SHIS was similar to that used in the National Health and Nutrition Examination Survey (NHANES) and the Behavioral Risk Factor Surveillance System (BRFSS) in the United States of America (USA) (CDC 2016; CDC 2016). Furthermore, a random cluster sampling technique was used in BSR1 and BSR2. A convenience sampling technique was used in RVS. As it did not consider older age groups (women > 60 years, men >65 years) both male and female participants of the RVS are younger than subjects from other surveys. Based on published reports of BSR1 and BSR2, children were included in studies, resulting in an age range of 7 to 80 years. However, the available data from these studies concerning subjects aged 18 years and over show that the BSR2 subjects (median 48 years (IQR 38-55 years) for women; median 51 years, (IQR 39-61 years) for men) are older than subjects from other surveys for both women and men. There are differences in height, weight, BMI, WC, and HC between respondents from each survey due to the differences in sampling techniques in each survey. There is high completion rate of anthropometric measurements. However, SHIS did not collect HC measurements from all subjects (Table 5.3-1). Study sample derivation process is shown in Figure 5.3-1.

Table 5.3-1: Comparison of five health surveys in Saudi Arabia in 10 years period (2004-2014).

Cross-sectional Surveys	*Area of Recruitment*	*Year*	*Sampling technique*	*Response Rate* [©] *(n(%))*	*Data received (n)*	*Women n n(%)*	*Men (n(%)*	*Age range (years)*	*Age Median(IQR)* [*]	*Weight (n(%))* [$]	*Height (n(%))* [$]	*BMI (n(%))* [$]	*WC (n(%))* [$]	*HC (n(%))* [$]
RVS	Riyadh city (City Survey)	October-November 2013	Convenience	601/768 (78.3)[a]	601	336 (56)	265 (44)	19-60	29 (24-38)	601 (100)	600 (100)	600 (100)	598 (99.5)	597 (99.3)
BSR1	Riyadh region (Regional Survey)	2008-2009	Random cluster	9164/17000 (ND)	5,331[€]	2836 (53)	2495 (47)	7-80[£]	42 (27-55)	4931 (92)	4897 (91)	4645 (87)	4795 (90)	4795 (90)
BSR2	Riyadh region (Regional Survey)	2013-2014	Random cluster	4413/16000 (ND)	4,270[€]	2881 (67)	1389 (33)	7-80[£]	49 (38-57)	3981 (90)	3926 (89)	3924 (89)	3198 (73)	3198 (73)
NHS	All Saudi Arabia (National Survey)	2004-2005	random multistage stratified cluster	4883/5000 (97.7)[b]	4,883	2298 (51)	2180 (49)	15-64[£]	37 (27-47)	4320 (89)	4325 (89)	4312 (88)	4157 (85)	4154 (85)
SHIS	All Saudi Arabia (National Survey)	April-June 2013	random multistage stratified cluster	10,735/12000 (89.5)[b]	10,735	5167 (52)	4842 (48)	≥15[£]	37 (28-49)	9688 (90)	9892 (91)	9638 (89)	9506 (88)	-

[©] The number of people who entered the study divided by the number of people who were initially approached (women and men)
[$] Sample collection number.
[£] The age in the original survey.
[*] The age based on received data.
[€] This is the received number from BSR after excluding the subjects who aged less than 18 years old.
[a] Completion rate
[b] Response rate.
BMI: body mass index; IQR: interquartile range; ND: Not Known; WC: waist circumference; HC: hip circumference; WHR: Waist to hip ratio; WHtR: waist to height ratio; CI: confidence interval; SE: standard error.

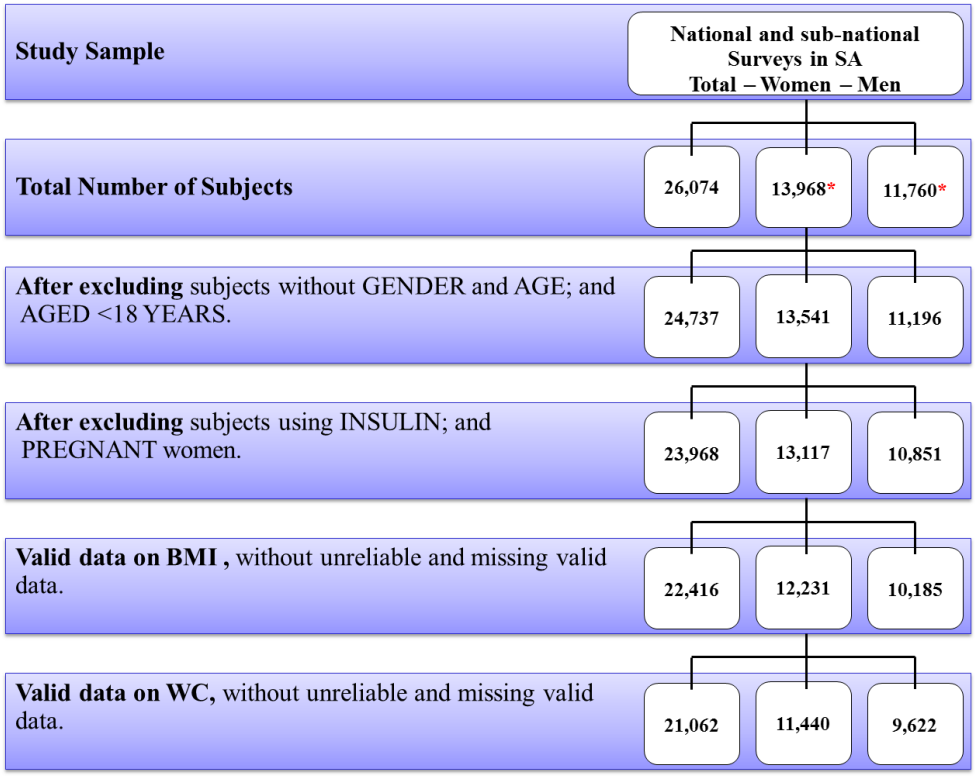


Figure 5.3-1: Study sample derivation.
** Number of subjects without gender is unknown (gender not collected or reported).*

5.3.2 Subject characteristics (pooled data)

5.3.2.1 Simple anthropometric measures

On average, Saudi men were one year older ($p<0.0001$), weighed 7 kg more ($p<0.0001$), were 12 cm taller ($p<0.0001$), have a WC 8 cm greater ($p<0.0001$) and a WHR 0.19 points higher ($p<0.0001$) than Saudi women. However, Saudi women had a significantly greater BMI (by 2 points) ($p<0.0001$) and HC (by 8 cm) ($p<0.0001$) than men (Table 5.3-2).

5.3.2.2 Estimated skeletal muscle mass (SMM)

Saudi men had a SMM 5 kg greater ($p<0.0001$), a %SMM percentage 3% higher and a SMI 0.5 kg/m^2 higher ($p<0.0001$) compared with Saudi women using the Al-Gindan equation. Also, Saudi men had a SMM 9 kg greater ($p<0.0001$), a %SMM percentage 9% higher and a SMI 2 kg/m^2 higher ($p<0.0001$) compared with Saudi women using the Lee equation with White and Hispanic racial group. Using the Lee equation with Asians

racial group, Saudi men had a SMM 9 kg greater (p<0.0001), a %SMM percentage 9% higher and a SMI 2 kg/m^2 higher (p<0.0001) compared with Saudi women.

5.3.2.3 Estimated body fat (BF) and adipose tissue mass (ATM)

In contrast, Saudi women had a %BF 11% higher (*p*<0.0001) compared with Saudi men using Lean *et al.* equation. Also, Saudi women had a %BF 12% higher (*p*<0.0001) compared with Saudi men using the equation of Deurenberg *et al.*. Furthermore, Saudi women had a TATM 7 kg higher (*p*<0.0001) and TATM percentage 12% compared with Saudi men using the equation of Al-Gindan *et al.*. Saudi women also had a TATFM 5 kg higher (*p*<0.0001) and TATFM percentage 9% higher compared with Saudi men using the equation of Al-Gindan *et al.*.

Table 5.3-2: Measured and estimated body composition characteristics.

Body Composition	Women (n=13,117)		Men (n=10,851)	
	N	Median (IQR)	N	Median (IQR)
Age (year)	13117	39 (28-50)	10851	40 (29-54)
Weight (kg)	12467	71 (60-82)	10348	78 (67-88)
Height (cm)	12539	156 (152-160)	10397	168 (164-173)
BMI (kg/m^2)	12231	29 (25-34)	10185	27 (24-31)
Waist circumference (cm)	11440	89 (78-100)	9622	97 (86-107)
Hip circumference (cm)	7096	107 (98-116)	5484	99 (89-108)
Waist to Hip Ratio (WHR)	7080	0.84 (0.77-0.90)	5472	1.03 (0.92-1.09)
Waist to Height Ratio (WHtR)	11320	0.57 (0.50-0.64)	9534	0.58 (0.51-0.64)
SMM (kg)	6985	19 (17-21)	5366	24 (21-26)
%SMM (%)	6973	27 (24-30)	5247	30 (28-34)
SMI (kg/m^2)	6973	7.9 (7.3-8.6)	5247	8.4 (7.8-9.1)
SMM (kg) (Ethnic A)	12231	22 (20-25)	10185	31 (29-34)
%SMM (%) (Ethnic A)	12231	31 (29-34)	10185	40 (38-43)
SMI (kg/m^2) (Ethnic A)	12231	9 (8-10)	10185	11 (10-12)
SMM (kg) (Ethnic B)	12231	21 (19-24)	10185	30 (27-33)
%SMM (%) (Ethnic B)	12231	30 (28-32)	10185	39 (36-41)
SMI (kg/m^2) (Ethnic B)	12231	9 (8-10)	10185	11 (10-12)
%BF (%)	11440	39 (32-45)	9622	28 (21-34)
%BF (%)	12231	39 (32-46)	10185	27 (21-32)
TATM (kg)	12387	31 (22-39)	9448	24 (17-31)
%TATM (%)	12273	43 (36-48)	9448	31 (25-36)
TATFM (kg)	12273	24 (18-31)	9448	19 (14-25)
%TATFM (%)	12273	34 (29-39)	9448	25 (20-29)

[a] Value was significantly different between males and females (P <0.002) based on Mann-Whitney test.
[$] P-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests)).
IQR: Interquartile Range; CI: confidence interval; SE: standard error; BMI: body mass index; WHR: Waist to hip ratio; WHtR: waist to height ratio; SMM: estimated muscle mass; %SMM: estimated skeletal muscle mass percentage per body weight; SMI: estimated skeletal muscle mass index; BF: estimated total body fat percentage; TATM: estimated total adipose tissue mass; %TATM: estimated total adipose tissue mass percentage; TATFM: estimated total adipose tissue fat mass; %TATFM: estimated total adipose tissue fat mass percentage; Ethnic A: White and Hispanic ethnic groups; Ethnic B: Asian ethnic group.

5.3.3 Impact of ageing on body composition

5.3.3.1 Simple anthropometric measures

All body composition measurements amongst women and men were affected by age (Table 5.3-3). In both men and women, subjects in the lowest tertile of age had a lower weight, BMI, WC, HC, WHR and WHtR than the subjects in highest tertile ($P<0.002$, One-Way ANOVA with Tukey's test). However, subjects in the lowest tertile of age were marginally taller than the subjects in highest tertile ($P<0.002$, One-Way ANOVA with Tukey's test).

Spearman's Correlation analysis shows a positive relationship between age and BMI amongst both female and male subjects ($R_S=0.373$; $R_S=0.209$, respectively). The relationship between age and WC was greater amongst women and men ($R_S=0.44$ $R_S=0.30$, respectively). The relationship between age and WHR was moderate amongst women but lower amongst men ($R_S=0.421$; $R_S=0.104$, respectively). Although a moderate relationship existed between age and WHtR in women, this was low amongst men ($R_S=0.47$; $R_S=0.344$, respectively). Age and HC had a weak relationship for both women and men ($R_S=0.319$; $R_S=0.200$, respectively) and similarly, the relationship between age and weight was low amongst women and male subjects ($R_S=0.30$; $R_S=0.12$, respectively). The results also show a negative and low relationship between age and height amongst women and men ($R_S=-0.16$; $R_S=-0.19$, respectively) (more details of correlations between continuous data are in the Appendix).

Linear regression analysis indicates a significant increase in body weight (1.0 kg), WC (1.7 cm) and BMI (3.24 kg/m^2) for every 5 years increase in age amongst Saudi women. A significant increase in body weight (0.26 kg), WC (1.1 cm) and BMI (2.0 (kg/m^2) for every 5 years increase in age amongst Saudi men can also be inferred. The linear regression analysis additionally highlights a decrease in body height with age amongst both women (0.34 cm) and men (0.43 cm). In both females and males, the measurement most affected by age was WHtR (17% and 8%, respectively) (more details in the Appendix). Although these changes may appear small, over time they contribute to substantial total fat gain.

5.3.3.2 Estimated skeletal muscle mass (SMM)

The comparison of study subjects' estimated skeletal muscle mass (SMM) characteristics by gender and age tertiles are summarised in Table 5.3-3. In both men and women, subjects in the lowest tertile of age had a higher SMM (kg), %SMM and SMI (kg/m^2) comparing with the subjects in highest tertile, except SMI (kg/m^2) among women (Table 5.3-3) (P<0.002, One-Way ANOVA with Tukey's test). Both SMM equations (Al-Gindan et al 2014 and Lee et al 2000) are similar.

Spearman's Correlation analysis using the equation of Al-Gindan et al. (2014) shows a negative relationship between age and SMM (kg) amongst females (R_S=-0.056, p<0.0001); and negative relationship between age and SMI (kg) amongst males R_S=-0.222, p<0.0001). Moreover, the relationship between age and %SMM was negative amongst both female and male subjects (R_S=0.532; R_S=0.418, respectively). Also, the relationship between age and SMI (kg/m^2) was negative among males but, surprisingly, it was positive among female subjects (R_S=-0.119; R_S=0.039, respectively) (more details of correlations between continuous data are in the Appendix. The two ethnic equations using the equation of Lee et al. 2000 give almost identical results. Correlation coefficient shows a negative relationship between age and SMM (kg) amongst females and males. Moreover, the relationship between age and %SMM was negative amongst females and males. However, the results also show no relationship between age and SMI (kg/m^2) amongst females but a negative relationship between them amongst males.

Linear regression analysis using the equation of Al-Gindan et al. (2014) indicates a significant decrease in SMM (1.8 kg) and %SMM (7.8 %), respectively) for every 5 years increase in age amongst Saudi women. However, no relationship was found between SMI and age among Saudi women (p=0.396). A decrease in SMM (4.5 kg), %SMM (7.0 %) and SMI (7.8 kg/m^2) for every 5 years increase in age amongst Saudi men can also be inferred.

The results using the equation of Lee et al. (2000) in White and Hispanic ethnic groups show also, a significant decrease in SMM (2.1 kg), %SMM (18.4 %) and SMI (2.5 kg/m^2), respectively) for every 5 years increase in age amongst Saudi women. A significant decrease in SMM (5.2 kg), %SMM (11.1 %) and SMI (12.2 kg/m^2), respectively) for every 5 years increase in age amongst Saudi men can also be inferred.

5.3.3.3 Estimated body fat percentage (BF) and total adipose tissue mass (TATM)

The comparison of study subjects' estimated body fat percentage (%BF) and adipose tissue mass (TATM) characteristics by gender and age groups are summarised in

Table 5.3-4. In both men and women, median values across age tertiles revealed that subjects in the lowest tertile of age had a lower %BF, TATM (kg), %TATM (%), TATFM (kg) and TATFM (%) than the subjects in highest tertile ($P<0.002$, One-Way ANOVA with Tukey's test). Both %BF equations (Lean et al. 1995 and Deurenberg et al. 1991) provide almost identical results. The linear regression analysis additionally highlights a significant increase in TATM and %TATM with age amongst both women (1.89 kg; and 3.65%) and men (1.7 kg; and 2.6%). The linear regression analysis additionally highlights a significant increase in TATFM and %TATFM with age amongst both women (2.4 kg; and 4.6%) and men (2.1 kg; and 3.2%). In females, the measurement most affected by age was %BF using the equation of Lean et al. (1995) (44%) whereas %BF using the equation of Deurenberg et al. (1991) was most affected by age (32%) among male subjects (

Table 5.3-4).

Spearman's Correlation analysis shows that %BF using the equations of Lean et al. and Deurenberg et al. has very positive relationships. Also, it shows that TATM and its indices using Lean et al equation have positive relationships (more details of correlations between continuous data are in the Appendix). The linear regression analysis indicates a significant increase in %BF using the equations of Lean et al. (1995) and Deurenberg et al. (1991) (5.4 (%); and 4.4 (%), respectively) for every 5 years increase in age amongst Saudi women. A significant increase in %BF using the equations of Lean et al. (1995) and Deurenberg et al. (1991) (2.9 (%); and 5.4 (%), respectively) for every 5 years increase in age amongst Saudi men can also be inferred.

Table 5.3-3: Association between tertiles of age and measured and estimated body composition among Saudi adults (n=23,968).

Body Composition	Tertile 1 (n=8,273)				Tertile 2 (n=7,883)				Tertile 3 (n=7,793)				Women	Men
	Women (n=4,697)		Men (n=3,576)		Women (n=4,460)		Men (n=3,423)		Women (n=3,947)		Men (n=3,846)			
	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	N	Median (IQR)	*p*-value (one-way ANOVA	*p*-value (one-way ANOVA
Age (year)	4697	25 (21-29)	3576	25 (21-29)	4460	40 (36-43)	3423	40 (36-43)	3947	55 (50-61)	3846	58 (53-65)	<0.0001 [a b c]	<0.0001 [a b c]
Weight (kg)	4522	64 (54-75)	3449	72.8 (62-85.9)	4265	75 (65-85)	3268	80.5 (71-91)	3675	75 (66-85)	3629	78 (69-87.7)	<0.0001 [a b]	<0.0001 [a b c]
Height (cm)	4566	157 (153-161)	3467	170 (165-174)	4293	156 (152-160)	3290	169 (165-174)	3675	155 (150-159)	3638	166 (162-171)	<0.0001 [a b c]	<0.0001 [b c]
BMI (kg/m^2)	4429	25.8 (22.1-30)	3388	25.4 (22-29.4)	4199	30.4 (26.6-34.6)	3232	28.1 (25.2-31.6)	3598	31.5 (27.6-35.5)	3563	28 (25.1-31.2)	<0.0001 [a b c]	<0.0001 [a b]
WC (cm)	4201	80 (70-90)	3250	90 (78-100)	3894	90 (81-100)	3027	98 (89-109)	3342	97 (88.9-105)	3345	102 (92-110)	<0.0001 [a b c]	<0.0001 [a b c]
HC (cm)	2409	100 (92-110)	1717	93 (82-104.2)	2355	109 (101-118)	1542	101 (92-110)	2329	110 (103-119)	2225	101 (93-109)	<0.0001 [a b c]	<0.0001 [a b]
WHR	2403	0.78 (0.73-0.85)	1710	1.01 (0.87-1.13)	2348	0.83 (0.77-0.89)	1537	1.02 (0.91-1.1)	2326	0.89 (0.83-119)	2225	1.04 (1.0-1.1)	<0.0001 [a b c]	<0.0001 [b c]
WHtR	4162	0.5 (0.4-0.6)	3221	0.5 (0.5-0.6)	3858	0.6 (0.5-0.6)	3003	0.6 (0.5-0.6)	3297	0.6 (0.6-0.7)	3310	0.6 (0.6-0.7)	<0.0001 [a b c]	<0.0001 [a b c]
SMM (kg) (Al-Gindan et al 2014)	2379	19 (17.2-20.9)	1695	30.2 (25.8-34.7)	2321	19.6 (17.7-21.8)	1520	28.9 (24.6-33.9)	2289	18.7 (16.8-20.7)	2196	25.1 (21.1-30.2)	<0.0001 [a b c]	<0.0001 [b c]
SMM (kg) (Lee et al 2000) (Ethnic A)	4429	22.1 (19.7-24.9)	3388	31.8 (29.1-35.1)	4199	23.2 (20.7-25.8)	3232	32.3 (29.9-35)	3594	21.6 (19-24.2)	3562	29.5 (26.9-32.1)	<0.0001 [a b c]	<0.0001 [b c]
SMM (kg) (Lee et al 2000) (Ethnic B)	4429	20.9 (18.5-23.7)	3388	30.6 (27.9-33.9)	4198	22 (19.5-24.6)	3232	31.1 (28.7-33.9)	3586	20.4 (17.8-23)	3560	28.3 (25.7-30.9)	<0.0001 [a b c]	<0.0001 [b c]
%SMM (%) (Al-Gindan et al 2014)	2379	30.1 (27.1-33.5)	1695	41.3 (36.6-47.3)	2321	26.4 (24.4-28.7)	1520	35.8 (32.5-39.9)	2289	24.9 (23.1-27)	2196	32.2 (28.4-36.1)	<0.0001 [a b c]	<0.0001 [a b c]
%SMM (%) (Lee et al 2000) (Ethnic A)	4429	34.5 (32.9-36.6)	3388	43.6 (40.9-47.1)	4199	31.1 (30.1-32.3)	3232	40 (38.2-41.9)	3594	28.7 (27.7-29.5)	3562	37.8 (36.2-39.4)	<0.0001 [a b c]	<0.0001 [a b c]
%SMM (%) (Lee et al 2000) (Ethnic B)	4429	32.6 (31.3-34.3)	3388	42 (39.5-45.1)	4198	29.5 (28.7-30.5)	3232	38.5 (36.9-40.3)	3586	27.1 (26.2-27.9)	3560	36.2 (34.8-37.7)	<0.0001 [a b c]	<0.0001 [a b c]
SMI (kg/m^2) (Al-Gindan et al 2014)	2379	7.7 (7.2-8.5)	1687	10.5 (9.2-11.9)	2321	8.1 (7.5-8.8)	1517	10.2 (8.9-11.7)	2289	7.9 (7.3-8.6)	2187	9.1 (7.8-10.7)	<0.0001 [a c]	<0.0001 [b c]
SMI (kg/m^2) (Lee et al 2000) (Ethnic A)	4429	8.9 (8.1-9.9)	3388	11.1 (10.3-12.1)	4199	9.4 (8.5-10.5)	3232	11.3 (10.5-12.2)	3594	9 (8.0-10.0)	3562	10.6 (9.8-11.4)	<0.0001 [a c]	<0.0001 [a b c]
SMI (kg/m^2) (Lee et al 2000) (Ethnic B)	4429	8.4 (7.6-9.4)	3388	10.7 (9.8-11.6)	4198	8.9 (8.1-10)	3232	10.8 (10.1-11.7)	3586	8.5 (7.5-9.5)	3560	10.2 (9.4-11)	<0.0001 [a c]	<0.0001 [a b c]
%BF (Lean et al 1995) (%)	4201	31.2 (26.8-35.9)	3214	21.7 (15.4-27.7)	3894	39.2 (35-43.6)	3004	28.1 (22.6-34)	3342	45.8 (41.9-49.7)	3339	32 (26.5-37)	<0.0001 [a b c]	<0.0001 [a b c]
%BF (Deurenberg et al1991) (%)	4429	31.4 (26.65-36.7)	3388	20.2 (15.6-24.9)	4199	40.1 (35.5-45.4)	3232	26.8 (23-31.2)	3598	45.5 (41-50.4)	3563	31.2 (27.6-35.3)	<0.0001 [a b c]	<0.0001 [a b c]
TATM (kg) (Al-Gindan et al 2015)	4497	23.2 (15.7-31.5)	3161	19.5 (12.6-26.5)	4237	32.9 (25.4-40.7)	2963	25.4 (19.4-31.8)	3642	35.3 (28.3-42.9)	3266	26.6 (21-32.3)	<0.0001 [a b c]	<0.0001 [a b]
%TATM (%)(Al-Gindan et al 2015)	4459	36.2 (28.9-42.3)	3161	27 (19.8-32.6)	4189	44.2 (39.1-48.5)	2963	31.5 (26.4-36.1)	3614	47.3 (42.8-50.8)	3266	34.7 (29.4-38.5)	<0.0001 [a b c]	<0.0001 [a b c]
TATFM (kg) (Al-Gindan et al 2015)	4459	18.5 (12.6-25.2)	3161	15.6 (10.1-21.2)	4189	26.3 (20.3-32.6)	2963	20.3 (15.5-25.4)	3614	28.2 (22.7-34.3)	3266	21.3 (16.8-25.9)	<0.0001 [a b c]	<0.0001 [a b]
%TATFM (%)(Al-Gindan et al 2015)	4459	29 (23.1-33.9)	3161	21.6 (15.9-26.1)	4189	35.3 (31.3-38.8)	2963	25.2 (21.1-28.9)	3614	37.8 (34.3-40.6)	3266	27.7 (23.5-30.8)	<0.0001 [a b c]	<0.0001 [a b c]

[*] Value was significantly different between males and females (*P* <0.002) bases on one-way ANOVA test; [$] *P*-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests)).

[a] Value was significantly different between Tertile 1 and Tertile 2 of age (*p* <0.002) bases on One-Way ANOVA test; [b] Value was significantly different between Tertile 1 and Tertile 3 of age (*p*<0.002) bases on One-Way ANOVA test; [c] Value was significantly different between Tertile 2 and Tertile 3 of age (*p*<0.002) bases on One-Way ANOVA test; IQR: Interquartile Range; CI: confidence interval; SE: standard error; BMI: body mass index; WHR: Waist to hip ratio; WHtR: waist to height ratio.SMM: estimated muscle mass; %SMM: estimated skeletal muscle mass percentage per body weight; SMI: estimated skeletal muscle mass index; BF: estimated total body fat percentage; TATM: estimated total adipose tissue mass; %TATM: estimated total adipose tissue mass percentage; TATFM: estimated total adipose tissue fat mass; %TATFM: estimated total adipose tissue fat mass percentage; ; Ethnic A: White and Hispanic ethnic groups; Ethnic B: Asian ethnic group.

Table 5.3-4: Anthropometric and body composition factors associated with age (years) increase among Saudi adults using linear regression analysis.

Body Composition	Women				Men			
	Estimate	SE	R Square	95% CI	Estimate	SE	R Square	95% CI
Weight (kg)	0.272	0.010	0.054[$]	0.252-0.292	0.062	0.011	0.003[$]	0.041-0.083
Height (cm)	-0.084	0.004	0.029[$]	(-0.092)-(-0.075)	-0.095	0.005	0.041[$]	(-0.103)-(-0.086)
BMI (kg/m^2)	0.146	0.004	0.095[$]	0.138-0.154	0.053	0.004	0.021[$]	0.046-0.060
WC (cm)	0.429	0.010	0.144[$]	0.410-0.448	0.266	0.011	0.057[$]	0.245-0.288
HC (cm)	0.284	0.012	0.077[$]	0.261-0.307	0.166	0.013	0.030[$]	0.141-0.191
WHR	0.003	0.000	0.134[$]	0.002-0.003	0.001	0.000	0.014[$]	0.001-0.001
WHtR	0.003	0.000	0.160[$]	0.003-0.003	0.002	0.000	0.077[$]	0.002-0.002
SMM (kg) (Al-Gindan et al 2014)	-0.020	0.003	0.007[$]	(-0.026)-(-0.015)	-0.051	0.003	0.047[$]	(-0.058)-(-0.045)
SMM (kg) (Lee et al 2000) (Ethnic A)	-0.036	0.003	0.015[$]	(-0.041)-(-0.031)	-0.091	0.003	0.094[$]	(-0.096)-(-0.085)
SMM (kg) (Lee et al 2000) (Ethnic B)	-0.035	0.003	0.014[$]	(-0.040)-(-0.030)	-0.090	0.003	0.093[$]	(-0.096)-(-0.085)
%SMM (%) (Al-Gindan et al 2014)	-0.163	0.003	0.256[$]	(-0.170)-(-0.157)	-0.127	0.004	0.179[$]	(-0.135)-(-0.120)
%SMM (%) (Lee et al 2000) (Ethnic A)	-0.192	0.001	0.702[$]	(-0.194)-(-0.189)	-0.169	0.002	0.375[$]	(-0.174)-(-0.165)
%SMM (%) (Lee et al 2000) (Ethnic B)	-0.183	0.001	0.765[$]	(-0.185)-(-0.182)	-0.167	0.002	0.417[$]	(-0.171)-(-0.164)
SMI (kg/m^2) (Al-Gindan et al 2014)	-0.001	0.001	0.0001	(-0.003)-(0.001)	-0.007	0.001	0.011[$]	(-0.009)-(-0.005)
SMI (kg/m^2) (Lee et al 2000) (Ethnic A)	-0.006	0.001	0.003[$]	(-0.008)-(-0.004)	-0.020	0.001	0.049[$]	(-0.022)-(-0.018)
SMI (kg/m^2) (Lee et al 2000) (Ethnic B)	-0.006	0.001	0.003[$]	(-0.008)-(-0.004)	-0.020	0.001	0.051[$]	(-0.022)-(-0.019)
%BF (Lean et al 1995) (%)	0.409	0.004	0.443[$]	0.401-0.418	0.247	0.006	0.146[$]	0.235-0.259
%BF (Deurenberg et al1991) (%)	0.405	0.005	0.358[$]	0.396-0.415	0.293	0.004	0.317[$]	0.285-0.302
TATM (kg) (Al-Gindan et al 2015)	0.323	0.008	0.122[$]	0.308-0.338	0.153	0.007	0.053[$]	0.140-0.166
%TATM (%)(Al-Gindan et al 2015)	0.328	0.005	0.241[$]	0.317-0.338	0.194	0.006	0.105[$]	0.183-0.206
TATFM (kg) (Al-Gindan et al 2015)	0.259	0.006	0.123[$]	0.247-0.271	0.122	0.005	0.053[$]	0.112-0.133
%TATFM (%)(Al-Gindan et al 2015)	0.262	0.004	0.241[$]	0.254-0.270	0.155	0.005	0.105[$]	0.146-0.164

[$] Value was significantly different between males and females (P <0.002) bases on one-way ANOVA test (p-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests))).

BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: Waist to hip ratio; WHtR: waist to height ratio; CI: confidence interval; SE: standard error.

SMM: estimated muscle mass; %SMM: estimated skeletal muscle mass percentage per body weight; SMI: estimated skeletal muscle mass index; BF: estimated total body fat percentage; TATM: estimated total adipose tissue mass; %TATM: estimated total adipose tissue mass percentage; TATFM: estimated total adipose tissue fat mass; %TATFM: estimated total adipose tissue fat mass percentage; ; Ethnic A: White and Hispanic ethnic groups; Ethnic B: Asian ethnic group.

5.3.4 Adiposity prevalence

The prevalence of obesity based on (BMI≥30 kg/m^2) was higher in women (45%) compared to men (30%). The prevalence of overweight (BMI 25-29.9 kg/m^2) was lower in women (30%) compared to men (38%) (Figure 5.3-2-A). The prevalence of "Risk 2 WC" (Substantially Increased WC: >88 cm for women, >102 cm for men) was 52% for women and 36% for men. The prevalence of "Risk 1 WC" (Increased WC: 80-88 cm for women, 94-102cm for men) was 18% for women and 21% for men ($p<0.0001$) (Figure 5.3-2-B). The prevalence of High-Risk WHR (WHR≥0.85 for women and ≥0.90 for men) was 45% for women and 80% for men (Figure 5.3-2-C). The prevalence of High-Risk WHtR (WHtR≥0.5) was 73% for women and 77% for men (Figure 5.3-2-D). All previous prevalences were statistically significant between men and women ($p<0.0001$).

Figure 5.3-3 shows the age pattern of overweight and obesity by BMI and adiposity risks by WC. An increasing trend of obesity (BMI≥30 kg/m^2) was seen across different age groups of the Saudi population ($p <0.001$) (Figure 5.3-3 (A-B)). An increasing trend of high-risk WC (Risk2) can also be seen across age groups of the Saudi population ($p<0.001$) (Figure 5.3-3 (C-D)).

The highest level of adiposity was seen at about age 53 years for women with a rate of 63% and 76% (using BMI and WC, respectively), and about 63 years for men with a rate of 35% and 53% (using BMI and WC, respectively) (Figure 5.3-3).

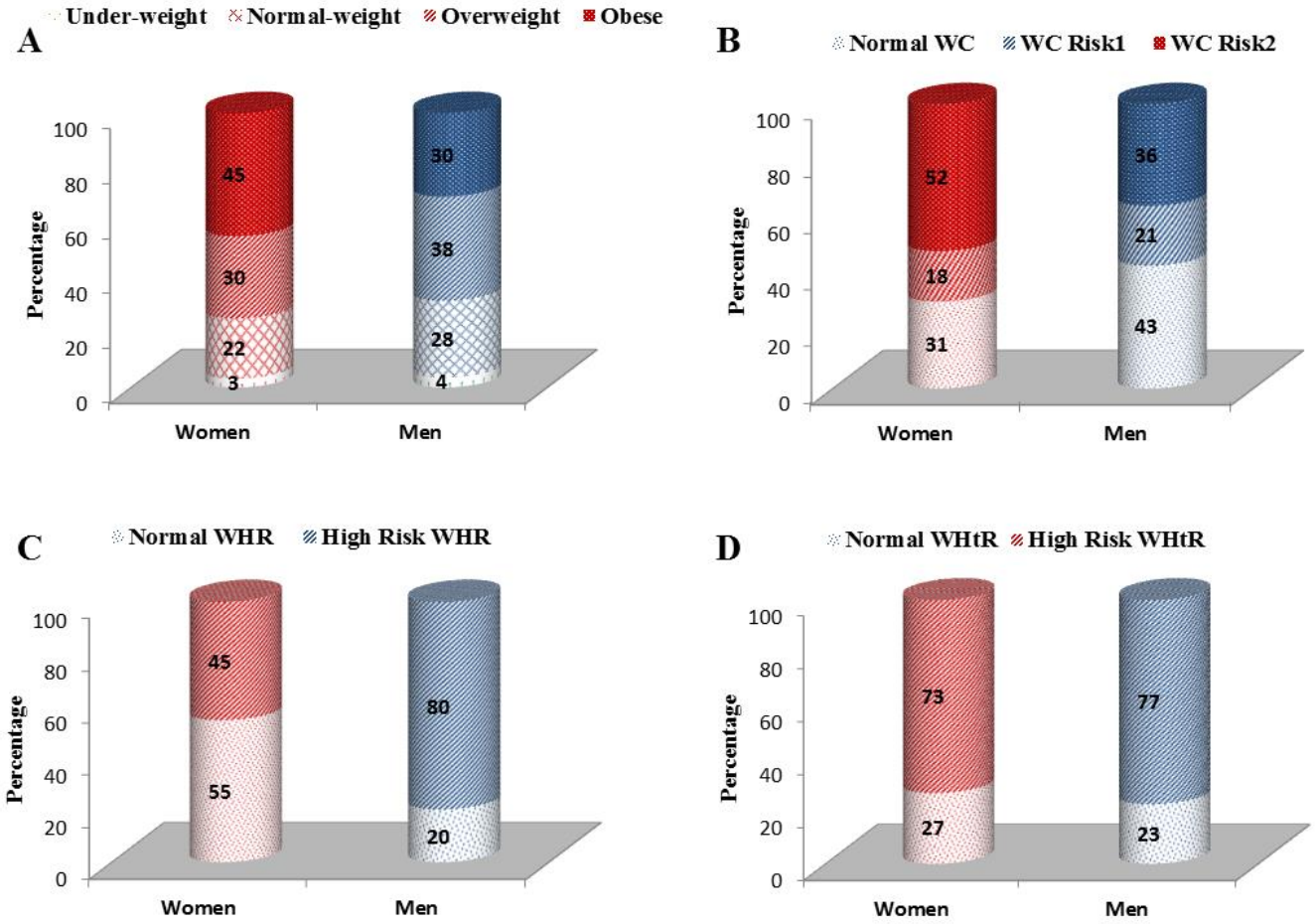


Figure 5.3-2: Characteristics of body mass index (BMI) (A) (n=22,416), waist circumference (WC) (B) (n=21,062), waist to hip Ratio (WHR) (C) (n=12,552), and waist to height Ratio (WHtR) (D) (n=20,854) among Saudi Arabian adults by gender.

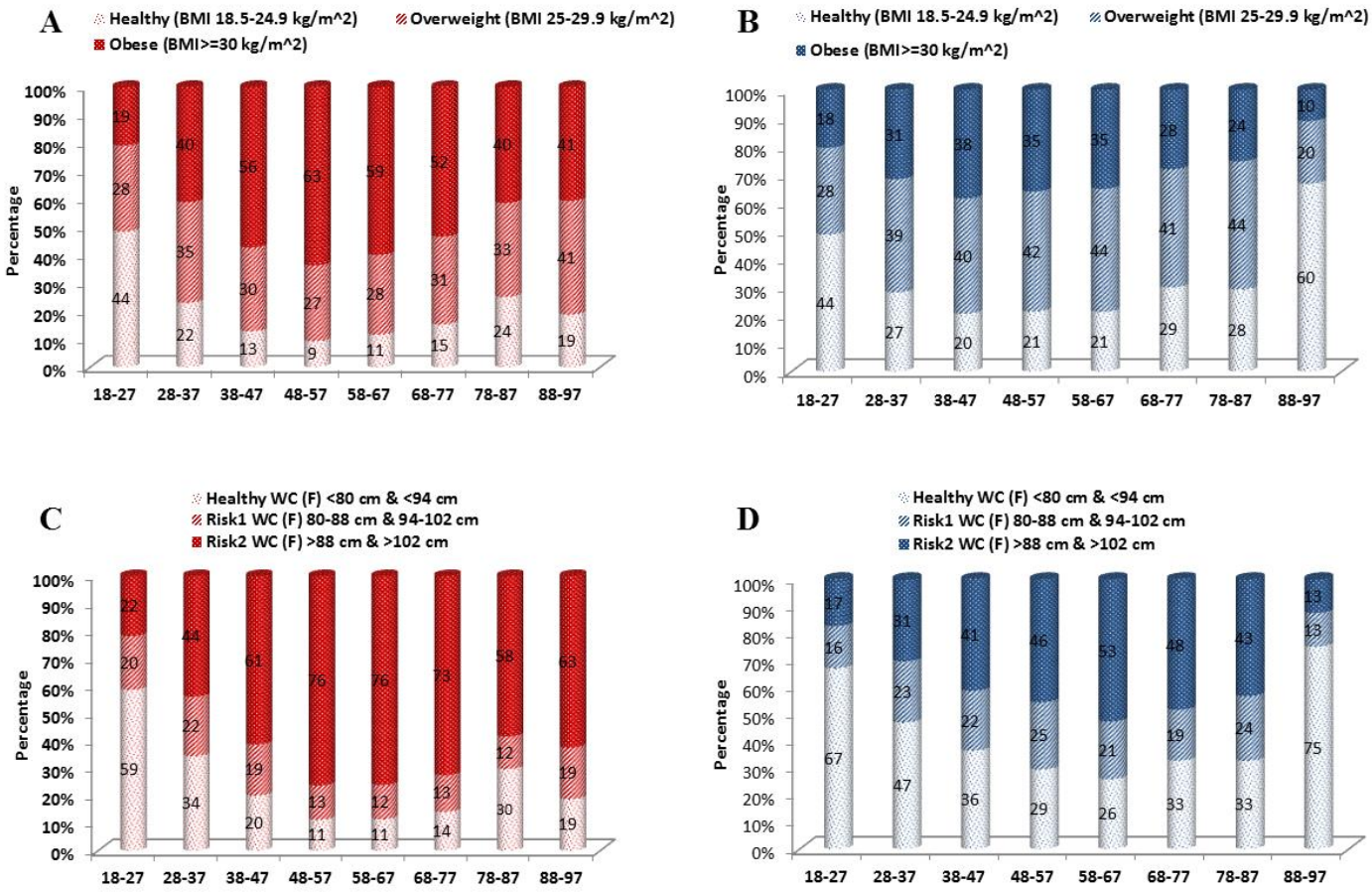


Figure 5.3-3: Prevalence by age of BMI 18.5–24.9, BMI 25-29.9 and BMI ≥30 among women (A) and men (B) (n=12,231 ♀ and n=10,185 ♂) and of WC<80 cm, WC 80-88 cm and WC>88 among women (C) (n=11,440), and WC WC<94 cm, WC 94-102 cm and WC>102 among men (D) (n=9,622).

5.3.4.1 Misclassification and agreement between different body composition measurements

5.3.4.1.1 Elevated-Risk body composition

Only 63% of women and 50% of men with elevated WC (>80 cm in women and >94 cm in men) would be identified as having elevated BMI (BMI≥25 kg/m^2). Nearly, 29% of women and 22% of men with an elevated WC would not have been identified as having risk because they had a non-elevated BMI (BMI <25 kg/m^2).

5.3.4.1.2 High-Risk body composition

Only 61% of women and 51% of men with Risk 2 WC (>88cm for women and >102cm for men) would be identified as obese based on BMI (BMI≥30 kg/m^2) with difference between women and men (chi-square=518.9, p<0.0001). Nearly, 25% of women and 30% of men with a Risk 2 WC would not have been identified as high-risk because they had a non-obese BMI (BMI <30 kg/m^2). Figure 5.3-4 (A-B) (gray shade) displays the general characteristics of agreement and misclassification of the Saudi population by gender.

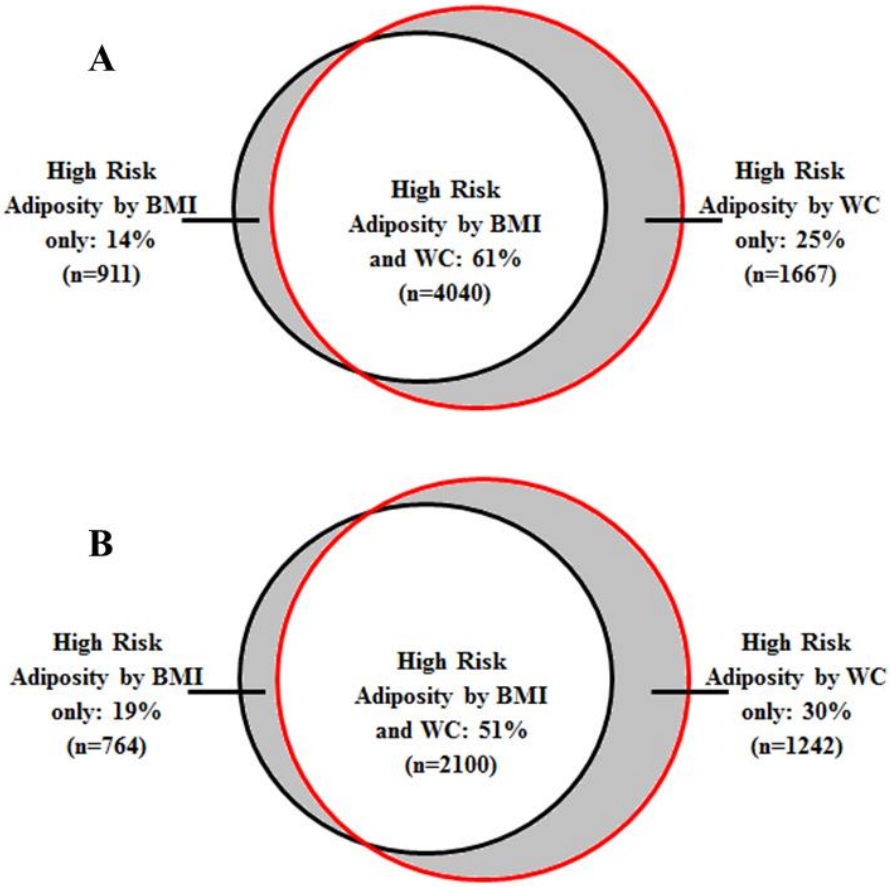


Figure 5.3-4: Adiposity misclassification among Saudi adult: (A) women (n=6,618) and (B) men (n=4,106).

Unlike the measurements made in younger individuals (Tertile1), the majority of body composition measurements were misclassified in older individuals (Tertile3) (Table 5.3-5). Regarding older individuals (Tertile3) with a BMI between 18.5–25, 62% of women and 36% of men had an unhealthily elevated WC whereas only 19% of women and 14% of men in Tertile 1 of age had an elevated WC (>80 cm in women and >94 cm in men) ($p<0.0001$) (Table 5.3-5). However, for those with a BMI<30, 29% of young women (Tertile1) had a High-Risk WC (>88cm), whilst this figure was lowered slightly to 26% in older women (Tertile 3) ($p <0.0001$). In males with BMI < 30, 24% of young men (Tertile 1) had a High-Risk WC (>102cm), whilst this figure was raised to 39% in older men (Tertile 3) ($p <0.0001$) (more details in the Appendix).

Amongst older individuals (tertile1) with normal WHR (WHR<0.85 in women and WHR<0.90 in men), 78% of women and 39% of men had elevated WC (>80 cm and >94 cm in women and men respectively) whilst only 35% of young females and 17% of young

males (Tertile1) had elevated WC using the same cut-offs. The magnitude of the difference in prevalence of unhealthily elevated WC categories amongst those with normal WHR in women and men was statistically significant (chi-square=368.5, p<0.0001; chi-square=56.1, p<0.0001, respectively).

Whilst 5% of older women (Tertile 3) with normal WHtR (WHtR<0.5) had elevated WC (>80 cm in women), 0.2% of men in this category had an elevated WC (>94 cm in men). Similarly, 5% of young women and none of young men (Tertile 1) with a normal WHtR had an elevated WC. The magnitude of the difference in prevalence of elevated WC categories amongst those with normal WHtR in women was statistically significant but not for men (chi-square=83.4, p<0.0001; chi-square=1.3, p=0.519, respectively). For both sexes, the prevalence of elevated WC significantly increased with age in individuals with a normal BMI (BMI 18.5–24.9 kg/m^2) (p<0.001) (Figure 5.3-5).

Table 5.3-5: Proportion of adult Saudi women and men with unhealthily elevated WC categories among those with normal-BMI (BMI 18.5–25 kg/m^2) (n=5,410).

	Elevated WC with normal BMI			**Risk1 WC with normal BMI**			**Risk2 WC with normal BMI**		
Gender	**Tertile1**	**Tertile2**	**Tertile 3**	**Tertile1**	**Tertile 2**	**Tertile 3**	**Tertile 1**	**Tertile2**	**Tertile 3**
Women (n/nn(%))	293/1516 (19)[a]	190/564 (34)[b]	213/346 (62)[b]	203/1516 (13)[a]	117/564 (21)[b]	110/346 (32)[b]	90/1516 (6)[a]	73/564 (13)[b]	103/346 (30)[b]
Men (n/nn(%))	169/1229 (14)[a]	141/635 (22)[b]	267/739 (36)[b]	128/1229 (10)[a]	97/635 (15)[b]	186/739 (25)[b]	41/1229 (3)[a]	44/635 (7)[b]	81/739 (11)[b]

[a, b]: Significant difference between age groups expressed with different letters (among the same gender).Those not sharing the same subscript within a column are significantly different at p-value<0.002 (Chi square test).

[$] *P*-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests)).

Elevated WC: WC (♀)>80cm and WC (♂)>94 cm; Risk1 WC: WC (♀) 80-88 cm and WC (♂) 94-102; and Risk2 WC: WC (♀)>88 cm and WC (♂)>102 cm.

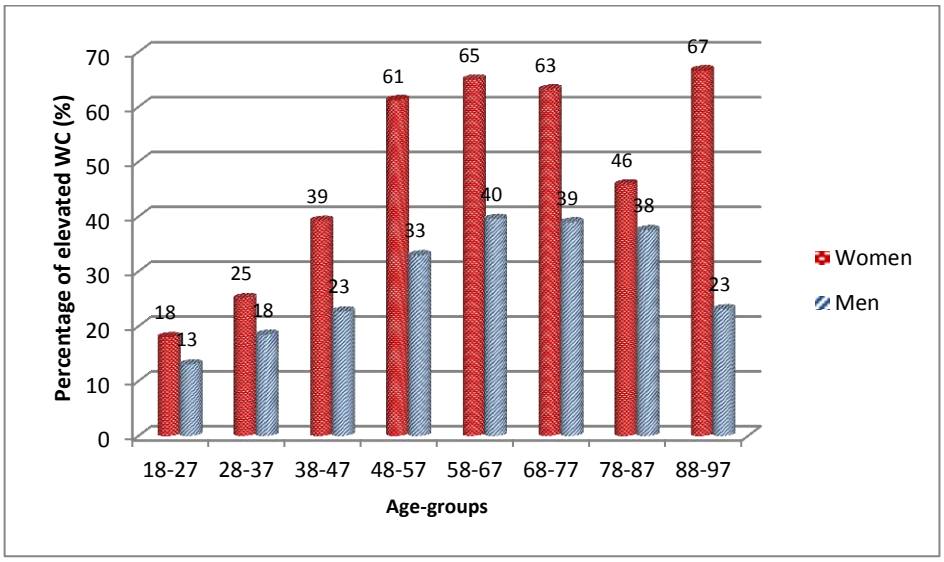


Figure 5.3-5: Prevalence by age of elevated WC (>80 cm for women, >94 cm for men) among individuals with "normal BMI" (18.5–24.9 kg/m^2)(n=5,029).

5.3.5 Muscle mass indices (SMM) and obesity related indices

This study showed positive relationships between the absolute total amount of SMM (kg), and body weight, height, body fat percentage (%BF), total adipose tissue mass (TATM) and total adipose tissue fat mass (TATFM) among both women and men Also, it showed positive relationships between the skeletal muscle mass index (SMI (kg/m^2)), and body weight, height, %BF, TATM and TATFM among both women and men. However, when expressed as a percentage of total body weight, there is a negative relationship between %SMM and body weight, height, %BF, TATM and TATFM in both sexes (Table 5.3-6).

In addition, this study showed that increased %SMM (as indicative of relative muscle mass) reduced the risk of being obese using conventional cut-off point of obesity related measures (BMI and WC) among both sexes ($p<0.0001$). However, SMM (kg) and SMI (kg/m^2) increased the risk of being obese using conventional cut-off point of obesity related measures (BMI and WC) in both sexes ($p<0.0001$). Table 5.3-7 shows the odds ratios and 95% confidence intervals for obesity incidence using BMI and WC conventional cut-off points according to increasing deciles of each SMM parameter.

Obesity prevalence based on BMI and WC increased proportionately with both SMM (kg) and SMI (kg/m^2) increase. However, obesity prevalence based on BMI and WC decreased proportionately with %SMM increase. Also, medians of BMI (kg/m^2) and WC (cm)

increased proportionately with both SMM (kg) and SMI (kg/m^2) increase. However, these medians decreased proportionately with %SMM increase (Figure 5.3-6 & Figure 5.3-7).

Table 5.3-6: Partial correlation coefficients, controlled for age, between skeletal muscle mass indices and body composition.

SMM indices*	*Women*			*Men*		
	SMM (n=6823)	SMI (n=6823)	%SMM (n=6823)	SMM (n=5248)	SMI (n=5248)	%SMM (n=5248)
%BF (Lean et al)	0.295[£]	0.291[£]	-0.676[£]	0.089[£]	0.052[£]	-0.575[£]
%BF (Deurenberg et al)	0.628[£]	0.785[£]	-0.724[£]	0.57[£]	0.62[£]	-0.243[£]
TATM (kg)	0.744[£]	0.791[£]	-0.69[£]	0.26[£]	0.238[£]	-0.512[£]
TATFM (kg)	0.744[£]	0.791[£]	-0.69[£]	0.26[£]	0.238[£]	-0.512[£]
Body weight (kg)	0.808[£]	0.767[£]	-0.641[£]	0.679[£]	0.596[£]	-0.195[£]
Body height (cm)	0.537[£]	0.05[£]	0.113[£]	0.363[£]	0.052[£]	0.072[£]

[$] p<0.002, age-adjusted odds ratios are presented (p-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests))).
N: participants' number; R: Correlation coefficient.
SMM: estimated muscle mass; %SMM: estimated skeletal muscle mass percentage per body weight; SMI: estimated skeletal muscle mass index.
* SMM indices are based on Al-Gindan et al. equation.
[£] Indicate significant correlations at <0.0001.

Table 5.3-7: Odds ratios and 95% confidence intervals for obesity prevalence using BMI and WC conventional cut-off points according to increasing deciles of each SMM parameter.

SMM Deciles*	Obesity					WC Risk 2				
	B	SE	OR	CI	p-value	B	SE	OR	CI	p-value
Women										
SMM	0.43	0.01	1.53	1.50-1.57	<0.0001	0.26	0.01	1.29	1.27-1.32	<0.0001
%SMM	-0.81	0.02	0.44	0.43-0.46	<0.0001	-0.63	0.02	0.53	0.51-0.55	<0.0001
SMI	0.71	0.02	2.03	1.97-2.10	<0.0001	0.29	0.01	1.33	1.30-1.36	<0.0001
Men										
SMM	0.4	0.01	1.5	1.46-1.54	<0.0001	0.31	0.01	1.37	1.34-1.40	<0.0001
%SMM	-0.77	0.02	0.46	0.45-0.48	<0.0001	-0.57	0.02	0.56	0.55-0.58	<0.0001
SMI	0.66	0.02	1.93	1.86-2.00	<0.0001	0.3	0.01	1.35	1.32-1.38	<0.0001

[$] p<0.002, age-adjusted odds ratios are presented (p-Value threshold was calculated using Bonferroni correction test (0.05(p-value)/20(n.of tests))).
WC Risk 2: WC (♀)>88 cm and WC (♂)>102 cm; Obesity: BMI≥30 kg/m^2
BMI: body mass index; WC: waist circumference; CI: confidence interval; OR: odds ratio; SE: standard error.
SMM: estimated muscle mass; %SMM: estimated skeletal muscle mass percentage per body weight; SMI: estimated skeletal muscle mass index.
* SMM indices are based on Al-Gindan et al. equation.

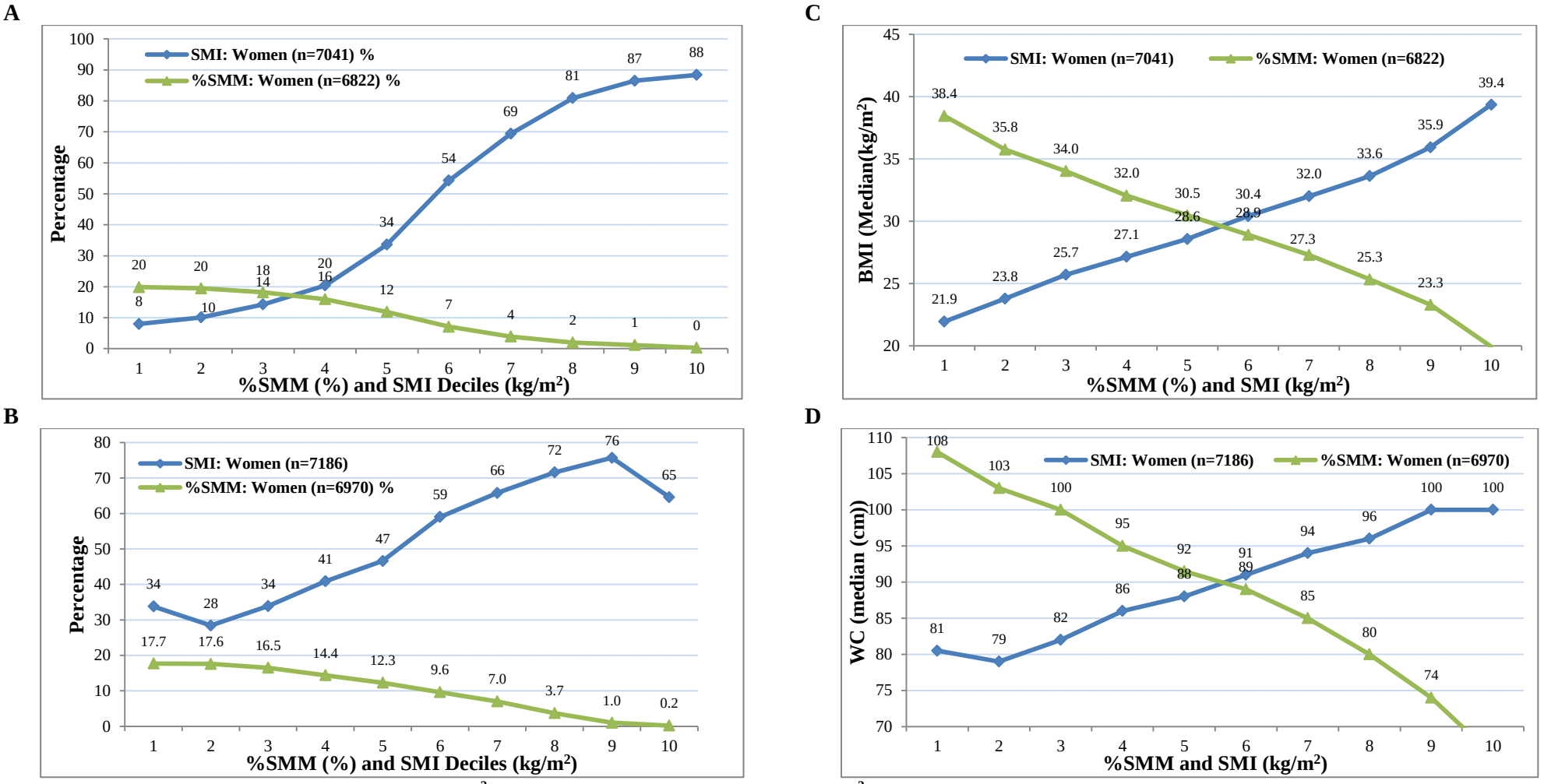


Figure 5.3-6: (A) Prevalence of obesity (BMI>30 kg/m^2) in each decile of %SMM and SMI (kg/m^2); (B) prevalence of high-risk WC (Risk2, >88cm for women and >102cm for men) in each decile of %SMM and SMI (kg/m^2); (C) median of BMI (kg/m^2) in each decile of %SMM and (D) median of WC (cm) in each decile of SMI (kg/m^2) in women.

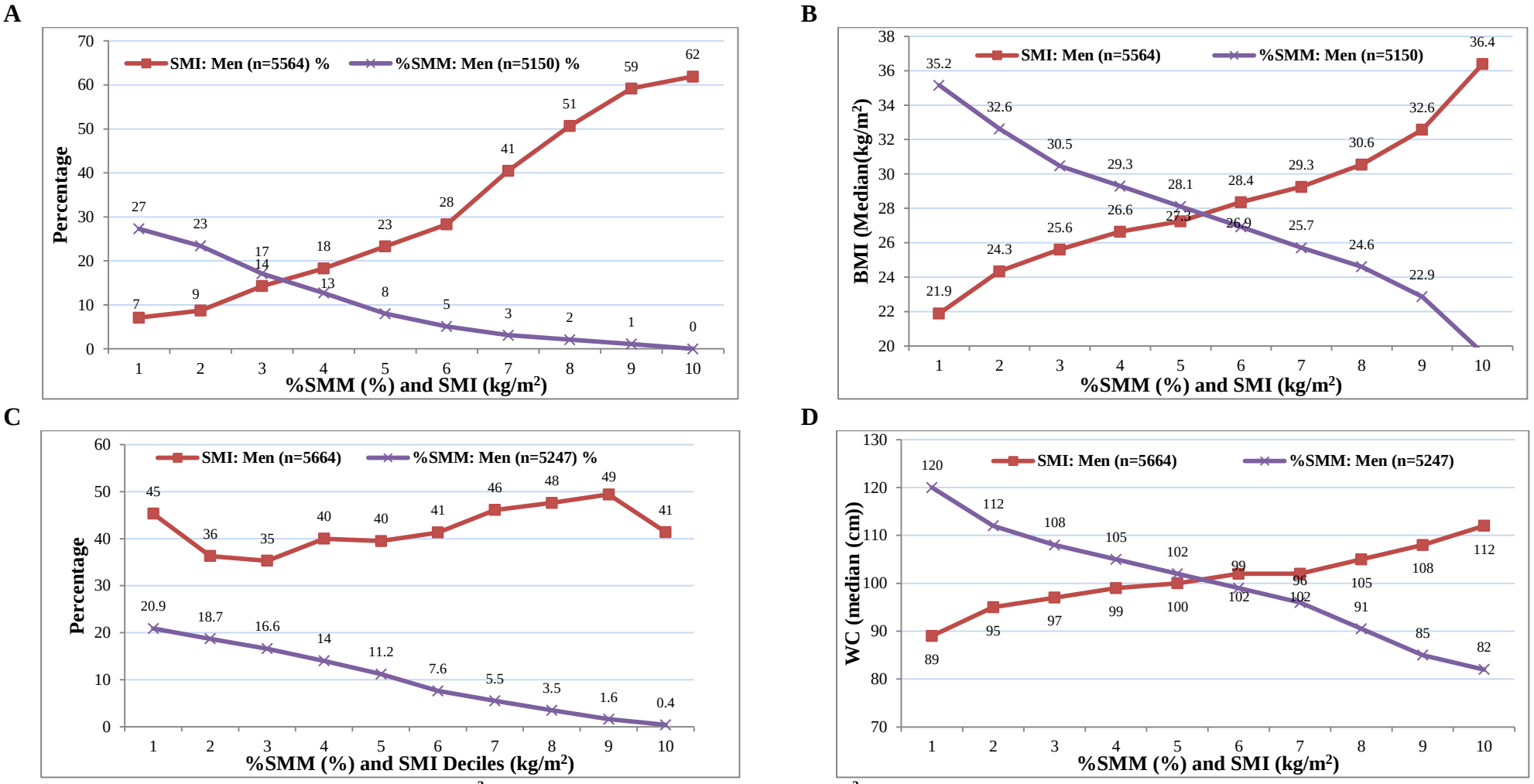


Figure 5.3-7: (A) Prevalence of obesity (BMI>30 kg/m^2) in each decile of %SMM and SMI (kg/m^2); (B) prevalence of high-risk WC (Risk2, >88cm for women and >102cm for men) in each decile of %SMM and SMI (kg/m^2); (C) median of BMI (kg/m^2) in each decile of %SMM; and (D) median of WC (cm) in each decile of SMI (kg/m^2) in men.

5.4 Discussion

This study demonstrates a high prevalence of overweight and obesity in the Saudi population between 2004 and 2014, consistent with data from other Arabian and Gulf countries (Musaiger and Al-Mannai 2001; Al Rashdan and Al Nesef 2010; Ng, Zaghloul et al. 2011), Kuwait and Bahrain (Musaiger and Al-Mannai 2001). The results show that women and men in SA have a higher prevalence of obesity than women and men in Mexico, which has the second highest prevalence of obesity in the world after the United States of America (USA) (OECD 2014). The prevalence of obesity in Mexico is 37.5% amongst women and 26.8% amongst men, whilst in SA 45% of females and 30% of males are obese. This study also revealed Saudi women also have a higher prevalence of obesity than women in the USA (36.6%) (OECD 2014). In 1996, Al-Nuaim et al. found that the prevalence of obesity (BMI $\geq$30 kg/m^2) in SA was 24 and 16% for women and men, respectively (al-Nuaim, al-Rubeaan et al. 1996). However, in 2005 the Saudi National Health Survey (SNHS) (WHO-STEPwise 2005) reported that the prevalence of obesity in SA was 44 and 28% for women and men respectively, indicating a significant rise in the obesity levels in SA within 20 years. These studies support the results of this paper, strengthening the evidence of the rise in obesity levels over time. The application of the post-stratification technique in SHIS 2013 to account for non-response and to reflect the general SA population prevent the comparison between the SHIS and the previous surveys.

Results in this study show an increasing trend of obesity and high-risk WC (Risk 2) across age groups of the Saudi population (Figure 5.3-3 (A-D). However, the prevalence of adiposity using both BMI and WC peaked in women at about 58-67 years of age and 58-67 years in men, then the prevalence start to decrease. These finding are consistent with the Global Burden of Disease Study in 2013 (Ng, Fleming et al. 2014) and this reduction could be happened due to reaching the life expectancy at birth year 74.5 years (76.0 years for women and 73.2 years for men) (WHO 2016).

The population of SA has increased around 75% since 2004, with 60% of the current population aged less than 30 years (MOEP 2015). The life expectancy at birth has increased from 53.9 years in 1970 to 74.5 years in 2015, with a 2.9% growth rate (MOH 2013; WHO 2016). There is concern that this steep rise in the youthful population will escalate the burden of NCDs in the forthcoming decades alongside the increase of

adiposity (WC, BMI, %BF and TATM) and decrease of muscle mass (SMM) with age as shown in the regression analysis of this study. Evidently, this will cause a financial burden on health care expenses in SA.

In addition, our results extend the notion that BMI is an inadequate measure for predicting health risks (Tanamas, Lean et al. 2015; Peeters, Tanamas et al. 2016). Since BMI is the most common method used for obesity assessment by the majority of dietitians in SA (87%) (Almajwal, Williams et al. 2009), overlooking these findings and continuing to use BMI as a sole indicator of health risks would mean that 14% of the whole SA population, and ~43% of the SA population who are judged to be normal weight using BMI, are misclassified and might not be alerted to the need to take care or action. BMI does not discriminate between body fat and muscle mass, which have contradictory health effects on human health (Prentice and Jebb 2001; Vlassopoulos, Combet et al. 2013). Body fat can be significantly underestimated, particularly in non-European groups including Chinese and South Asians, when BMI is employed (Lear, Humphries et al. 2007). Asians also have higher morbidity than Caucasians at lower cut-off points for BMI (WHO 2000; Snehalatha, Viswanathan et al. 2003; Vikram, Pandey et al. 2003; Razak, Anand et al. 2007). WC is a marginally better indicator of total body fat than BMI (Lean, Han et al. 1996) and the chronic health risks are better predicted by WC than by BMI (Pouliot, Despres et al. 1994; Lean, Han et al. 1995). Asian people have more body fat at the same conventional BMI categories (BMI≥25 kg/m^2 and BMI≥30 kg/m^2) than do Caucasians (Wang, Thornton et al. 1994; Deurenberg, Yap et al. 1998). Recent studies in Australia and the UK have similar findings to this study. A study in Scotland and England found that approximately 41% of older adults with normal BMI (65 years and over, BMI=18.5–25 kg/m^2) had elevated WC (WC>94cm for men, WC>80cm for women) (Vlassopoulos, Combet et al. 2013). In the Australian Diabetes, Obesity, and Lifestyle (AusDiab) study, 40% of individuals with BMI<30 kg/m^2 had a high-risk WC (WC >88cm for females and WC >102cm for males) (Tanamas, Shaw et al. 2014). Furthermore, the misclassification with using BMI alone is increased significantly with age as shown in Figure 5.3-5 and supported by (Vlassopoulos, Combet et al. 2013).

BMI also overestimated the adiposity risk compared to WC amongst both young men and women (Tertile 1 of age). This may be due to the fact that BMI does not discriminate between body fat and muscle mass and, as people age, muscle mass noticeably decreases

as body fat increases even without body weight changes (Janssen, Heymsfield et al. 2000; Prentice and Jebb 2001; Hughes, Frontera et al. 2002; Vlassopoulos, Combet et al. 2013).

Interestingly, our result shows that the WHtR was not only the measure which agreed the most with WC but also the measure which caused the least misclassifications, even in the older groups. These results support what has been previously reported by a meta-analysis which stated that WHtR proved to be significantly better than BMI and WC in the prediction of all health outcomes including T2DM, hypertension, and CVD ($P < 0.005$) in both men and women (Ashwell, Gunn et al. 2012). Ashwell and Gibson (2014) proposed a primary screening tool to use WHtR as a health promotion tool, suggesting that WC should be less than half of body height (Ashwell and Gibson 2014).

SA still uses the conventional reference cut-off points for BMI and WC which have been derived from data based on European Caucasian populations (MOH 2014). These cut-off points have been adopted by the International Diabetes Federation (IDF) (Alberti, Zimmet et al. 2007) and the World Health Organization (WHO) (WHO 2008), and IDF recommends that researchers from Eastern Mediterranean and the Middle East (Arab) populations utilise European cut-points for BMI and WC measurements for both genders until more ethnic-specific data is available. However, it is not ideal to extrapolate the data derived from a European Caucasian population to non-Caucasian communities and especially among Arab ethnic group since the data on appropriateness of BMI, WC, WHR, WHtR, SMM, BF and TATM cut-offs in predicting metabolic risks are contradicted. Thus, it is necessary to investigate whether BMI, WC, WHR, WHtR, SMM, BF and TATM is a better predictor of health outcomes (metabolic risks) among Saudi Arabs. Also, for health promotion purposes, it is required to determine optimal cut-points for each of these measures to allow the characterisation of an individual's body fat and muscle mass in relation to their estimated risk.

5.4.1 Muscle mass Indices (SMM) and obesity related indices

This study showed positive relationships between the absolute total amount of SMM (kg) and skeletal muscle mass index (SMI), and body weight, height, %BF, TATM and TATFM in both sexes. However, when muscle mass expressed as a percentage of total body weight (%SMM), found negative relationships between muscle mass and body weight, height, %BF, TATM and TATFM were found in both sexes. The obesity

prevalence based on BMI and WC also increased proportionately with both SMM (kg) and SMI (kg/m^2) increase. However, obesity prevalence based on BMI and WC decreased proportionately with %SMM increase.

These finding agree with several studies (Janssen, Heymsfield et al. 2000; Park and Yoon 2013; Sampaio, Sampaio et al. 2014). Janssen et al (2000) found that body weight was significantly (P<0.001) correlated with SMM in both men (r =0.69) and women (r =0.65); however, when they expressed SMM as a percentage of total body weight, they found a negative relationship between %SMM and body weight (Janssen, Heymsfield et al. 2000). Park and Yoon (2013) also reported that body fat mass (BFM) had a significant positive correlation with SMM (kg) and height (Park and Yoon 2013). Sampaio et al. showed that low SMI subjects had a lower BMI and fat mass index (kg/m^2) than the normal group (Sampaio, Sampaio et al. 2014). These findings raised a concern regarding the suitability of SMI use in predicting low muscle mass and its related diseases.

5.4.2 Strengths and limitations

There are many limitations to analyses of cross-sectional survey data, however this study has many strengths from developed hypotheses. The numbers of subjects in the study were very large and the average response rate of subjects was high (69%). Although due to different sampling techniques, the SNHS, BSR, and RVS did not include data for individuals above 64, 80 and 60 years of age, respectively, the population in this study closely represents (88.2%) the adult population in SA (20-59 years) compared to the adult population Saudi census (91.5%) in 2010 (Ministry of Economy and Planning 2010). However, subjects without a WC measurement (~10% of all population (n=2435)) had slightly higher BMI (p<0.0001) (29.1 v.s 28.1 kg/m^2) (data not shown) which may affect data interpretation. This study, we have excluded nearly 4% (860/21,922) of the total population provided WC. These implausible data may be raised because the investigators were using double-sided plastic tapes (centimetres/ inches). It was decided to not try to convert these data from inches to centimetres which may affect the data and not reflect the real measures of the subjects.

Furthermore, the present findings of SMM, %BF and TATM were estimated using equations contain simple anthropometric measures. However, these equations were derived from Caucasians' data which may or may not be suitable for the Saudi Arabs.

Also, the available cut-off points for %BF were not validated yet and corresponded to BMI categories (overweight (≥25 kg/m^2) and obesity (≥30 kg/m^2)) based on Caucasians' data (Ho-Pham, Campbell et al. 2011). The available cut-off points for SMI were also not validated and based on arbitrary derivation (2 standard deviations below the mean) were not based on health risks alongside the derivation from the Caucasians' data (Cruz-Jentoft, Baeyens et al. 2010). This should reiterate our call to establish such evidence-based cut-off points for BF and SMM for Saudi Arabs population.

5.4.3 Conclusion

Merging these five cross-sectional surveys together provides a powerful and representative dataset for understanding overweight and obesity situation in SA. Almost 38% of all SA adults are now obese, and many older people (~43%) have an elevated WC despite a normal BMI (18.5–25). The Saudi population tends to grow fatter later in life, with WC rising more persistently than BMI. However, these findings are based on cross-sectional study designs which does not allow for comment on the impact of age on body composition variables. Therefore, further prospective studies are required to estimate the impact of aging on body composition. It can be concluded that the use of BMI as a measure for adiposity is misleading, especially in older people and these findings are a useful reminder of the limitations of BMI as a measure of adiposity across populations. Furthermore, the positive association between SMM and SMI measures raised a concern regarding the suitable use of these indices in predicting low muscle mass and its related diseases. Therefore, further research are required to identify if WC and WHtR, or more complex estimates of body fat and skeletal muscle mass, can predict accurately health metabolic risks in SA (better than BMI and SM); and what are appropriate thresholds of these measures. These questions are addressed in **Chapter 6**.

Chapter Six

Muscle mass and non-communicable diseases in Saudi Arabia

6.1 Introduction

As people age, skeletal muscle (SMM) noticeably decreases (Gallagher, Visser et al. 1997; Janssen, Heymsfield et al. 2000) and body fat increases (adiposity) (Hughes, Frontera et al. 2002; Vlassopoulos, Combet et al. 2013) even in absence of body weight changes (Prentice and Jebb 2001; Zamboni, Zoico et al. 2003). As discussed in Chapter 5, the traditional marker to identify low muscle mass is SMI (SMM/height^2) highly associated with BMI and hence poor in predicting low muscle mass in populations with high BMI. Weight adjusted SMM (%SMM) or muscle mass to fat mass ratios have been proposed as alternatives with good performance against WC. Strong associations between poor skeletal muscle mass (low muscle mass and poor strength) and NCDs have been reported previously as muscle is one of the main sites of insulin action, and fat and glucose oxidation (Stump, Henriksen et al. 2006; Han and Lean 2015). Some studies found that SMI contradicted %SMM in predicting metabolic risk factors and diseases. A cross-sectional study among Korean population (n=838) aged 20 to 75 years, found that SMI (kg/m^2) positively predicted high triglyceride (OR, 1.40; 95% CI, 1.08 to 1.82), high BP (1.31; 95% CI, 1.09 to 1.57), metabolic syndrome (OR 2.18 (95% CI 1.63-2.92) (Park and Yoon 2013). However, the same study found that %SMM negatively predicted high triglyceride (OR, 0.77; 95% CI, 0.61 to 0.97), high BP (0.72; 95% CI, 0.61 to 0.86), or metabolic syndrome (OR 0.51 (95% CI 0.40-0.65). Investigating SMI and %SMM as predictors of health outcomes (metabolic risks) among Saudi Arabs is therefore of interest. For health promotion purposes, determination of optimal cut-points for each of these measures will be useful to allow the characterisation of an individual's muscle mass in relation to their estimated risk. Therefore, the following question should be answered to fill the above gaps:

Are skeletal muscle mass indices better metrics to estimate the likelihood of having metabolic diseases?

6.2 Methodology and materials Population and surveys

This study is a secondary analysis of integrated data from the Saudi National Surveys (Saudi Health Information Survey (SHIS) and Saudi National Health Survey (SNHS)), the

Riyadh Region Surveys (two), and the Riyadh Validation Survey (RVS). These surveys have been previously presented and discussed in Chapter 5.

6.3 Data collection

6.3.1 Anthropometric and body composition measures estimations

Height, weight, waist and hip circumferences (WC, HC) were measured by trained professionals (WHO-STEPwise 2005; Al-Daghri, Al-Attas et al. 2011; Memish, El Bcheraoui et al. 2014; Alkhalaf, Edwards et al. 2015). All anthropometric measurements followed specified protocols using calibrated scales and non-stretchable plastic tapes. The body composition variables including Total Adipose Tissue Fat Mass (TATFM), skeletal muscle mass (SMM) and total body fat percent (%BF) were estimated using simple anthropometric and demographic measures. More details are discussed in **Chapter 5**.

6.3.2 Biochemical and blood pressure measurements

Consenting adults were asked to fast overnight (10-hour) before blood withdrawal. Blood was drawn, centrifuged and processed on the same day. Both whole blood and serum were stored at -20°C. All serum samples were analysed by routinely calibrated biochemical analyzers for HbA1c and blood lipids (Triglyceride HDL cholesterol, Total Cholesterol LDL Cholesterol). Systolic and diastolic blood pressures were measured twice within 20 minutes using validated upper arm automatic sphygmomanometer (OMRON M6 COMFORT (HEM-7223-E), Japan) for normal, large arm and obese adults (Belghazi, El Feghali et al. 2007; R. 2012) and according to the revised (2010) European Society of Hypertension International Protocol (ESH-IP) (O'Brien, Atkins et al. 2010).

6.3.3 Biochemical and blood pressure classifications

Subjects diagnosed or reported with T2DM and/or with HbA1c ≥6.1 mmol/L. Subjects diagnosed or reported with dyslipidaemia: Triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (men) and <1.30 mmol/L (women), and/ or total Cholesterol ≥6.2 mmol/L. The average of both readings was recorded. Hypertension was defined as a systolic blood pressure (SBP) of 140 mmHg or above, and/ or diastolic blood pressure (DBP) of 90 mmHg or above great extent (WHO 2003). Subjects who reported to have been diagnosed with hypertension by a physician were considered as having hypertension. However,

subjects who were diagnosed with hypertension and subjects were using antihypertensive drugs were considered as having hypertension as well.

6.3.4 Statistical analysis

Data from the five surveys were combined into a single database. Body composition between males and females is different and affected by age increase, as shown in Chapter 5. Therefore, analyses were conducted separately for men and women. Multiple-regression analyses were performed to determine the relationship between skeletal muscle mass indices and metabolic diseases (crude and adjusted for age) within each gender. Furthermore, each SMM indices were categorised to deciles and the prevalence of metabolic diseases in each decile was calculated. Additionally calculated were age-adjusted odds ratios with 95% confidence intervals (ORs) by applying logistic regression models of the different metabolic risk factors in case of an increase of one decile of the respective estimated SMM parameter. Statistical significance was set at $P<0.05$. Incomplete anthropometric data was considered as missing.

The optimal sensitivity and specificity using different SMM cut-off values to predict the presence of T2DM, hypertension, and/ or dyslipidemia were examined by receiver operating characteristic curve (ROC) analysis. The methods described by DeLong et al. were used to compare ROC curves, which accounts for the correlation among variables (DeLong, DeLong et al. 1988). A greater area under the curve (AUC) indicates a better predictive capability. AUC=1.0 indicates perfect discrimination, and AUC<0.5 indicates that the test performs no better than chance (non-informative). To find out the optimal cut-off points, the shortest distance between any point on the curve and the top left corner on the y-axis is determined. Distance is estimated at each one-half unit of SMM measures according to the following equation (Almajwal, Al-Baghli et al. 2009; Zeng, He et al. 2014):

$$\text{Distance in ROC} = \sqrt{(1-\text{sensitivity})^2 + (1-\text{specificity})^2}$$

6.4 Results

A total of n=23,968 adults from 5 different surveys in SA were included in the study: 13,117 (55%) women and 10,851 (45%) men. The median age of participants with

complete body composition data (n=12,123) was 41 (IQR 29-53) years. The detailed descriptions of the surveys (pooled data) and subject characteristics were discussed in Chapter 5.

6.4.1 Prevalence of metabolic diseases

6.4.1.1 Blood pressure and hypertension

A total of 5,123 participants were hypertensive with higher prevalence among men than women (24.2 vs 19.1 p<0.0001). Only 38.1% (1527/4003) of the hypertensive participants were aware that they had hypertension. Of these diagnosed with hypertension, only 31.2% (694/2221) participants had controlled blood pressure (BP under 140/90 mmHg). The prevalences of measured, diagnosed, and total measured and/or diagnosed hypertension are shown in Figure 6.2-1**.**

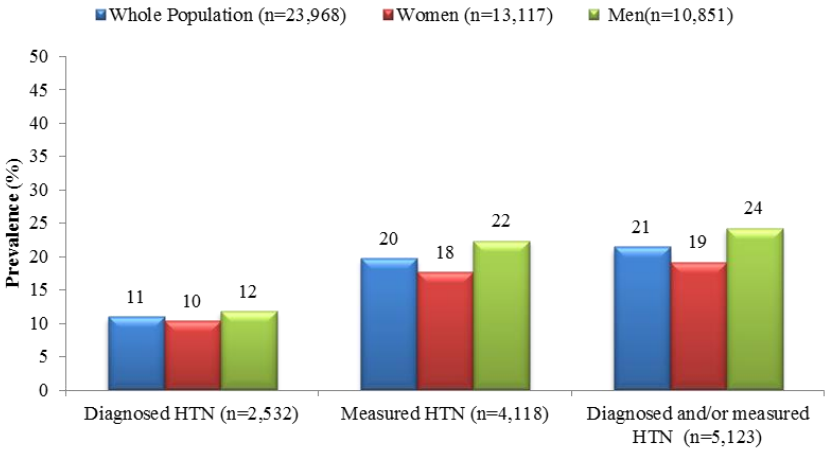


Figure 6.2-1: Prevalence of measured, diagnosed, and total measured and/ or diagnosed hypertension among women and men.

6.4.1.2 Blood sugar and Type 2 Diabetes Mellitus (T2DM)

A total of n=6,733 (28.1%) were Type 2 diabetic individuals (median age 52, IQR 43-60). The prevalence of diabetes among women was 26.6% (n=3488; median age 50, IQR 42-58) and among men was 29.9% (n=3245; median age 54, IQR 44-62) with difference (p<0.0001) between genders (Table 6.2-1). The median HbA1c was 5.4 mmol/L (IQR 4.9-6.7 mmol/L) for women and 5.5 mmol/L (4.9-7.3 mmol/L) with differences between genders (p<0.0001) (Table 6.2-2). Only 53% (3599/6,733) of the diabetic participants were

aware that they had diabetes. Of these who were diagnosed with diabetes, only 8.2% (322/3921) had controlled fasting blood sugar (HbA1c under 6.1 mmol/L). The prevalence of measured, diagnosed, and total measured and/or diagnosed T2DM are shown in Figure 6.2-2.

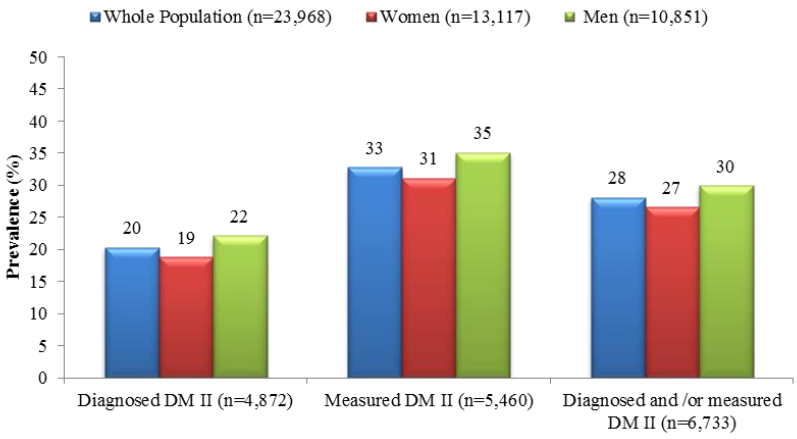


Figure 6.2-2: Prevalence of measured, diagnosed, and total measured and/ or diagnosed T2DM among women and men.

6.4.1.3 Blood lipids and dyslipidaemia

A total of n=1,804 individuals (10.8%) were hypercholesterolemic. The prevalence of hypercholesterolemia among women was 10.5% (n=1,001) and 11.1% among men (n=803) with no statistical significant difference (p=0.101) between men and women. A total of n=5,933 (35.5%) had hypertriglyceridemia. The prevalence of hypertriglyceridemia among women was 30% (n=2,860) and among women was 42.7% (n=3,073) with statistical significant difference (p<0.0001) between men and women. A total of n=10,725 (66.2 %) had low HDL (68.8 and 62.9% for men and women, respectively.

Table 6.2-1: Blood profile characteristics of the study participants (n=23,968)

Body Composition	Women (n=13,117)		Men (n=10,851)		*P* [a]
	N	Median (IQR)	N	Median (IQR)	
Age (year)	13117	39 (28-50)	10851	40 (29-54)	<0.0001
SBP (mmHg)	11421	119 (110-130)	9523	122 (115-132)	<0.0001
DBP (mmHg)	11400	76 (70-81)	9501	80 (73-85)	<0.0001
Cholesterol (mmol/l)	9550	4.8 (4.1-5.5)	7228	4.7 (4.0-5.5)	0.003
HbA1c (mmol/l)	9482	5.4 (4.9-6.7)	7147	5.5 (4.9-7.3)	<0.0001
HDL-Cholesterol (mmol/l)	9203	1.12 (0.90-1.37)	6987	0.94 (0.73-1.16)	<0.0001
Triglyceride (mmol/l)	9526	1.3 (0.92-1.8)	7200	1.5 (1.1-2.2)	<0.0001

[a] Value was significantly different between males and females (P <0.05) bases on Mann-Whitney analysis; IQR: Interquartile Range; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: Glycated haemoglobin; HDL: high density lipoprotein; LDL: low density lipoprotein.

The prevalence of measured, diagnosed, and total measured and/or diagnosed dyslipidemia are shown in Figure 6.2-3. This study revealed a high prevalence of dyslipidemia in both genders (71%). In contrast, the study shows a small prevalence of diagnosed dyslipidemia (5%). A total of n=13170 (71.7%) were dyslipidaemic (median age 42, IQR 30-53). The prevalence of dyslipidaemia among women was 72.7% (n=7526; median age 41, IQR 30-51) and among men was 70.3% (n=5644; median age 44, IQR 31-56) with statistical significant difference (p<0.0001) between men and women (Table 6.2-2). Only 3.7% (277/7567) of the dyslipidaemic participants were aware that they had dyslipidaemia. Of these diagnosed with dyslipidaemia, only 0.72% (2/279) participants had controlled blood lipids (triglyceride>= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (men) and <1.30 mmol/L (women), and/or total cholesterol ≥6.2 mmol/L). Table 6.2-2 show detailed distribution of metabolic risks and diseases among the Saudi men and women.

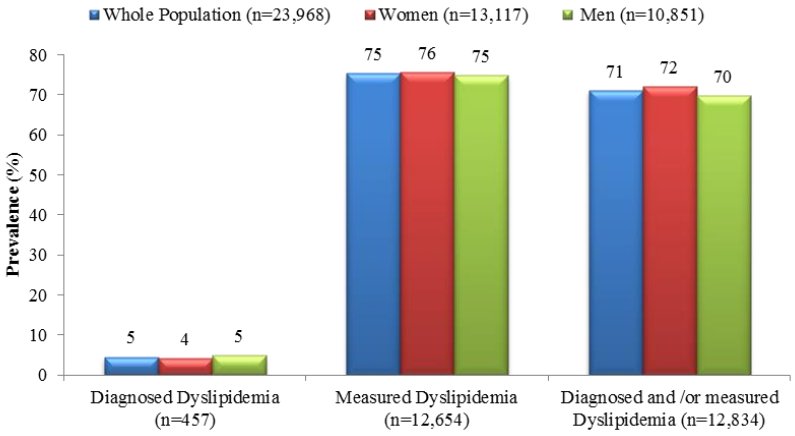


Figure 6.2-3: Prevalence of measured, diagnosed, and total measured and/ or diagnosed dyslipidemia among women and men.

Table 6.2-2: Prevalence metabolic risks among Saudi adult men and women (n=23,968).

Category	Whole Population		Women		Men		*P* [a]
	n/nn	*%*	*n/nn*	*%*	*n/nn*	*%*	
HTN, T2DM or Dys	16140/23968	67.3	8832/13117	67.3	7308/10851	67.3	0.235
HTN and T2DM	2445/23986	10.2	1222/13117	9.3	1223/10851	11.3	<0.0001
HTN and Dys	2940/23945	12.3	1525/13104	11.6	1415/10841	13.1	0.001
T2DM and Dys	4903/23962	20.5	2630/13112	20.1	2273/10850	20.9	0.043
Any morbidity	16140/23968	67.3	8832/13117	67.3	7308/10851	67.3	0.235
Any 2 co-morbidities	6812//23968	28.4	3569/13117	27.2	3243/10851	29.9	<0.0001
Any 3 co-morbidities	1738/23968	7.3	904/13117	6.9	834/10851	7.7	0.011

[a] Value was significantly different between males and females (P <0.05) bases on chi square analysis.
Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.
Any morbidity: any subject with HTN, T2DM or Dys; Any 2 co-morbidities: any subject with HTN and T2DM, HTN and Dys, or T2DM and Dys; Any 2 co-morbidities: HTN, T2DM and Dys.
SBP: Systolic blood pressure; DBP: diastolic blood pressure; Dys: Dyslipidemia; HTN: hypertension; T2DM: Type 2 diabetes mellitus.

6.4.2 Muscle mass indices and metabolic risks – risk factors prediction (blood pressure; blood profile)

This section focuses on metabolic risk with increasing deciles of different muscle mass indices. Linear regression (adjusted for age), showed that %SMM negatively predicted HbA1c (mmol/l) in both men (B= -0.139) and women (B= -0.169) whereas SMI (kg/m^2) predicted HbA1c (mmol/l) positively in men (B= 1.67) and women (B= 0.176) (Table 6.2-3). Moreover, %SMM negatively predicted SBP (mmHg) in both men (B= -

1.07) and women (B= -1.2) whereas SMI (kg/m^2) predicted SBP (mmHg) positively in men (B= 1.03) and women (B= 1.81) (Table 6.2-4). The analysis showed also that %SMM negatively predicted DBP (mmHg) in both men (B= -0.61) and women (B= -0.62) whereas SMI (kg/m^2) predicted DBP (mmHg) positively in men (B= 0.69) and women (B= 1.17) (Table 6.2-5). The %SMM negatively predicted blood cholesterol (mmol/l) in both men (B= -0.051) and women (B= -0.054) whereas SMI (kg/m^2) predicted blood cholesterol (mmol/l) positively in men (B= 0.088) and women (B= 0.018) (Table 6.2-6). The %SMM positively predicted HDL-cholesterol (mmol/l) in men (B= 0.008) but not in women (B= -0.005) whereas SMI (kg/m^2) negatively predicted HDL-cholesterol (mmol/l) in men (B= -0.063) but not in women (B= 0.018) (Table 6.2-7). The %SMM negatively predicted blood triglycerides (mmol/l) in both men (B= -0.055) and women (B= -0.042) whereas SMI (kg/m^2) predicted blood triglycerides (mmol/l) positively in men (B= 0.058) and women (B= 0.067) (Table 6.2-8).

Table 6.2-3: Body composition factors associated with HbA1c (mmol/l) increase among Saudi adults using multiple linear regression.

Body Composition [£]	Women- HbA1c (mmol/l)						Men - HbA1c (mmol/l)					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	0.025	0.014	0.023	0.001	(-0.002)-(0.05)	0.068	-0.001	0.015	-0.001	0.00001	(-0.03)-0.03	0.925
SMM (%) - (Al-Gindan et al. 2014)	-0.169	0.009	-0.219	0.048	(-0.19)-(-0.15)	<0.0001	-0.139	0.012	-0.174	0.030	(-0.16)-(-0.12)	<0.0001
SMI (kg/m^2) -(Al-Gindan et al. 2014)	0.167	0.039	0.053	0.003	0.09-0.24	<0.0001	0.176	0.053	0.049	0.002	0.07-0.28	0.001
SMM (kg) (Lee et al 2000) (White and Hispanic)	0.013	0.008	0.016	0.0003	(-0.003)-0.03	0.125	-0.036	0.009	-0.048	0.002	(-0.05)-(-0.02)	<0.0001
SMM (%)-(Lee et al 2000) (White and Hispanic)	-0.317	0.01	-0.314	0.099	(-0.34)-(-0.30)	<0.0001	-0.209	0.009	-0.264	0.070	(-0.23)-(-0.19)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	0.109	0.022	0.053	0.003	0.07-0.15	<0.0001	-0.034	0.029	-0.014	0.0002	(-0.09)-(0.02)	0.247
SMM (kg)- (Lee et al 2000) (Asians)	0.013	0.008	0.016	0.0003	(-0.003)-0.03	0.125	-0.036	0.009	-0.048	0.002	(-0.05)-(-0.02)	<0.0001
SMM (%)-(Lee et al 2000) (Asians)	-0.353	0.011	-0.32	0.103	(-0.37)-(-0.33)	<0.0001	-0.231	0.01	-0.273	0.075	(-0.25)-(-0.21)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	0.105	0.022	0.051	0.003	0.06-0.15	<0.0001	-0.038	0.03	-0.015	0.0002	(-0.10)-(0.02)	0.199

[£] All variables were adjusted for age.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;

Table 6.2-4: Body composition factors associated with SBP (mmHg) increase among Saudi adults using normal linear regression.

Body Composition [£]	Women- SBP (mmHg)						Men - SBP (mmHg)					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	0.33	0.07	0.06	0.004	0.20-0.47	<0.0001	0.06	0.06	0.01	0.0002	(-0.07)-0.18	0.380
SMM (%) - (Al-Gindan et al. 2014)	-1.2	0.05	-0.31	0.096	(-1.29)-(-1.10)	<0.0001	-1.07	0.05	-0.32	0.103	(-1.16)-(-0.97)	<0.0001
SMI (kg/m^2) -(Al-Gindan et al. 2014)	1.81	0.2	0.12	0.013	1.41-2.20	<0.0001	1.03	0.22	0.07	0.005	0.60-1.45	<0.0001
SMM (kg) (Lee et al 2000) (White and Hispanic)	0.26	0.04	0.06	0.004	0.19-0.34	<0.0001	0.11	0.03	0.03	0.001	0.05-0.18	<0.0001
SMM (%)-(Lee et al 2000) (White and Hispanic)	-2.32	0.05	-0.44	0.196	(-2.4)-(-2.23)	<0.0001	-1.33	0.03	-0.38	0.142	(-1.4)-(-1.26)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	1.14	0.1	0.1	0.011	0.94-1.35	<0.0001	0.78	0.11	0.07	0.005	0.56-1.0	<0.0001
SMM (kg)- (Lee et al 2000) (Asians)	0.26	0.04	0.06	0.004	0.19-0.34	<0.0001	0.11	0.03	0.03	0.001	0.05-0.18	<0.0001
SMM (%)-(Lee et al 2000) (Asians)	-2.55	0.05	-0.45	0.201	(-2.65)-(-2.46)	<0.0001	-1.45	0.04	-0.38	0.148	(-1.52)-(-1.38)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	1.12	0.1	0.1	0.010	0.92-1.33	<0.0001	0.77	0.11	0.07	0.005	0.55-0.99	<0.0001

[£] All variables were adjusted for age.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;

Table 6.2-5: Body composition factors associated with DBP (mmHg) increase among Saudi adults using normal linear regression.

Body Composition [£]	Women- DBP (mmHg)						Men - DBP (mmHg)					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	0.31	0.04	0.10	0.010	0.23-0.39	<0.0001	0.18	0.04	0.07	0.005	0.10-0.25	<0.0001
SMM (%) - (Al-Gindan et al. 2014)	-0.62	0.03	-0.27	0.074	(-0.67)-(-0.56)	<0.0001	-0.61	0.03	-0.3	0.091	(-0.67)-(-0.55)	<0.0001
SMI (kg/m^2) -(Al-Gindan et al. 2014)	1.17	0.12	0.13	0.016	0.94-1.4	<0.0001	0.96	0.13	0.11	0.012	0.70-1.21	<0.0001
SMM (kg) (Lee et al 2000) (White and Hispanic)	0.32	0.02	0.13	0.018	0.28-0.37	<0.0001	0.25	0.02	0.12	0.014	0.20-0.29	<0.0001
SMM (%)-(Lee et al 2000) (White and Hispanic)	-1.06	0.03	-0.34	0.118	(-1.11)-(-1.003)	<0.0001	-0.72	0.02	-0.33	0.108	(-0.77)-(-0.68)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	0.99	0.06	0.15	0.024	0.87-1.11	<0.0001	0.91	0.07	0.14	0.019	0.78-1.05	<0.0001
SMM (kg)- (Lee et al 2000) (Asians)	0.32	0.02	0.13	0.018	0.28-0.37	<0.0001	0.25	0.02	0.12	0.014	0.20-0.29	<0.0001
SMM (%)-(Lee et al 2000) (Asians)	-1.13	0.03	-0.34	0.115	(-1.19)-(-1.08)	<0.0001	-0.78	0.02	-0.33	0.110	(-0.82)-(-0.73)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	0.99	0.06	0.15	0.023	0.87-1.11	<0.0001	0.92	0.07	0.14	0.019	0.78-1.05	<0.0001

[£] All variables were adjusted for age.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;

Table 6.2-6: Body composition factors associated with cholesterol (mmol/l) increase among Saudi adults using normal linear regression.

Body Composition [£]	Women- Cholesterol (mmol/l)*						Men - Cholesterol (mmol/l)*					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	0.004	0.005	0.012	0.0001	(-0.005)-(0.013)	0.341	0.014	0.005	0.042	0.002	0.004-0.023	0.004
SMM (%) - (Al-Gindan et al. 2014)	-0.054	0.003	-0.206	0.043	(-0.06)-(-0.048)	<0.0001	-0.051	0.004	-0.196	0.038	(-0.058)-(-0.043)	<0.0001
SMI (kg/m^2) -(Al-Gindan et al. 2014)	0.018	0.013	0.017	0.0004	(-0.007)-(0.044)	0.162	0.088	0.017	0.077	0.006	0.056-0.121	<0.0001
SMM (kg) (Lee et al 2000) (White and Hispanic)	0.005	0.003	0.019	0.0004	(-0.0004)-(0.011)	0.069	0.009	0.003	0.035	0.001	0.003-0.015	0.003
SMM (%)-(Lee et al 2000) (White and Hispanic)	-0.085	0.004	-0.233	0.054	(-0.092)-(-0.077)	<0.0001	-0.065	0.003	-0.241	0.058	(-0.071)-(-0.059)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	0.023	0.008	0.031	0.001	0.008-0.039	0.003	0.045	0.01	0.054	0.003	0.025-0.065	<0.0001
SMM (kg)- (Lee et al 2000) (Asians)	0.005	0.003	0.019	0.0004	(-0.0004)-0.011	0.069	0.009	0.003	0.035	0.001	0.003-0.015	0.003
SMM (%)-(Lee et al 2000) (Asians)	-0.093	0.004	-0.236	0.056	(-0.101)-(-0.086)	<0.0001	-0.071	0.003	-0.244	0.060	(-0.077)-(-0.064)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	0.023	0.008	0.031	0.001	0.008-0.038	0.004	0.045	0.01	0.054	0.003	0.025-0.064	<0.0001

[£] All variables were adjusted for age.
* The presence or absence of lipid / cholesterol lowering medication was not accounted for in this analysis.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;

Table 6.2-7: Body composition factors associated with HDL-cholesterol (mmol/l) increase among Saudi adults using normal linear regression.

Body Composition [£]	Women- HDL-Cholesterol (mmol/l)						Men - HDL-Cholesterol (mmol/l)					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	-0.003	0.002	-0.019	0.0003	(-0.007)-(0.001)	0.144	-0.017	0.002	-0.107	0.011	(-0.022)-(-0.012)	<0.0001
SMM (%) - (Al-Gindan et al. 2014)	0.008	0.002	0.07	0.005	0.005-0.011	<0.0001	-0.005	0.002	-0.043	0.002	(-0.009)-(-0.002)	0.004
SMI (kg/m^2) -(Al-Gindan et al. 2014)	0.003	0.006	0.006	0.00004	(-0.009)-(0.015)	0.625	-0.063	0.008	-0.114	0.013	(-0.078)-(-0.047)	<0.0001
SMM (kg) (Lee et al 2000) (White and Hispanic)	-0.006	0.001	-0.049	0.002	(-0.008)-(-0.003)	<0.0001	-0.005	0.001	-0.04	0.002	(-0.007)-(-0.002)	0.001
SMM (%)-(Lee et al 2000) (White and Hispanic)	0.014	0.002	0.089	0.008	0.011-0.017	<0.0001	0.008	0.001	0.07	0.005	0.006-0.011	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	-0.011	0.003	-0.035	0.001	(-0.018)-(-0.005)	0.001	-0.012	0.005	-0.033	0.001	(-0.021)-(-0.003)	0.007
SMM (kg)- (Lee et al 2000) (Asians)	-0.006	0.001	-0.049	0.002	(-0.008)-(-0.003)	<0.0001	-0.005	0.001	-0.04	0.002	(-0.007)-(-0.002)	0.001
SMM (%)-(Lee et al 2000) (Asians)	0.015	0.002	0.085	0.007	0.011-0.018	<0.0001	0.009	0.002	0.069	0.005	0.006-0.012	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	-0.012	0.003	-0.036	0.001	(-0.019)-(-0.005)	0.001	-0.013	0.005	-0.033	0.001	(-0.022)-(-0.004)	0.006

[£] All variables were adjusted for age.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;

Table 6.2-8: Body composition factors associated with TGA (mmol/l) increase among Saudi adults using normal linear regression.

Body Composition [£]	Women- TGA (mmol/l)						Men- TGA (mmol/l)					
	B	SE	Beta	R Square	CI	p-value	B	SE	Beta	R Square	CI	p-value
SMM (kg)- (Al-Gindan et al. 2014)	0.018	0.003	0.064	0.004	0.011-0.024	<0.0001	0.007	0.005	0.022	0.001	(-0.002)-(0.016)	0.120
SMM (%) - (Al-Gindan et al. 2014)	-0.042	0.002	-0.215	0.046	(-0.047)-(-0.038)	<0.0001	-0.055	0.004	-0.22	0.048	(-0.062)-(-0.048)	<0.0001
SMI (kg/m^2) -(Al-Gindan et al. 2014)	0.067	0.01	0.085	0.007	0.048-0.086	<0.0001	0.058	0.016	0.052	0.003	0.026-0.09	<0.0001
SMM (kg) (Lee et al 2000) (White and Hispanic)	0.012	0.003	0.044	0.002	0.006-0.017	<0.0001	0.015	0.003	0.059	0.003	0.009-0.021	<0.0001
SMM (%)-(Lee et al 2000) (White and Hispanic)	-0.079	0.004	-0.222	0.049	(-0.086)-(-0.071)	<0.0001	-0.058	0.003	-0.219	0.048	(-0.064)-(-0.052)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (White and Hispanic)	0.041	0.008	0.056	0.003	0.026-0.056	<0.0001	0.073	0.01	0.09	0.008	0.054-0.092	<0.0001
SMM (kg)- (Lee et al 2000) (Asians)	0.012	0.003	0.044	0.002	0.006-0.017	<0.0001	0.015	0.003	0.059	0.003	0.009-0.021	<0.0001
SMM (%)-(Lee et al 2000) (Asians)	-0.086	0.004	-0.222	0.049	(-0.094)-(-0.078)	<0.0001	-0.063	0.003	-0.221	0.049	(-0.069)-(-0.056)	<0.0001
SMI (kg/m^2) -(Lee et al 2000) (Asians)	0.04	0.008	0.056	0.003	0.026-0.055	<0.0001	0.073	0.01	0.089	0.008	0.054-0.092	<0.0001

[£] All variables were adjusted for age.
CI: Confidence Interval; SE: Standard Error; B: Coefficient; HbA1c: glycated haemoglobin A1c; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index

6.4.3 Prediction of the body composition-related metabolic risks as categorical variables (deciles)

This section shows the development of metabolic diseases with increasing deciles of different muscle mass indices.

6.4.3.1 Individual comorbidity (hypertension, T2DM or dyslipidemia)

ORs for each level of hypertension, T2DM and dyslipidaemia according to deciles of each muscle mass parameters are also shown in Table 6.2-9**.** In both men and women, the risk of developing comorbidity (hypertension, T2DM and dyslipidaemia) increased positively with increasing deciles of SMM and SMI. However, the risk of developing comorbidity (hypertension, T2DM and dyslipidaemia) decreased with increasing deciles of %SMM (Table 6.2-9). ORs did not differ significantly between genders. The risk of developing hypertension increased with increasing deciles of SMI in men (OR, 1.12; 95% CI, 1.09 to 1.15) and women (OR, 1.10; 95% CI, 1.08 to 1.13), but was negatively associated with increasing deciles of SMM% in men (OR, 0.85; 95% CI, 0.83 to 0.87) and women (OR, 0.91; 95% CI, 0.89 to 0.94), respectively.

The risk of developing T2DM also increased with increasing deciles of SMI in men (OR, 1.11; 95% CI, 1.08 to 1.14) and women (OR, 1.12; 95% CI, 1.10 to 1.14), but was negatively associated with increasing deciles of SMM% in men (OR, 0.94; 95% CI, 0.92 to 0.96) and women (OR, 0.93; 95% CI, 0.91 to 0.95), respectively.

Also, the risk of developing dyslipidaemia increased with increasing deciles of SMI in men (OR, 1.06; 95% CI, 1.04 to 1.09) and women (OR, 1.04; 95% CI, 1.02 to 1.06), but was negatively associated with increasing deciles of SMM% in men (OR, 0.93; 95% CI, 0.91 to 0.95) and women (OR, 0.93; 95% CI, 0.91 to 0.95), respectively.

Table 6.2-9: Odds ratios (95% CI) for development of metabolic diseases (hypertension, T2DM, and dyslipidemia) according to increasing deciles of each anthropometric and body composition parameters (age-adjusted).

Body Composition [£]	Gender	Hypertension					T2DM					Dyslipidemia				
		B	**SE**	**OR**	***CI***	***p*-value**	**B**	**SE**	**OR**	***CI***	***p*-value**	**B**	**SE**	**OR**	***CI***	***p*-value**
SMM (Deciles)	♀	0.09	0.011	1.094	1.070-1.119	<0.0001	0.087	0.010	1.091	1.069-1.113	<0.0001	0.04	0.010	1.041	1.021-1.061	<0.0001
	♂	0.101	0.013	1.106	1.079-1.134	<0.0001	0.094	0.012	1.098	1.072-1.125	<0.0001	0.049	0.012	1.05	1.026-1.074	<0.0001
%SMM (Deciles)	♀	-0.092	0.013	0.912	0.889-0.935	<0.0001	-0.071	0.012	0.932	0.911-0.953	<0.0001	-0.078	0.012	0.925	0.905-0.946	<0.0001
	♂	-0.165	0.014	0.848	0.826-0.871	<0.0001	-0.063	0.012	0.939	0.916-0.962	<0.0001	-0.076	0.012	0.927	0.905-0.950	<0.0001
SMI (Deciles)	♀	0.099	0.011	1.104	1.080-1.129	<0.0001	0.113	0.010	1.119	1.097-1.142	<0.0001	0.042	0.010	1.043	1.023-1.063	<0.0001
	♂	0.113	0.012	1.12	1.093-1.147	<0.0001	0.104	0.012	1.11	1.084-1.136	<0.0001	0.063	0.011	1.065	1.042-1.089	<0.0001

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.
OR: Odds Ratio; CI: Confidence Interval; BP: blood pressure; T2DM: type 2 diabetes mellitus; SMM: Skeletal muscle mass; %SMM: percentage of muscle mass; SMI Muscle mass index.
*Value was significant (p<0.05).
[£] All variables were adjusted for age.

6.4.3.2 Clustered comorbidity (any morbidity or more)

ORs for each level of morbidity according to deciles of muscle mass index parameters are also shown in Table 6.2-10. In both men and women, the risk of developing morbidity (any morbidity, any 2 co-morbidities, or any 3 co-morbidities) increased positively with increasing deciles of SMM and SMI. However, the risk of developing morbidity (any or more co-morbidity) decreased with increasing deciles of %SMM (Table 6.2-10).

The risk of developing any morbidity increased with increasing deciles of SMI in men (OR, 1.13; 95% CI, 1.10 to 1.16) and women (OR, 1.10; 95% CI, 1.07 to 1.12), but was negatively associated with increasing deciles of SMM% in men (OR, 0.92; 95% CI, 0.89 to 0.95) and women (OR, 0.91; 95% CI, 0.89 to 0.94), respectively. The risk of developing any 2 comorbidities also increased with increasing deciles of SMI in men (OR, 1.13; 95% CI, 1.10 to 1.15) and women (OR, 1.12; 95% CI, 1.09 to 1.14), but was negatively associated with increasing deciles of SMM% in men (OR, 0.87; 95% CI, 0.85 to 0.89) and women (OR, 0.89; 95% CI, 0.87 to 0.91), respectively. Also, the risk of developing any 3 comorbidities increased with increasing deciles of SMI in men (OR, 1.15; 95% CI, 1.12 to 1.19) and women (OR, 1.12; 95% CI, 1.08 to 1.15), but was negatively associated with increasing deciles of SMM% in men (OR, 0.83; 95% CI, 0.80 to 0.86) and women (OR, 0.88; 95% CI, 0.85 to 0.92), respectively.

Table 6.2-10: Odds ratios (95% CI) for development of metabolic diseases (any morbidity or more) according to increasing deciles of each anthropometric and body composition parameters (age-adjusted).

Body Composition [£]	Gender	Any co-morbidity					Any 2 co-morbidities					Any 3 co-morbidities				
		B	**SE**	**OR**	***CI***	***p*-value**	**B**	**SE**	**OR**	***CI***	***p*-value**	**B**	**SE**	**OR**	***CI***	***p*-value**
SMM (Deciles)	♀	0.09	0.01	1.09	1.06-1.12	<0.0001	0.09	0.01	1.09	1.07-1.11	<0.0001	0.09	0.02	1.09	1.06-1.13	<0.0001
	♂	0.1	0.01	1.11	1.08-1.14	<0.0001	0.10	0.01	1.1	1.08-1.13	<0.0001	0.13	0.02	1.13	1.10-1.17	<0.0001
%SMM (Deciles)	♀	-0.09	0.01	0.92	0.89-0.94	<0.0001	-0.11	0.01	0.89	0.87-0.91	<0.0001	-0.12	0.02	0.88	0.85-0.92	<0.0001
	♂	-0.08	0.02	0.92	0.89-0.95	<0.0001	-0.14	0.01	0.87	0.85-0.89	<0.0001	-0.19	0.02	0.83	0.80-0.86	<0.0001
SMI (Deciles)	♀	0.09	0.01	1.10	1.07-1.12	<0.0001	0.11	0.01	1.12	1.09-1.14	<0.0001	0.11	0.02	1.12	1.08-1.15	<0.0001
	♂	0.12	0.01	1.13	1.10-1.16	<0.0001	0.12	0.01	1.13	1.10-1.15	<0.0001	0.14	0.02	1.15	1.12-1.19	<0.0001

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.
OR: Odds Ratio; CI: Confidence Interval; BP: blood pressure; SMM: Skeletal muscle mass; %SMM: percentage of Skeletal muscle mass; SMI: Skeletal muscle mass index;
*Value was significant (p<0.05).
[£] All variables were adjusted for age

6.4.4 Prediction trends of metabolic risks among the deciles of muscle mass measures

This section is showing the prediction trend for development of metabolic diseases with increasing deciles of different muscle mass indices.

6.4.4.1 The percentage of skeletal muscle mass to body weight (%SMM)

Table 6.2-11 and Table 6.2-12 show the odds ratios of the association between metabolic risks and %SMM in men and women. A significant negative association between any morbidity and %SMM values was observed starting at 29.1% (7^{th} decile) to 53.9% (10^{th} decile) and at 30.1% (5^{th} decile) to 53.8% (10^{th} decile) for women and men, respectively and decreasing progressively with higher %SMM values for both sexes.

A significant negative association between any 2 comorbidities and %SMM values was observed starting at 29.1% (7^{th} decile) to 53.9% (10^{th} decile) and at 27.2% (2^{nd} decile) to 53.8% (10^{th} decile) for women and men, respectively and decreasing progressively with higher %SMM values for in men only. Also, a significant negative association between any 3 comorbidities and %SMM values was observed starting at 25.8% (4^{th} decile) to 53.9% (10^{th} decile) and at 28.3% (3^{rd} decile) to 53.8% (10^{th} decile) for women and men, respectively and decreasing progressively with higher %SMM values for in men only.

6.4.4.2 The skeletal muscle mass index (SMI (kg/m^2))

Table 6.2-13 and Table 6.2-14 show the odds ratios of the association between metabolic risks and SMI (kg/m^2) in men and women. A significant positive association between any morbidity and SMI (kg/m^2) values was observed starting at 10.3 (3^{rd} decile) to 24.6 kg/m^2 (10^{th} decile) and at 9.6 (2^{nd} decile) to 24.2 kg/m^2 (10^{th} decile) for women and men, respectively and was increasing progressively with higher SMI values for both sexes. A significant positive association between any 2 comorbidities and SMI (kg/m^2) values was observed starting at 10.7 (4^{th} decile) to 24.6 kg/m^2 (10^{th} decile) and at 9.6 (2^{nd} decile) to 24.2 kg/m^2 (10^{th} decile) for women and men, respectively and was increasing progressively with higher SMI values for both sexes. A significant positive association between any 2 comorbidities and SMI (kg/m^2) values was observed starting at 9.9 (2^{nd} decile) to 24.6 kg/m^2 (10^{th} decile) and at 10.3 (4^{th} decile) to 24.2 kg/m^2 (10^{th} decile) for

women and men, respectively and was increasing progressively with higher SMI values for both sexes.

Table 6.2-11: Risk of metabolic diseases associated with increasing %SMM in Saudi women, based on regression (adjusted for age).

Body Composition	Decile	Any co-morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
%SMM Decile1	22.6						<0.0001						<0.0001						<0.0001
%SMM Decile2	23.9	0.11	0.20	1.12	0.75	1.66	0.589	0.28	0.12	1.32	1.04	1.66	0.020	0.03	0.14	1.03	0.78	1.36	0.845
%SMM Decile3	24.9	-0.17	0.19	0.85	0.58	1.23	0.379	0.04	0.12	1.04	0.82	1.31	0.749	-0.06	0.15	0.94	0.70	1.26	0.679
%SMM Decile4	**25.8**	-0.30	0.18	0.74	0.52	1.07	0.108	-0.18	0.12	0.83	0.66	1.05	0.124	**-0.38**	**0.16**	**0.68**	**0.50**	**0.94**	**0.018**
%SMM Decile5	26.8	-0.33	0.18	0.72	0.50	1.03	0.074	-0.17	0.12	0.84	0.67	1.07	0.152	-0.62	0.17	0.54	0.38	0.75	<0.0001
%SMM Decile6	27.9	-0.34	0.18	0.71	0.50	1.01	0.058	-0.23	0.12	0.79	0.63	1.01	0.060	-0.26	0.17	0.77	0.55	1.07	0.116
%SMM Decile7	**29.1**	**-0.42**	**0.18**	**0.66**	**0.46**	**0.94**	**0.020**	**-0.55**	**0.13**	**0.58**	**0.45**	**0.74**	<0.0001	-0.37	0.18	0.69	0.49	0.99	0.041
%SMM Decile8	31	-0.68	0.18	0.51	0.36	0.72	<0.0001	-0.38	0.13	0.69	0.53	0.88	0.004	-0.75	0.21	0.47	0.31	0.72	<0.0001
%SMM Decile9	33.8	-0.45	0.18	0.64	0.45	0.90	0.011	-0.67	0.15	0.51	0.39	0.68	<0.0001	-0.96	0.25	0.38	0.23	0.63	<0.0001
%SMM Decile10	53.9	-0.81	0.18	0.44	0.31	0.63	<0.0001	-1.26	0.18	0.28	0.20	0.40	<0.0001	-2.28	0.52	0.10	0.04	0.28	<0.0001
Age		0.04	0.00	1.04	1.04	1.05	<0.0001	0.08	0.00	1.08	1.08	1.09	<0.0001	0.07	0.00	1.07	1.06	1.08	<0.0001
Constant		0.49	0.20	1.63			0.016	-3.67	0.16	0.03			<0.0001	-5.06	0.22	0.01			<0.0001

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with SBP≥140 or DBP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive;
Any morbidity: any subject with HTN, T2DM or Dys; Any 2 co-morbidities: any subject with HTN and T2DM, HTN and Dys, or T2DM and Dys; Any 2 co-morbidities: HTN, T2DM and Dys;
OR: Odds Ratio; CI: Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; Dys: Dyslipidemia; HTN: hypertension; T2DM: Type 2 diabetes mellitus; %SMM: percentage of Skeletal muscle mass.
*Value was significant (p<0.05); [£] All variables were adjusted for age.

Table 6.2-12: Risk of metabolic diseases associated with increasing %SMM in Saudi men, based on regression (adjusted for age).

Body Composition	Decile	Any co-morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
%SMM Decile1	25.9						<0.0001						<0.0001						<0.0001
%SMM Decile2	**27.2**	0.10	0.25	1.11	0.68	1.81	0.679	**-0.37**	**0.14**	**0.69**	**0.53**	**0.92**	**0.0100**	-0.24	0.15	0.79	0.58	1.06	0.121
%SMM Decile3	**28.3**	-0.05	0.24	0.95	0.59	1.52	0.823	-0.58	0.14	0.56	0.42	0.74	<0.0001	**-0.57**	**0.16**	**0.57**	**0.41**	**0.78**	<0.0001
%SMM Decile4	29.2	-0.21	0.23	0.81	0.52	1.27	0.361	-0.61	0.14	0.54	0.41	0.72	<0.0001	-0.81	0.17	0.44	0.32	0.62	<0.0001
%SMM Decile5	**30.1**	**-0.55**	**0.22**	**0.58**	**0.38**	**0.89**	**0.012**	-0.80	0.14	0.45	0.34	0.59	<0.0001	-0.74	0.18	0.48	0.34	0.67	<0.0001
%SMM Decile6	31.3	-0.52	0.22	0.59	0.39	0.91	0.016	-0.92	0.14	0.40	0.30	0.53	<0.0001	-0.95	0.19	0.39	0.27	0.56	<0.0001
%SMM Decile7	32.7	-0.55	0.21	0.58	0.38	0.87	0.010	-0.86	0.14	0.42	0.32	0.56	<0.0001	-1.12	0.20	0.32	0.22	0.48	<0.0001
%SMM Decile8	34.7	-0.65	0.21	0.52	0.35	0.79	0.002	-1.00	0.15	0.37	0.28	0.49	<0.0001	-1.15	0.21	0.32	0.21	0.48	<0.0001
%SMM Decile9	37.8	-0.63	0.21	0.53	0.36	0.80	0.003	-1.41	0.16	0.24	0.18	0.33	<0.0001	-1.82	0.29	0.16	0.09	0.28	<0.0001
%SMM Decile10	53.8	-0.64	0.21	0.53	0.35	0.79	0.002	-1.42	0.17	0.24	0.17	0.34	<0.0001	-1.92	0.36	0.15	0.07	0.30	<0.0001
Age		0.05	0.00	1.05	1.05	1.06	<0.0001	0.07	0.00	1.08	1.07	1.08	<0.0001	0.06	0.00	1.06	1.05	1.06	<0.0001
Constant		0.23	0.22	1.26			0.298	-2.81	0.16	0.06			<0.0001	-3.99	0.21	0.02			<0.0001

*Value was significant (p<0.05); [£] All variables were adjusted for age.

Table 6.2-13: Risk of metabolic diseases associated with increasing SMI (kg/m^2) in Saudi women, based on regression (adjusted for age).

Body Composition	Decile	Any co-morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
SMI Decile1	9.3						<0.0001						0<0.0001						<0.0001
SMI Decile2	**9.9**	0.06	0.13	1.06	0.82	1.38	0.660	0.03	0.14	1.03	0.78	1.37	0.822	**0.44**	**0.21**	**1.55**	**1.02**	**2.33**	**0.038**
SMI Decile3	**10.3**	**0.31**	**0.14**	**1.37**	**1.04**	**1.79**	**0.023**	0.18	0.14	1.20	0.91	1.58	0.201	0.19	0.22	1.21	0.79	1.86	0.384
SMI Decile4	10.7	0.48	0.14	1.61	1.22	2.12	0.001	**0.50**	**0.14**	**1.65**	**1.26**	**2.17**	<0.0001	0.49	0.21	1.64	1.09	2.46	0.017
SMI Decile5	11.1	0.29	0.14	1.34	1.02	1.76	0.035	0.44	0.14	1.55	1.18	2.02	0.002	0.50	0.21	1.64	1.09	2.47	0.017
SMI Decile6	11.5	0.65	0.15	1.91	1.43	2.56	<0.0001	0.66	0.13	1.94	1.49	2.52	<0.0001	0.69	0.20	1.99	1.34	2.94	0.001
SMI Decile7	12.1	0.59	0.15	1.81	1.35	2.41	<0.0001	0.64	0.13	1.90	1.46	2.48	<0.0001	0.85	0.20	2.33	1.58	3.44	<0.0001
SMI Decile8	12.9	0.60	0.15	1.83	1.36	2.44	<0.0001	0.67	0.13	1.95	1.50	2.54	<0.0001	0.61	0.20	1.83	1.23	2.72	0.003
SMI Decile9	14.2	0.67	0.15	1.95	1.45	2.61	<0.0001	0.85	0.13	2.33	1.79	3.03	<0.0001	1.05	0.19	2.87	1.97	4.19	<0.0001
SMI Decile10	24.6	0.93	0.16	2.54	1.86	3.46	<0.0001	1.05	0.13	2.87	2.21	3.73	<0.0001	1.16	0.19	3.17	2.17	4.65	<0.0001
Age		0.05	0.00	1.05	1.05	1.06	<0.0001	0.09	0.00	1.10	1.09	1.10	<0.0001	0.08	0.00	1.09	1.08	1.09	<0.0001
Constant		-0.64	0.13	0.53			<0.0001	-4.99	0.16	0.01			<0.0001	-6.69	0.26	0.00			<0.0001

*Value was significant (p<0.05); [£] All variables were adjusted for age.

Table 6.2-14: Risk of metabolic diseases associated with increasing SMI (kg/m^2) in Saudi men, based on regression (adjusted for age).

Body Composition	Decile	Any co-morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
SMI Decile1	9.0						<0.0001						<0.0001						<0.0001
SMI Decile2	**9.6**	**0.50**	**0.17**	**1.66**	**1.19**	**2.31**	**0.003**	**0.31**	**0.15**	**1.37**	**1.01**	**1.85**	**0.043**	0.24	0.23	1.27	0.81	2.00	0.292
SMI Decile3	10.0	0.48	0.17	1.62	1.17	2.26	0.004	0.77	0.15	2.17	1.61	2.93	<0.0001	0.33	0.23	1.40	0.89	2.19	0.147
SMI Decile4	**10.3**	0.49	0.17	1.64	1.18	2.27	0.003	0.64	0.15	1.90	1.40	2.56	<0.0001	**0.54**	**0.23**	**1.71**	**1.10**	**2.68**	**0.018**
SMI Decile5	10.7	0.74	0.17	2.10	1.50	2.93	<0.0001	0.65	0.15	1.91	1.41	2.59	<0.0001	0.60	0.23	1.82	1.16	2.84	0.009
SMI Decile6	11.2	0.82	0.17	2.26	1.62	3.16	<0.0001	0.91	0.15	2.47	1.83	3.34	<0.0001	0.98	0.22	2.67	1.73	4.13	<0.0001
SMI Decile7	11.7	1.05	0.18	2.86	2.01	4.05	<0.0001	0.85	0.15	2.33	1.72	3.16	<0.0001	0.65	0.23	1.91	1.21	3.01	0.006
SMI Decile8	12.4	1.03	0.18	2.79	1.97	3.94	<0.0001	0.94	0.15	2.57	1.90	3.48	<0.0001	1.04	0.22	2.83	1.82	4.38	<0.0001
SMI Decile9	13.6	1.09	0.18	2.98	2.10	4.23	<0.0001	1.27	0.15	3.56	2.64	4.81	<0.0001	1.28	0.22	3.60	2.34	5.54	<0.0001
SMI Decile10	24.2	1.25	0.19	3.48	2.42	5.00	<0.0001	1.26	0.15	3.52	2.61	4.75	<0.0001	1.33	0.22	3.80	2.48	5.81	<0.0001
Age		0.06	0.00	1.06	1.06	1.07	<0.0001	0.08	0.00	1.09	1.08	1.09	<0.0001	0.07	0.00	1.07	1.07	1.08	<0.0001
Constant		-1.23	0.16	0.29			<0.0001	-4.88	0.17	0.01			<0.0001	-6.20	0.27	0.00			<0.0001

*Value was significant (p<0.05); [£] All variables were adjusted for age.

6.4.5 Best predictors and optimal cut-points for different muscle mass indices in relation to metabolic diseases using ROC curve

This section is showing the highest level of Area Under Curve (AUC) and cut-off points on the basis of the equivalence of sensitivity to specificity for muscle mass indices. The method of DeLong et al. (DeLong, DeLong et al. 1988) was used to compare ROC curves of skeletal muscle mass (SMM) related measures to predict metabolic risks, which accounts for the correlation among variables. Table 6.2-15 shows the diagnostic performance of SMM measures in predicting morbidity (hypertension, T2DM, dyslipidemia, any morbidity, any 2 co-morbidities and any 3 co-morbidities).

Among women, %SMM provided the highest level of Area Under Curve (AUC) in predicting hypertension (0.668), T2DM (0.679) and dyslipidemia (0.582) compared with SMI (kg/m^2) which provided the lowest AUC in predicting hypertension (0.560), T2DM (0.565) and dyslipidemia (0.536). Among men, %SMM provided the highest level of AUC in predicting hypertension (0.685), T2DM (0.650) and dyslipidemia (0.579) compared with SMI (kg/m^2) which provided the lowest AUC in predicting hypertension (0.545), T2DM (0.519) and dyslipidemia (0.542).

Furthermore, among women, %SMM provided the highest level of AUC in predicting any morbidity (0.648), any 2 comorbidities (0.703) and any 3 comorbidities (0.696) comparing with SMI (kg/m^2) which provided the lowest AUC in predicting any morbidity (0.582), any 2 comorbidities (0.564) and any 3 comorbidities (0.552). Among men, %SMM provided the highest level of AUC in predicting any morbidity (0.652), any 2 comorbidities (0.689) and any 3 comorbidities (0.703) compared with SMI (kg/m^2) which provided the lowest AUC in predicting any morbidity (0.572), any 2 comorbidities (0.528) and any 3 comorbidities (0.553).

Table 6.2-15: Diagnostic performance of skeletal muscle mass (SMM) measures in predicting co-morbidity* (hypertension, T2DM, dyslipidemia, any morbidity, any 2 co-morbidities and any 3 co-morbidities) using optimal SMM cut-off values based on the shortest distance in ROC curves in Saudi adults [$]

Metabolic Risks		SMM (kg)				SMI (kg/m^2)				%SMM (%)			
		AUC	SE	CI	Cut-off	AUC	SE	CI	Cut-off	AUC	SE	CI	Cut-off
Hypertension*	♀	0.531	0.009	0.519-0.543	19.7	0.560	0.008	0.548-0.572	8.6	**0.668**	0.008	0.657-0.679	27.8
	♂	0.517	0.009	0.503-0.530	26.9	0.545	0.009	0.532-0.559	9.2	**0.685**	0.008	0.672-0.697	29.7
T2DM*	♀	0.525	0.007	0.513-0.537	19.7	0.565	0.007	0.554-0.577	7.9	**0.679**	0.007	0.668-0.690	26.8
	♂	0.512	0.008	0.499-0.526	19.4	0.519	0.008	0.505-0.533	9.1	**0.650**	0.008	0.637-0.663	31.2
Dyslipidaemia*	♀	0.528	0.008	0.516-0.540	19.4	0.536	0.008	0.524-0.548	7.6	**0.582**	0.008	0.570-0.594	28.2
	♂	0.524	0.009	0.510-0.538	22.4	0.542	0.009	0.529-0.556	8.2	**0.579**	0.009	0.565-0.592	29.3
Any co-morbidity*	♀	0.561	0.009	0.549-0.572	19.6	0.582	0.009	0.570-0.593	7.9	**0.648**	0.009	0.637-0.659	28.3
	♂	0.536	0.011	0.522-0.549	21.3	0.572	0.011	0.558-0.585	8.2	**0.652**	0.011	0.639-0.665	31.7
Any 2 co-morbidities*	♀	0.525	0.007	0.513-0.537	19.7	0.564	0.007	0.552-0.576	7.9	**0.703**	0.006	0.692-0.713	27.8-26.8
	♂	0.509	0.008	0.495-0.523	27.9	0.528	0.008	0.515-0.542	7.6	**0.689**	0.007	0.677-0.702	30.3-29.4
Any 3 co-morbidities*	♀	0.514	0.01	0.503-0.526	19.8	0.552	0.01	0.540-0.563	7.9	**0.696**	0.009	0.685-0.707	25.9
	♂	0.519	0.012	0.505-0.533	24.5	0.553	0.012	0.539-0.566	8.9	**0.703**	0.011	0.690-0.715	29.1

[$] The above table was constructed from the receiver-operating characteristic (ROC) analysis using SMM (kg), %SMM and SMI (kg/m^2) as covariate and any morbidity, any 2 co-morbidities or any 3 co-morbidities as an outcome.

AUC: Area under curve; SMM: Skeletal muscle mass (kg); %SMM: Skeletal muscle mass percentage; SMI: Skeletal muscle mass index

*Value was significant ($p<0.05$).

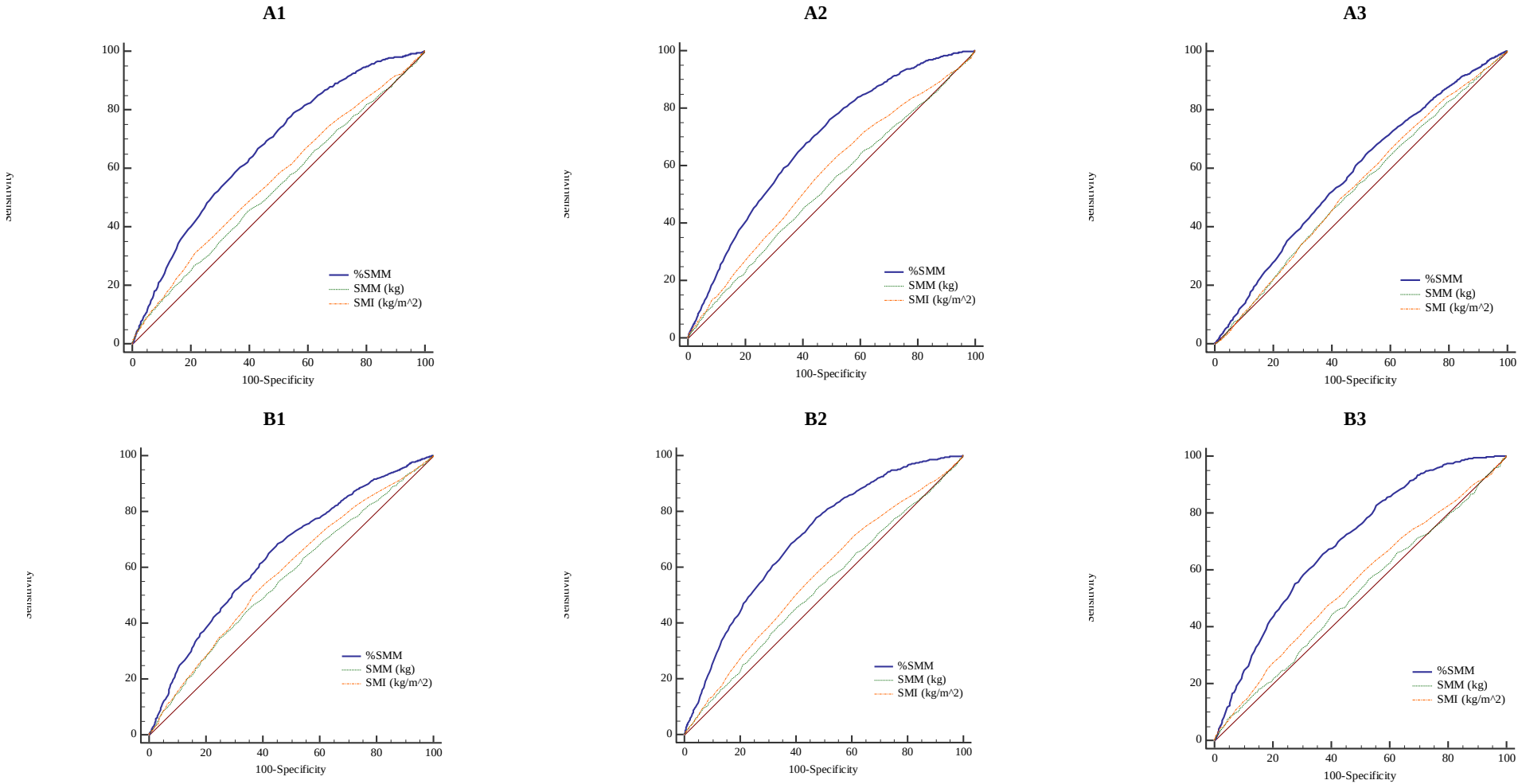


Figure 6.2-4: Receiver operating characteristic curves (ROC) for SMM (kg), %SMM and SMI (kg/m^2) to predict the presence of hypertension (A1), T2DM (A2), dyslipidemia (A3), any comorbidity (B1), any 2 comorbidities (B2), and any 3 comorbidities (B3), in women.

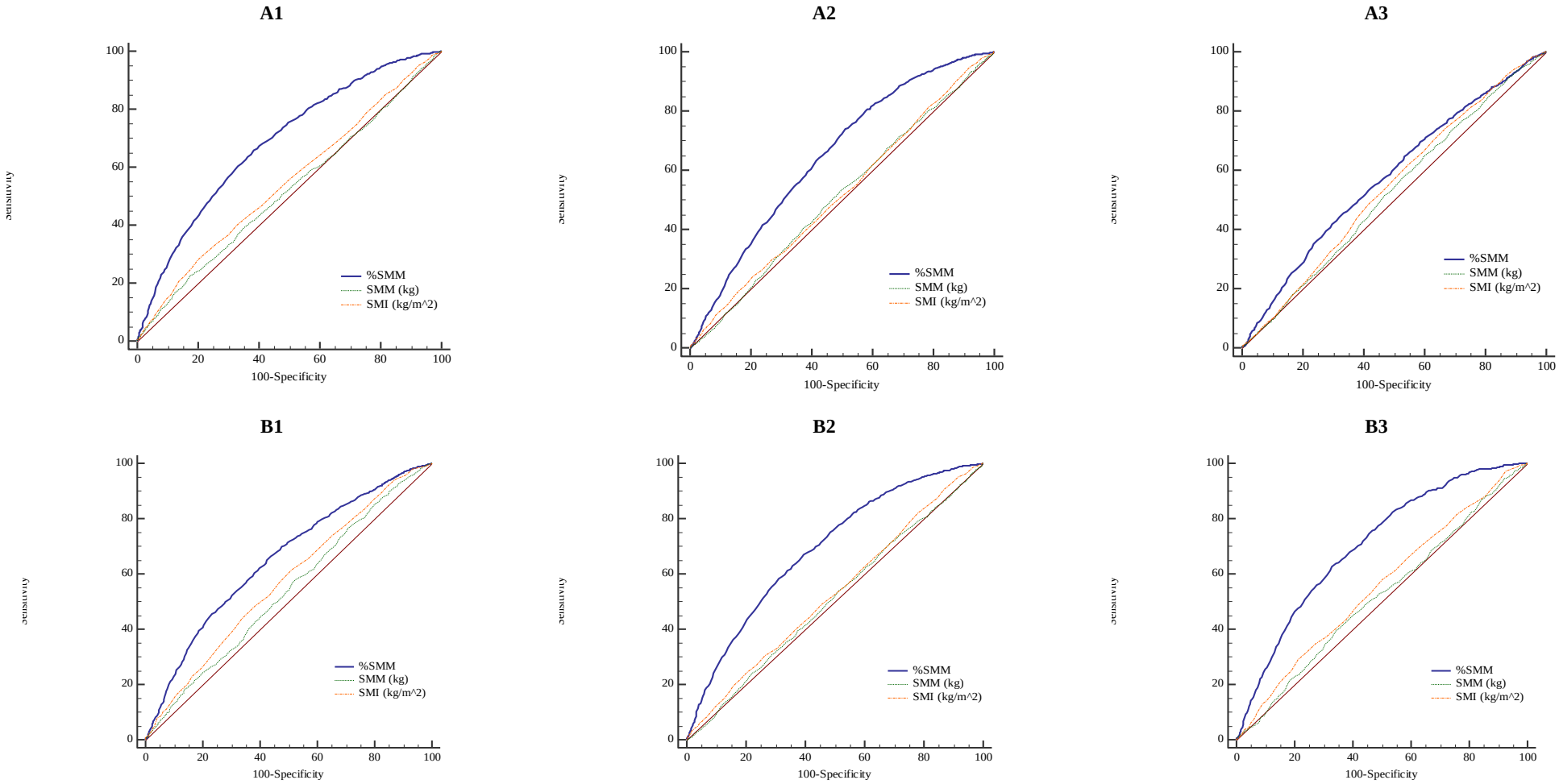


Figure 6.2-5: Receiver operating characteristic curves (ROC) for SMM (kg), %SMM and SMI (kg/m^2) to predict the presence of hypertension (A1), T2DM (A2), dyslipidemia (A3), any comorbidity (B1), any 2 comorbidities (B2), and any 3 comorbidities (B3), in men.

6.5 Discussion

This study demonstrates a high prevalence of hypertension, T2DM and dyslipidemia in Saudi population between 2004 and 2014, consistent with data from other Arabian Gulf countries (Mabry, Reeves et al. 2010; Ng, Zaghloul et al. 2011; Musaiger and Al-Hazzaa 2012). The prevalence of T2DM in this study is higher than the Eastern Mediterranean Region results which is the highest prevalence's among the world's regions (28% in this study vs. 14%) (WHO 2016). Hypertension (SBP≥140 OR DBP≥90) prevalence in this study is 21% which is less than the prevalence in gulf countries (Musaiger and Al-Hazzaa 2012; WHO 2015). The dyslipidemia prevalence in this study is extremely high (71%). This is because of the high prevalence of low HDL-cholesterol levels (66%) followed by hypertriglyceridemia (35%), and hypercholesterolemia (11%). A hypercholesterolemia result is lower than the Gulf countries' results: Bahrain (16%), Kuwait (16%), Oman (14%), Qatar (18%) and United Arab Emirates (18%).

This study shows that the increase of the absolute total amount of SMM (kg) and SMI related to increase the risk of metabolic diseases including hypertension, T2DM, and dyslipidemia. However, when muscle mass was expressed as a percentage of total body weight (%SMM), it was found that increased %SMM (as indicative of relative muscle mass) reduced the risk of metabolic diseases including hypertension, T2DM, and dyslipidemia. Also, higher SMI increased the risk of increasing blood sugar (HbA1c), blood pressure, cholesterol, and triglyceride in both men and women. However, it shows that higher %SMM reduced the risk of increasing blood sugar (HbA1c), blood pressure, cholesterol, and triglyceride in both men and women.

These results are consistent with number of recent studies (Srikanthan and Karlamangla 2011; Park and Yoon 2013). The National Health and Nutrition Examination Survey III (NHANES III) found that each 10% increase in SMI (the ratio of total SMM to total body weight) was associated with 11% relative reduction in homeostasis model assessment of insulin resistance (HOMA-IR) (95% confidence interval, 6–15%) (Srikanthan and Karlamangla 2011). Also, NHANES III found that the highest quintile of SMI (the ratio of total SMM to total body weight) was associated with improved insulin sensitivity and lower risk of transitional/pre- or overt diabetes mellitus (Srikanthan and Karlamangla 2011).

Findings of the present study are also similar to a cross-sectional study among the Korean population (n=838) aged 20 to 75 years, found that SMI (kg/m^2) positively predicted high triglyceride (OR, 1.40; 95% CI, 1.08 to 1.82), High BP (1.31; 95% CI, 1.09 to 1.57), metabolic syndrome (OR 2.18 (95% CI 1.63-2.92) (Park and Yoon 2013). Also, they found that the fifth quintile of muscle mass to body fat ratio (MFR), %SMM, and skeletal muscle to visceral fat area (SVR) accounted for the smallest proportion in subjects with metabolic syndrome (Park and Yoon 2013).

A recent cross-sectional study, (n=414) among older Korean people (≥60 years) and using DEXA, found that the prevalence of low muscle mass in older women with diabetes was higher than those without diabetes by appendicular skeletal muscle mass/weight (ASM/Wt) (25.9% vs 15.0%, p=0.044) and total body skeletal muscle mass/weight (TSM/Wt) (32.9% vs 20.0%, p=0.030), but not by the appendicular skeletal muscle mass/height2 (ASM/Ht2) (7.1% vs 8.6%, p=0.685) (Kim, Park et al. 2014). Atlantis et al. (2009) also reported that low muscle mass (using whole-body LM (%)) was the strongest risk factor for metabolic syndrome, independent of abdominal fat (Atlantis, Martin et al. 2009).

These results of increasing metabolic risk with SMI increase may be caused by total body fat mass (BF), including total adipose tissue mass (TATM), which often increases with SMM. This hypothesis is supported by findings of cohort study (n=2,984) among older (70-79) black and white US communities (Newman, Kupelian et al. 2003). They found that lean mass index (LM/ht^2) was highly correlated with BMI (men, r=0.76, women, r=0.85), whereas a method using the residual of the regression of lean mass on height and fat mass was not (men, r=0.38, women, =0.25). Actually, in our study, estimated percentage of body fat and adipose tissue mass had a significant positive correlation with SMM (discussed in previous chapter).

The method described by DeLong et al. is usually used to compare ROC curves of different measures, which accounts for the correlation among variables (DeLong, DeLong et al. 1988). A measure with highest level of AUC has a better predictive capability. The results of this study show that %SMM provided the best prediction power of any morbidity (or more) and all individual risk factors for both men (0.579-0.703) and women (0.582-0.703) compared to SMI was markedly poorer predictor of these risk factors in both men (0.519-0.572) and women (0.536-0.582) (Table 6.2-15). This study also assesses a new cut-off points for %SMM and SMI based on development of metabolic diseases. The new

cut-off points for %SMM ranged between 29 to 32% for men and 26 to 28% for women. To the knowledge of the researcher, this is the first study assessing cut-off points based on metabolic diseases using ROC analyses. Previous studies defined low muscle mass (sarcopenia) based on different criteria such as two standard deviations (SD) below the mean of a young reference population, 20th percentile below the elderly sample distribution, or muscular dysfunction (strength and function) using ROC analyses (Pagotto and Silveira 2014).

The present study results show that the %SMM from Lee et al (2000) is predicting metabolic risks better than Al-Gindan et al. (2014).

6.5.1 Strengths and limitations

This study has some limitations. First, this study was a cross-sectional study which limits our ability to draw causal inferences from the relationships observed. Second, physical fitness which may affect SMM (Hirose, Saito et al. 2003; Petersen, Dufour et al. 2007; Al-Dokhi 2015) was not taken into account in this study. In Saudi Arabia, Al-Dokhi (2015) found a high significant correlation between physical fitness score and muscle mass/fat mass ratio (Al-Dokhi 2015). Third, muscle strength which is a factor in insulin sensitivity of SMM (Atlantis, Martin et al. 2009) was not taken into account.

Strengths of this study include a large random sample obtained using clustering and stratification techniques based on National Saudi census data (Chapter 5). Subjects with type 1 diabetes were excluded in this study because in type 1 diabetes mellitus the primary pathology is loss of β-cells function, rather than increased insulin resistance. Therefore, individuals with type 1 diabetes mellitus may be less sensitive by changes in SMM, and their inclusion likely weakened SMM associations with hyperglycemia (Srikanthan and Karlamangla 2011). Moreover, body composition (i.e. SMM, %BF and TATM) in this study was estimated using simple predictive equations. Antihypertensive drugs (including diuretics, beta blockers, Angiotensin-converting enzyme (ACE) inhibitors, Angiotensin II receptor blockers (ARBs), Calcium channel blockers, and renin inhibitors) may affect blood pressure and salt metabolism in human body (Sciarretta, Palano et al. 2011; Thompson, Hu et al. 2011). In the present study, subjects who were diagnosed with hypertension and subjects were using antihypertensive drugs were considered as having hypertension and included in the analyses. Lipid / cholesterol lowering drugs including

statins which inhibit HMG-CoA reductase thereby blocking cholesterol synthesis; and fibrates (a group of PPARα agonists) which primarily enhance fatty acid oxidation (Robinson, Smith et al. 2005; Staels and Fruchart 2005). However, in present study, the presence or absence of lipid / cholesterol lowering medication was not accounted for in the analysis, which may affect the study results.

Computed tomography (CT) and Magnetic resonance imaging (MRI) are the reference methods to measure skeletal muscle mass (SMM) and adipose tissue volumes accurately (Fosbøl and Zerahn 2015). Also, body fat and appendicular portion of skeletal muscle mass can be measured with good precision using a dual-energy X-ray absorptiometry (DEXA). Nevertheless, these methods are unfeasible for large epidemiologic studies and in clinical settings because of the high cost for application of these methods, high radiation exposure in CT and DEXA, and time consuming (Springer, Ehehalt et al. 2012; Fosbøl and Zerahn 2015). Body impedance analysis (BIA) has been proposed for analysis of body composition, due to its lower cost, safety and higher availability (Kushner 1992; Ellis and Wong 1998). However, adipose tissue is significantly less conductive than muscle or bone (Scharfetter, Schlager et al. 2001). Therefore, the electric current flows are proportional to total body water and to high water concentration tissues such as the skeletal muscle. Therefore, the percentage fat mass and fat-free mass from BIA are estimated based on derived equations including factors such as age, height, gender and weight (Dehghan and Merchant 2008). In contrast, these equations used in this study offer a simpler and more rapid means of estimating skeletal muscle mass with no risk or logistic expenses and high validity levels (Al-Gindan, Hankey et al. 2014; Al-Gindan, Hankey et al. 2015). Therefore, they are most probably the better candidate for assessment of body composition measures at the population level.

6.6 Conclusion

Decreased SMM may play a critical role in the development of metabolic diseases. Skeletal muscle mass percentage (%SMM) is the best overall predictor of metabolic diseases, whereas the absolute total amount of SMM (kg) and the skeletal muscled mass index (SMI) are poor measures to predict metabolic diseases and should not be used as surrogate measures of low muscle mass (sarcopenia).

These data provide another approach to identify those at risk for morbidity and to further explore the risk factors for low muscle mass. Future studies such as prospective studies should examine the role of the quantity of low muscle mass in determining important health outcomes, including declines in metabolic diseases, muscle strength and function to further validate the best approach to defining low muscle mass in population.

Chapter Seven

Anthropometric measurements in Saudi Arabia: Optimal cut-off values and prediction of metabolic diseases

7.1 Introduction

Chapter 5 extend the notion that BMI is an inadequate measure for predicting health risks among SA adults. Since BMI is the most common method used for adiposity assessment in SA (Almajwal, Williams et al. 2009), overlooking these findings and continuing to use BMI as a sole indicator of health risks would mean that ~43% of the SA population categorised as "normal weight" using BMI might not be notified to take action. Body fat is significantly underestimated, particularly in non-European groups including Chinese and South Asians, when BMI is employed (Lear, Humphries et al. 2007). Asians have higher morbidity than Caucasians at lower cut-off points for BMI (WHO 2000; Snehalatha, Viswanathan et al. 2003; Vikram, Pandey et al. 2003; Razak, Anand et al. 2007). WC is a marginally better indicator of total body fat than BMI (Lean, Han et al. 1996) and the chronic health risks are better predicted by WC than by BMI (Pouliot, Despres et al. 1994; Lean, Han et al. 1995). A recent systematic review and meta-analysis (n=31,968 patients, 25 studies, 3341 abstracts) showed that the pooled sensitivity of BMI to detect high risk adiposity (defined as percentage body fat, measured by bioelectrical impedance analysis, DEXA, hydrostatic weighing, isotope dilution and skin fold) was only 50% (Okorodudu, Jumean et al. 2010). Meanwhile, WC was found to explain 60 to 90% of body fat variance against MRI or DEXA (Janssen, Heymsfield et al. 2002; Lear, Humphries et al. 2007). However, current WC cut-offs were derived from data based on European Caucasian populations which may not suitable for other populations as body fat differs by ethnicity (Deurenberg and Deurenberg-Yap 2003; Lear, Humphries et al. 2007).

In Chapter 5, Caucasian-defined BMI cut-offs were shown not to be optimal for the Saudi population. Nearly, 25% of women and 30% of men with a Risk 2 WC would not have been identified as high-risk because they had a non-obese BMI (BMI <30 kg/m^2). This observation is in line with the IDF recommendation that researchers from Eastern Mediterranean and Middle East (Arab) populations utilise European cut-points for BMI and WC measurements for both genders until more ethnic specific data is available. When setting BMI cut-offs, the WHO Expert Consultation in 2008 suggested that the basis for effective use of anthropometrics cut-off points in clinical and public health should relate to health outcomes rather than to associations with body fat; the main reason being that risk prediction is more straightforward if based on health outcomes.

Furthermore, Janssen et al (2002) found that addition of WC to BMI improved the variance of visceral (11–16%) and total fat mass (2–4%) by BMI, but WC was not a significant predictor of abdominal subcutaneous fat after BMI was controlled for (Janssen, Heymsfield et al. 2002). This is further compounded by the meta-analysis of Lee et al. (10 studies, 88,514 individuals) which concluded that combining WC with BMI did not improve upon its discriminatory capability (Lee, Huxley et al. 2008).

Thus, it is necessary to investigate whether BMI, WC, WHR and WHtR better predict health outcomes (metabolic risks) among Saudi Arabs and whether the addition of WC to BMI can improve on the prediction of metabolic diseases. For health promotion purposes, it is required to determine optimal cut-points for each of these measures, to allow the characterisation of body fat in relation to estimated health risks. Therefore, the following question should be answered to fulfill the above gaps:

RQ: Is BMI alone or a combination of BMI and WC the better metric to estimate the likelihood of having metabolic diseases in Saudi Arabs?

7.2 Methodology and materials

7.2.2 Population and surveys

This study is a secondary analysis of integrated data from the Saudi National Surveys (Saudi Health Information Survey (SHIS) and Saudi National Health Survey (SNHS)), the Riyadh Region Surveys (two), and the Riyadh Validation Survey (RVS). These surveys have been previously presented and discussed in **Chapter 5**.

7.2.3 Data collection

7.2.3.1 Anthropometric and body composition measures estimations

Height, weight, waist and hip circumferences (WC, HC) were measured by trained professionals (WHO-STEPwise 2005; Al-Daghri, Al-Attas et al. 2011; Memish, El Bcheraoui et al. 2014; Alkhalaf, Edwards et al. 2015). All anthropometric measurements followed specified protocols using calibrated scales and non-stretchable plastic tapes. A full account is presented in Chapter 5.

7.2.3.2 Biochemical and blood pressure measurements

Blood pressure was measured in all surveys and blood samples were also collected. A full account is presented in Chapter 6.

7.2.3.3 Statistical analysis

Data from the five surveys were combined into a single database. The analyses were performed for women and men to compare the prevalence of metabolic diseases including hypertension, dyslipidemia and T2DM in the same sample by level of normal weight, overweight, obesity, normal, and Risk1 and Risk2 WC using the conventional cut-off points. Body composition between males and females is different and affected by age increase, as shown in Chapter 5. Therefore, analyses were conducted separately for men and women. Multiple-regression analyses were performed to determine the relationship between anthropometric measures and metabolic diseases (crude and adjusted for age) within each gender. Furthermore, each anthropometric measure was categorised to deciles and the prevalence of metabolic diseases in each decile was calculated. Additionally calculated were age-adjusted odds ratios with 95% confidence intervals (ORs) by applying logistic regression models of the different metabolic risk factors in case of an increase of one decile of the respective anthropometric parameter. Statistical significance was set at $P<0.05$. Incomplete anthropometric data was considered as missing. The optimal sensitivity and specificity using different BC cut-off values to predict the presence of T2DM, hypertension, and/ or dyslipidemia were examined by receiver operating characteristic curve (ROC) analysis. The methods described by DeLong et al were used to compare ROC curves, which accounts for the correlation among variables (DeLong, DeLong et al. 1988) (Chapter 5).

7.3 Results

A total of n=23,968 adults from 5 different surveys in SA were included in the study: 13,117 (55%) women and 10,851 (45%) men. The median age of participants with complete body composition data (n=12,123) was 41 (IQR 29-53) years. The detailed descriptions of the surveys (pooled data) and subject characteristics are presented in Chapter 5. Prevalence of metabolic diseases and the proportion of metabolic diseases in body composition categories are presented in Chapter 6.

7.3.2 Association between anthropometric measures using conventional cut-off points and metabolic diseases

This section focuses on the use of conventional cut-off points of BMI and WC (before and after adding them together) as predictors of metabolic diseases.

7.3.2.1 Individual morbidities (hypertension, T2DM or dyslipidemia)

Results of the logistic regression, which show the ORs for the various obesity-related morbidities according to BMI category (e.g. normal weight, overweight or obese) and WC category (normal, Risk1 and Risk2 WC) are shown in Table 7.3-1 and Table 7.3-2. As expected, the odds for all morbidities were higher for the overweight and obese women and men than for the normal-weight subjects, based on BMI cut-offs (Table 7.3-1).

Among (OR women, obesity was associated with hypertension (OR 4.2; 95% CI 3.6 to 4.8), T2DM (OR 4.7; 95% CI 4.1 to 5.3) and dyslipidemia (OR 1.9; 95% CI 1.7 to 2.1). A large waist (risk II) was associated with hypertension 3.5; 95% CI 3.1 to 3.9), T2DM (OR 4.4; 95% CI 4.0 to 5.0) and dyslipidemia (OR 2.1; 95% CI 1.9 to 2.4).

Among men, obesity was also associated with hypertension (OR 3.2; 95% CI 2.8 to 3.6), T2DM (OR 2.7; 95% CI 2.4 to 3.0) and dyslipidemia (OR 2.0; 95% CI 1.7 to 2.3). A large waist (risk II) was associated with development of hypertension (OR 3.0; 95% CI 2.7 to 3.3), T2DM (OR 3.7; 95% CI 3.4 to 4.2) and dyslipidemia (OR 2.6; 95% CI 2.3 to 2.9) (Table 7.3-1).

Based on BMI, obese women are four to five times more likely (than lean counterparts) to have hypertension or T2DM, and twice more likely to be dyslipidemic. The odds were slightly different for obese men, who were approximately three times more likely to have hypertension or T2DM, but 2.6 times more likely to be dyslipidemic.

Using WC cut-offs, women with a large waist (risk 2) had a slightly lower likelihood to have hypertension or T2DM (but were still three to four time more likely to, compared to lean counterparts). A similar picture was painted for men with a large waist.

Using WC as a (categorical) co-variate, the odds for most morbidities reduced but stayed significantly higher in the overweight and obese groups (except obese men for T2DM, obese and overweight men for dyslipidemia, and obese women for dyslipidemia). The odds for many of comorbidities also reduced but stayed significantly higher in the Risk 1 and Risk 2 WC groups (Table 7.3-2). Among obese women, the odds of having hypertension reduced from 4.2 to 2.4, the odds of having T2DM reduced from 4.7 to 2.2, and the odds of having dyslipidemia became not significant. Among obese men, the odds of having T2DM and dyslipidemia became not significant ($p=0.201$, $p=0.656$, respectively) and the odds of having hypertension reduced from 3.2 to 2.0 (Table 7.3-2).

Table 7.3-1: Anthropometric factors associated with metabolic risks among Saudi adults using logistic regression (n=23,968)

Gender	Body composition [£]	Hypertension				T2DM				Dyslipidemia			
		B	OR	95% CI	p-value	B	OR	95% CI	p-value	B	OR	95% CI	p-value
Univariate regression													
♀	**Normal BMI** [a]				<0.0001				<0.0001				<0.0001
	Overweight	0.87	2.4	2.05-2.80	<0.0001	0.87	2.38	2.08-2.73	<0.0001	0.33	1.38	1.23-1.56	<0.0001
	Obese	1.42	4.12	3.58-4.76	<0.0001	1.55	4.7	4.14-5.32	<0.0001	0.64	1.9	1.7-2.12	<0.0001
	Constant	-2.43	0.09		<0.0001	-2.09	0.12		<0.0001	0.59	1.81		<0.0001
	Normal WC [b]				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.41	1.51	1.27-1.78	<0.0001	0.52	1.68	1.44-1.96	<0.0001	0.34	1.41	1.23-1.61	<0.0001
	Risk2 WC	1.24	3.47	3.06-3.93	<0.0001	1.49	4.43	3.95-4.98	<0.0001	0.76	2.13	1.92-2.37	<0.0001
	Constant	-2.21	0.11		<0.0001	-2.04	0.13		<0.0001	0.53	1.7		<0.0001
Univariate regression													
♂	**Normal BMI**				<0.0001				<0.0001				<0.0001
	Overweight	0.6	1.83	1.62-2.07	<0.0001	0.78	2.17	1.94-2.43	<0.0001	0.41	1.51	1.34-1.7	<0.0001
	Obese	1.15	3.17	2.8-3.59	<0.0001	1	2.71	2.41-3.04	<0.0001	0.68	1.98	1.74-2.25	<0.0001
	Constant	-1.8	0.16		<0.0001	-1.5	0.22		<0.0001	0.52	1.69		<0.0001
	Normal WC				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.52	1.69	1.48-1.93	<0.0001	0.76	2.14	1.89-2.42	<0.0001	0.52	1.68	1.47-1.92	<0.0001
	Risk2 WC	1.09	2.99	2.68-3.33	<0.0001	1.32	3.74	3.37-4.16	<0.0001	0.95	2.58	2.29-2.91	<0.0001
	Constant	-1.7	0.18		<0.0001	-1.6	0.2		<0.0001	0.42	1.51		<0.0001

[a] Categorization of overweight & obesity from BMI according to WHO (2014) (BMI 25-29.9 & BMI≥30 kg/m^2 respectively); [b] categorization of Risk1 & Risk2 WC (Risk1 WC 80-88 cm (♀), 94-102 cm (♂) & Risk2 WC>88 cm (♀),>102 cm (♂));

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.

OR: Odds Ratio; CI: 95% Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; WC: waist circumference; BMI: body mass index; HTN: hypertension; T2DM: Type 2 diabetes mellitus.

[£] All variables were adjusted for age.

Table 7.3-2: Odds ratios (and 95% CIs) for metabolic risks (normal weight, overweight, and obese adults) after multinomial regression with BMI and WC.

Gender	Body composition [£]	Hypertension				T2DM				Dyslipidemia			
		B	OR	95% CI	p-value	B	OR	95% CI	p-value	B	OR	95% CI	p-value
Multinomial regression													
♀	**Normal BMI [a]**				<0.0001				<0.0001				0.132
	Overweight	0.57	1.77	1.49-2.11	<0.0001	0.47	1.59	1.36-1.87	<0.0001	0.05	1.06	0.92-1.21	0.436
	Obese	0.89	2.44	2.04-2.91	<0.0001	0.81	2.25	1.92-2.65	<0.0001	0.15	1.16	1.0-1.35	0.054
	Normal WC [b]				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.15	1.17	0.97-1.39	0.094	0.31	1.36	1.16-1.61	<0.0001	0.3	1.35	1.16-1.56	<0.0001
	Risk2 WC	0.76	2.14	1.84-2.5	<0.0001	1.04	2.84	2.46-3.27	<0.0001	0.68	1.98	1.72-2.27	<0.0001
	Constant	-2.5	0.08		<0.0001	-2.3	0.1		<0.0001	0.48	1.62		<0.0001
Multinomial regression													
♂	**Normal BMI [a]**				<0.0001				<0.0001				0.631
	Overweight	0.38	1.46	1.27-1.68	<0.0001	0.31	1.37	1.2-1.55	<0.0001	0.07	1.07	0.93-1.22	0.34
	Obese	0.71	2.03	1.73-2.37	<0.0001	0.1	1.1	0.95-1.28	0.201	0.04	1.04	0.88-1.23	0.656
	Normal WC [b]				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.33	1.4	1.21-1.61	<0.0001	0.68	1.97	1.72-2.25	<0.0001	0.51	1.66	1.43-1.92	<0.0001
	Risk2 WC	0.72	2.06	1.79-2.36	<0.0001	1.26	3.53	3.09-4.03	<0.0001	0.93	2.55	2.19-2.96	<0.0001
	Constant	-1.9	0.15		<0.0001	-1.71	0.18		<0.0001	0.39	1.47		<0.0001

[a] Categorization of overweight & obesity from BMI according to WHO (2014) (BMI 25-29.9 & BMI≥30 kg/m^2 respectively); [b] categorization of Risk1 & Risk2 WC (Risk1 WC 80-88 cm (♀), 94-102 cm (♂) & Risk2 WC>88 cm (♀),>102 cm (♂)); [c] categorization of Substantially Increased Risk from WHR (WHR≥0.85 (♀), WHR≥0.90 (♂)); [d] categorization of obesity from WHtR (WHtR>0.5);
Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.
OR: Odds Ratio; CI: Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; WC: waist circumference; WHR:waist to hip ratio; WHtR: waist to height ratio; BMI: body mass index; HTN: hypertension; T2DM: Type 2 diabetes mellitus.
[£] All variables were adjusted for age.

7.3.2.2 Clustered comorbidity (any one morbidity or more)

Results of the logistic regression, which show the ORs for the various obesity-related comorbidities (any one or more) according to BMI category (e.g. normal weight, overweight or obese) and WC category (normal, Risk1 and Risk2 WC) are shown in Table 7.3-3.

Using univariate regression, as expected, the odds for all comorbidities were higher for overweight and obese compared to normal-weight subjects (Table 7.3-3). Among women, the obesity was positively associated with development of any morbidity (OR 3.1; 95% CI 2.8 to 3.4), any 2 comorbidities (OR 5.1; 95% CI 4.5 to 5.8) and any 3 comorbidities (OR 5.5; 95% CI 4.2 to 7.0). Also, Risk 2 WC was positively associated with development of any morbidity (OR 2.8; 95% CI 2.6 to 3.1), any 2 comorbidities (OR 5.2; 95% CI 4.6 to 5.8) and any 3 comorbidities (OR 6.8; 95% CI 5.3 to 8.8). Among men, obesity was also positively associated with development of any morbidity (OR 2.7; 95% CI 2.4 to 3.0), any 2 comorbidities (OR 3.4; 95% CI 3.0 to 3.8) and any 3 comorbidities (OR 4.4; 95% CI 3.6 to 5.6). Also, Risk 2 WC was positively associated with development of any morbidity (OR 4.3; 95% CI 3.9 to 4.8), any 2 comorbidities (OR 4.8; 95% CI 4.3 to 5.4) and any 3 comorbidities (OR 5.9; 95% CI 4.8 to 7.3) (Table 7.3-3).

Based on BMI cut offs, obese women were three times more likely to have any one morbidity, and approximately five times more likely to two or three co-morbidities. Based on WC cut-offs, women with a large waist (risk 2) were similarly approximately three times more likely to have any one morbidity, with the risk rising to five time for 2 co-morbidities and seven times for three co-morbidities, compared to lean counterparts. Similar, if not slightly lower odds, are depicted for men. Including WC as a covariate in the regression, the odds for comorbidities stayed significantly higher for overweight and obese individuals, but not for men with a single morbidity (Table 7.3-4). For women, the odds of having any single morbidity reduced from 3.1 to 1.8, the odds of having any 2 comorbidities reduced from 5.1 to 2.2, and the odds of having any 3 comorbidities reduced from 5.5 to 1.9. Among men, the odds of having any morbidity became not significant (p=0.95), the odds of having any 2 comorbidities reduced from 3.4 to 1.3, and the odds of having any 3 comorbidities reduced from 4.4 to 1.7 (Table 7.3-4).

Table 7.3-3: Anthropometric factors associated with metabolic risks among Saudi adults using logistic regression (n=23,968) (model: 0=Normal BMI, 1=Overweight and 2=Obese, and 0=Normal WC, 1=Risk1 WC and 2=Risk2 WC).

Body Composition [£]	Health Risks	Any morbidity				Any 2 co-morbidities				Any 3 co-morbidities			
		B	OR	95% CI	p-value	B	OR	95% CI	p-value	B	OR	95% CI	p-value
Before adding WC to BMI (categorical)													
♀	**Normal BMI [a]**												
	Overweight	0.53	1.69*	1.53-1.87	<0.0001	0.95	2.59*	2.26-2.97	<0.0001	0.94	2.56*	1.94-3.39	<0.0001
	Obese	1.12	3.07*	2.79-3.38	<0.0001	1.63	5.12*	4.52-5.8	<0.0001	1.7	5.46*	4.23-7.04	<0.0001
	Constant	0.15	1.16*		<0.0001	-2.08	0.13*		<0.0001	-3.79	0.02*		<0.0001
♂	**Normal BMI [a]**				<0.0001				<0.0001				<0.0001
	Overweight	0.51	1.66*	1.5-1.83	<0.0001	0.87	2.39*	2.13-2.68	<0.0001	0.88	2.41*	1.92-3.03	<0.0001
	Obese	0.99	2.70*	2.42-3.02	<0.0001	1.23	3.42*	3.05-3.85	<0.0001	1.49	4.45*	3.56-5.55	<0.0001
	Constant	0.28	1.32*		<0.0001	-1.58	0.21*		<0.0001	-3.4	0.03*		<0.0001
Before adding WC to BMI (categorical)													
♀	**Normal WC [b]**				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.38	1.46*	1.31-1.64	<0.0001	0.66	1.94*	1.67-2.26	<0.0001	0.7	2.01*	1.44-2.81	<0.0001
	Risk2 WC	1.03	2.79*	2.55-3.06	<0.0001	1.65	5.21*	4.63-5.85	<0.0001	1.92	6.82*	5.28-8.81	<0.0001
	Constant	0.24	1.27*		<0.0001	-2.07	0.13*		<0.0001	-3.95	0.02*		<0.0001
♂	**Normal WC [b]**				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.68	1.97*	1.76-2.21	<0.0001	0.89	2.44*	2.15-2.77	<0.0001	1	2.73*	2.13-3.5	<0.0001
	Risk2 WC	1.46	4.32*	3.87-4.81	<0.0001	1.58	4.84*	4.3-5.39	<0.0001	1.78	5.95*	4.84-7.31	<0.0001
	Constant	0.17	1.19*		<0.0001	-1.69	0.18*		<0.0001	-3.54	0.03*		<0.0001

[a] Categorization of overweight & obesity from BMI according to WHO (2014) (BMI 25-29.9 & BMI≥30 kg/m^2 respectively); [b] categorization of Risk1 & Risk2 WC (Risk1 WC 80-88 cm (♀), 94-102 cm (♂) & Risk2 WC>88 cm (♀),>102 cm (♂));

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.

OR: Odds Ratio; CI: Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; WC: waist circumference; BMI: body mass index; T2DM: Type 2 diabetes mellitus.

[£] All variables were adjusted for age.

Table 7.3-4: Odds ratios (and 95% CIs) for metabolic risks (normal weight, overweight, and obese adults) after combination of BMI and WC (categorical).

Body Composition [£]	Health Risks	Any morbidity				Any 2 co-morbidities				Any 3 co-morbidities			
		B	OR	CI1	p-value	B	OR	CI1	p-value	B	OR	CI1	p-value
After combination with WC (categorical) (0,1 &2)													
♀	**Normal BMI [a]**				<0.0001				<0.0001				<0.0001
	Overweight	0.24	1.27	1.13-1.42	<0.0001	0.46	1.59	1.36-1.86	<0.0001	0.26	1.3	0.94-1.78	0.11
	Obese	0.58	1.79	1.58-2.03	<0.0001	0.8	2.22	1.9-2.6	<0.0001	0.63	1.88	1.37-2.56	<0.0001
	Normal WC [b]				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.23	1.25	1.11-1.41	<0.0001	0.48	1.61	1.37-1.9	<0.0001	0.51	1.67	1.16-2.39	0.005
	Risk2 WC	0.69	1.99	1.78-2.24	<0.0001	1.24	3.44	2.98-3.98	<0.0001	1.55	4.69	3.45-6.37	<0.0001
	Constant	0.05	1.05		0.23	-2.36	0.09		<0.0001	-4.13	0.02		<0.0001
♂	**Normal BMI [a]**				0.509				<0.0001				0.001
	Overweight	0.05	1.06	0.94-1.18	0.337	0.35	1.42	1.24-1.62	<0.0001	0.35	1.42	1.09-1.84	0.01
	Obese	0	1	0.86-1.15	0.951	0.23	1.26	1.08-1.47	0.003	0.55	1.73	1.31-2.28	<0.0001
	Normal WC [b]				<0.0001				<0.0001				<0.0001
	Risk1 WC	0.68	1.97	1.75-2.23	<0.0001	0.78	2.18	1.9-2.49	<0.0001	0.87	2.39	1.83-3.13	<0.0001
	Risk2 WC	1.48	4.38	3.83-5.02	<0.0001	1.45	4.25	3.72-4.86	<0.0001	1.51	4.53	3.52-5.83	<0.0001
	Constant	0.12	1.12		0.003	-1.84	0.16		<0.0001	-3.75	0.02		<0.0001

[a] Categorization of overweight & obesity from BMI according to WHO (2014) (BMI 25-29.9 & BMI≥30 kg/m^2 respectively); [b] categorization of Risk1 & Risk2 WC (Risk1 WC 80-88 cm (♀), 94-102 cm (♂) & Risk2 WC>88 cm (♀),>102 cm (♂));

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.

OR: Odds Ratio; CI: Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; WC: waist circumference; WHR:waist to hip ratio; WHtR: waist to height ratio; BMI: body mass index; HTN: hypertension; T2DM: Type 2 diabetes mellitus.

[£] All variables were adjusted for age.

7.3.3 Prediction of the body composition-related metabolic risks as categorical variables (deciles)

BMI and WC were categorised as deciles and used to model (co)morbidity risk in the population, since traditional cut-offs may not be optimum in this population.

Results of the logistic regression, which show the ORs for the various obesity-related comorbidities (any one or more comorbidities) according to BMI and deciles are shown in Table 7.3-5**.** In both men and women, the risk of having one or more morbidity increased with increasing deciles of BMI and WC.

Among women, each extra decile of BMI was associated with having (any) one morbidity (OR 1.1; 95% CI 1.1-1.1), any 2 comorbidities (OR 1.2; 95% CI 1.1-1.2) and any 3 comorbidities (OR 1.2; 95% CI 1.1-1.2). Similar odds were seen for each extra decile of WC. The picture was similar for men, except for a slightly increased odd (OR 1.29; 95% CI 1.25 to 1.34) of having any 3 co-morbidities for each extra decile of WC (Table 7.3-5).

When adding WC and BMI as covariates in the regression models, odds for many of the comorbidities stayed significantly higher in BMI (except for BMI any morbidity) (Table 7.3-6). In both men and women, the odds of having 2 or 3 comorbidities reduced from 1.2 to 1.1 (Table 7.3-6).

Table 7.3-5: Odds ratios and 95% confidence intervals for development of metabolic diseases (any morbidity or more) according to increasing deciles of each anthropometric and body composition parameters (age-adjusted).

Body Composition [£]	Gender	Any morbidity					Any 2 co-morbidities					Any 3 co-morbidities				
		B	**SE**	**OR**	**95% CI**	***p*-value**	**B**	**SE**	**OR**	**95% CI**	***p*-value**	**B**	**SE**	**OR**	**95% CI**	***p*-value**
BMI (Deciles)	♀	0.11	0.01	1.12	1.10-1.14	<0.0001	0.16	0.01	1.17	1.15-1.19	<0.0001	0.17	0.01	1.19	1.15-1.22	<0.0001
	♂	0.10	0.01	1.11	1.09-1.13	<0.0001	0.17	0.01	1.18	1.16-1.20	<0.0001	0.22	0.02	1.25	1.21-1.29	<0.0001
WC (Deciles)	♀	0.10	0.01	1.11	1.09-1.12	<0.0001	0.17	0.01	1.18	1.16-1.20	<0.0001	0.20	0.02	1.22	1.18-1.26	<0.0001
	♂	0.18	0.01	1.20	1.18-1.22	<0.0001	0.21	0.01	1.23	1.21-1.25	<0.0001	0.26	0.02	1.29	1.25-1.34	<0.0001

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with systolic BP≥140 or Diastolic BP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive.
OR: Odds Ratio; CI: Confidence Interval; BMI: body mass index; BP: blood pressure; WC: waist circumference.
*Value was significant (p<0.05).
[£] All variables were adjusted for age.

Table 7.3-6: Odds ratios and 95% confidence intervals for development of metabolic diseases (any morbidity, any 2 co-morbidities and any 3 co-morbidities) according to increasing deciles of combined WC and BMI (age-adjusted)

Body Composition [£]		Any morbidity					Any 2 co-morbidities					Any 3 co-morbidities				
		B	**SE**	**OR**	**95% CI**	***p*-value**	**B**	**SE**	**OR**	**95% CI**	***p*-value**	**B**	**SE**	**OR**	**95% CI**	***p*-value**
Combined BMI and WC (Women)	BMI	0.075	0.01	1.078	1.06-1.10	<0.0001	0.091	0.012	1.095	1.07-1.12	<0.0001	0.087	0.02	1.091	1.05-1.13	<0.0001
	WC	0.05	0.011	1.051	1.03-1.07	<0.0001	0.108	0.012	1.114	1.09-1.14	<0.0001	0.144	0.021	1.154	1.11-1.20	<0.0001
Combined BMI and WC (Men)	BMI	-0.03	0.011	0.97	0.95-0.99	0.006	0.057	0.013	1.058	1.03-1.09	<0.0001	0.117	0.021	1.125	1.08-1.17	<0.0001
	WC	0.206	0.012	1.229	1.20-1.26	<0.0001	0.167	0.013	1.182	1.15-1.21	<0.0001	0.174	0.022	1.19	1.14-1.24	<0.0001

[£] All variables were adjusted for age.

7.3.4 Prediction trends of metabolic risks among the deciles of anthropometric and body composition measures

This section shows the prediction trend for development of metabolic diseases with increasing deciles of different anthropometric indices using age adjusted logistic regression analyses.

A significant association between any morbidity and WC was observed from 93 cm (5^{th} decile) to 181 cm (10^{th} decile) in women, and from 93 cm (4^{th} decile) to 287 cm (10^{th} decile) in men (Table 7.3-7 and Table 7.3-8). Association between WC and any 2 co-morbidities and any 3 co-morbidities, started at 89 cm (6^{th} decile) to 181 cm (10^{th} decile) in women, and 97 cm (5^{th} decile) to 287 cm (10^{th} decile) in men (Table 7.3-7 and Table 7.3-8).

As waists go larger from 93 cm onwards, the odds for morbidities / co-morbidities increased, from 1.3 to 2.2 for a single morbidity, 1.4 to 3.3 for 2 co-morbidities and 2.1 to 5.4 for 3 co-morbidities in women. In men, similar odds are observed, except for the highest deciles of waist, where odds are markedly higher than for women, for any one or more co-morbidities.

A significant association between BMI as deciles and any single morbidity from the 2^{nd} decile (BMI 24) to the 10^{th} decile (BMI 76) for women (with the exception of the 3^{rd} decile, and the 3^{rd} decile (BMI 25) to the 10^{th} decile (BMI 73) in men (with the exception of the 4^{th} decile) (

Table 7.3-9 and Table 7.3-10).

As BMI deciles increase, the odds for morbidities / co-morbidities increased, from 1.3 to 3.2 for a single morbidity, 1.9 to 6.3 for 2 co-morbidities and 3.4 to 12.0 for 3 co-morbidities in women. In men, similar odds are observed, except for the highest deciles of BMI, were odds are slightly lower than women for any one or two morbidities, and slightly higher for 3 co-morbidities.

Table 7.3-7: Risk of metabolic diseases associated with increasing WC in Saudi women, based on regression (adjusted for age).

Body Composition [£]	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WC Decile1	67						<0.0001						<0.0001						<0.0001
WC Decile2	75	-0.11	0.08	0.90	0.76	1.06	0.197	-0.39	0.15	0.68	0.51	0.91	0.009	-0.21	0.35	0.81	0.41	1.61	0.553
WC Decile3	80	-0.13	0.09	0.87	0.74	1.04	0.123	-0.07	0.14	0.93	0.71	1.22	0.611	0.34	0.30	1.40	0.78	2.51	0.260
WC Decile4	85	0.14	0.09	1.16	0.97	1.37	0.100	0.25	0.13	1.28	1.00	1.65	0.052	0.52	0.28	1.68	0.97	2.92	0.065
WC Decile5	**89**	0.06	0.09	1.06	0.89	1.26	0.506	**0.37**	**0.12**	**1.44**	**1.13**	**1.84**	**0.003**	**0.76**	**0.27**	**2.14**	**1.27**	**3.61**	**0.004**
WC Decile6	**93**	**0.30**	**0.09**	**1.36**	**1.13**	**1.62**	**0.001**	0.58	0.12	1.78	1.40	2.25	<0.0001	0.88	0.26	2.41	1.45	4.00	0.001
WC Decile7	98	0.49	0.09	1.64	1.37	1.96	<0.0001	0.78	0.12	2.19	1.74	2.76	<0.0001	1.13	0.25	3.11	1.91	5.07	<0.0001
WC Decile8	102	0.43	0.10	1.53	1.26	1.86	<0.0001	0.85	0.12	2.35	1.85	2.97	<0.0001	1.38	0.25	3.98	2.45	6.49	<0.0001
WC Decile9	109	0.78	0.10	2.17	1.77	2.67	<0.0001	1.10	0.12	3.01	2.39	3.81	<0.0001	1.43	0.25	4.20	2.59	6.80	<0.0001
WC Decile10	181	0.78	0.10	2.17	1.77	2.67	<0.0001	1.20	0.12	3.32	2.63	4.19	<0.0001	1.70	0.24	5.45	3.39	8.78	<0.0001
Age		0.04	0.00	1.04	1.03	1.04	<0.0001	0.07	0.00	1.07	1.07	1.07	<0.0001	0.06	0.00	1.07	1.06	1.07	<0.0001
Constant		-0.91	0.08	0.40			<0.0001	-4.38	0.12	0.01			<0.0001	-6.54	0.27	0.00			<0.0001

Subjects; with triglyceride >= 1.7 mmol/L, HDL cholesterol <1.04 mmol/L (♂) and <1.30 mmol/L (♀), and/or total Cholesterol ≥6.2 mmol/L, or diagnosed by physician were considered as dyslipidaemic; with T2DM and/or with HbA1c ≥6.1 mmol/L were considered as diabetic individuals; and with SBP≥140 or DBP≥90 mmHg, and/or diagnosed by physician with hypertension were considered as hypertensive;
Any morbidity: any subject with HTN, T2DM or Dys; Any 2 co-morbidities: any subject with HTN and T2DM, HTN and Dys, or T2DM and Dys; Any 2 co-morbidities: HTN, T2DM and Dys;
OR: Odds Ratio; CI: Confidence Interval; SBP: Systolic blood pressure; DBP: diastolic blood pressure; Dys: Dyslipidaemia; HTN: hypertension; T2DM: Type 2 diabetes mellitus; BMI: Body mass index; WC: Waist circumference; WHR: Waist to hip ratio; WHtR: Waist to height ratio.
[£] All variables were adjusted for age.

Table 7.3-8: Risk of metabolic diseases associated with increasing WC in Saudi men, based on regression (adjusted for age).

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WC Decile1	74						<0.0001						0<0.0001						<0.0001
WC Decile2	82	-0.16	0.10	0.85	0.71	1.03	0.095	-0.16	0.15	0.85	0.64	1.14	0.283	-0.33	0.33	0.72	0.37	1.37	0.313
WC Decile3	88.3	0.01	0.10	1.01	0.83	1.21	0.947	-0.02	0.14	0.98	0.74	1.30	0.912	0.14	0.29	1.15	0.65	2.02	0.632
WC Decile4	**93**	**0.33**	**0.09**	**1.40**	**1.16**	**1.68**	**0.000**	0.05	0.14	1.05	0.80	1.37	0.737	0.07	0.29	1.07	0.61	1.88	0.802
WC Decile5	**97**	0.50	0.10	1.64	1.36	1.99	<0.0001	**0.52**	**0.13**	**1.69**	**1.30**	**2.18**	**0.000**	**0.53**	**0.26**	**1.69**	**1.01**	**2.84**	**0.046**
WC Decile6	101	0.54	0.10	1.71	1.41	2.07	<0.0001	0.72	0.13	2.06	1.60	2.64	0.000	0.89	0.25	2.44	1.50	3.98	<0.0001
WC Decile7	105	0.95	0.11	2.59	2.10	3.19	<0.0001	0.93	0.13	2.53	1.97	3.24	0.000	0.93	0.25	2.55	1.57	4.12	<0.0001
WC Decile8	110	1.26	0.11	3.52	2.82	4.39	<0.0001	1.24	0.13	3.44	2.69	4.41	0.000	1.30	0.24	3.67	2.29	5.87	<0.0001
WC Decile9	118	1.26	0.11	3.52	2.82	4.40	<0.0001	1.26	0.13	3.53	2.75	4.53	0.000	1.49	0.24	4.44	2.78	7.09	<0.0001
WC Decile10	287	1.44	0.12	4.21	3.34	5.30	<0.0001	1.55	0.13	4.73	3.69	6.07	0.000	1.97	0.24	7.20	4.54	11.41	<0.0001
Age		0.04	0.00	1.04	1.04	1.05	<0.0001	0.07	0.00	1.07	1.06	1.07	0.000	0.06	0.00	1.06	1.06	1.07	<0.0001
Constant		-1.46	0.09	0.23			<0.0001	-4.47	0.13	0.01			0.000	-6.29	0.26	0.00			<0.0001

[£] All variables were adjusted for age.

Table 7.3-9: Risk of metabolic diseases associated with increasing BMI in Saudi women, based on regression (adjusted for age).

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
BMI Decile1	21.4						<0.0001						<0.0001						<0.0001
BMI Decile2	**23.9**	**0.17**	**0.08**	**1.19**	**1.01**	**1.40**	**0.039**	**0.65**	**0.16**	**1.92**	**1.41**	**2.62**	<0.0001	**1.24**	**0.39**	**3.44**	**1.61**	**7.35**	**0.001**
BMI Decile3	25.9	0.12	0.08	1.13	0.96	1.33	0.153	0.78	0.15	2.18	1.62	2.94	<0.0001	1.52	0.37	4.56	2.20	9.48	<0.0001
BMI Decile4	**27.5**	**0.23**	**0.09**	**1.26**	**1.06**	**1.49**	**0.008**	0.94	0.15	2.56	1.91	3.43	<0.0001	1.35	0.37	3.86	1.86	8.01	<0.0001
BMI Decile5	29.2	0.36	0.09	1.43	1.20	1.69	<0.0001	1.16	0.15	3.20	2.40	4.25	<0.0001	1.70	0.37	5.49	2.68	11.24	<0.0001
BMI Decile6	30.8	0.48	0.09	1.62	1.36	1.92	<0.0001	1.22	0.14	3.40	2.56	4.52	<0.0001	1.73	0.36	5.63	2.77	11.47	<0.0001
BMI Decile7	32.5	0.57	0.09	1.77	1.48	2.12	<0.0001	1.37	0.14	3.94	2.98	5.22	<0.0001	1.99	0.36	7.35	3.64	14.84	<0.0001
BMI Decile8	35	0.67	0.09	1.96	1.63	2.35	<0.0001	1.54	0.14	4.66	3.52	6.16	<0.0001	2.11	0.36	8.21	4.08	16.53	<0.0001
BMI Decile9	38.3	0.89	0.10	2.44	2.02	2.94	<0.0001	1.60	0.14	4.94	3.73	6.52	<0.0001	2.23	0.36	9.26	4.61	18.59	<0.0001
BMI Decile10	75.7	1.15	0.10	3.17	2.60	3.86	<0.0001	1.84	0.14	6.32	4.79	8.34	<0.0001	2.49	0.35	12.04	6.02	24.09	<0.0001
Age		0.04	0.00	1.04	1.04	1.04	<0.0001	0.07	0.00	1.07	1.07	1.08	<0.0001	0.07	0.00	1.07	1.07	1.08	<0.0001
Constant		-1.26	0.08	0.28			<0.0001	-5.23	0.15	0.01			<0.0001	-7.63	0.37	0.00			<0.0001

[£] All variables were adjusted for age.

Table 7.3-10: Risk of metabolic diseases associated with increasing BMI in Saudi men, based on regression (adjusted for age).

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
BMI Decile1	21.0						<0.0001						<0.0001						<0.0001
BMI Decile2	**23.2**	-0.01	0.10	0.99	0.83	1.20	0.955	**0.37**	**0.15**	**1.45**	**1.07**	**1.95**	**0.015**	**0.99**	**0.39**	**2.70**	**1.26**	**5.78**	**0.010**
BMI Decile3	**24.8**	**0.20**	**0.10**	**1.22**	**1.01**	**1.48**	**0.037**	0.57	0.15	1.77	1.33	2.36	<0.0001	1.37	0.37	3.95	1.91	8.19	<0.0001
BMI Decile4	26.0	0.04	0.10	1.04	0.86	1.26	0.688	0.75	0.14	2.11	1.59	2.79	<0.0001	1.31	0.37	3.71	1.79	7.70	<0.0001
BMI Decile5	**27.3**	**0.38**	**0.10**	**1.46**	**1.20**	**1.77**	**<0.0001**	1.01	0.14	2.75	2.08	3.62	<0.0001	1.76	0.36	5.83	2.86	11.91	<0.0001
BMI Decile6	28.6	0.26	0.10	1.30	1.07	1.58	0.007	1.12	0.14	3.06	2.32	4.03	<0.0001	1.80	0.36	6.08	2.98	12.38	<0.0001
BMI Decile7	30.1	0.45	0.10	1.57	1.29	1.91	<0.0001	1.28	0.14	3.58	2.72	4.71	<0.0001	1.97	0.36	7.18	3.55	14.54	<0.0001
BMI Decile8	31.9	0.66	0.10	1.93	1.58	2.36	<0.0001	1.35	0.14	3.87	2.95	5.09	<0.0001	2.14	0.36	8.52	4.22	17.19	<0.0001
BMI Decile9	34.9	0.91	0.11	2.48	2.01	3.04	<0.0001	1.48	0.14	4.38	3.34	5.75	<0.0001	2.52	0.35	12.41	6.19	24.87	<0.0001
BMI Decile10	72.4	0.85	0.10	2.35	1.92	2.87	<0.0001	1.69	0.14	5.43	4.14	7.13	<0.0001	2.72	0.35	15.23	7.60	30.53	<0.0001
Age		0.05	0.00	1.05	1.05	1.05	<0.0001	0.07	0.00	1.07	1.07	1.08	<0.0001	0.06	0.00	1.07	1.06	1.07	<0.0001
Constant		-1.56	0.08	0.21			<0.0001	-4.96	0.14	0.01			<0.0001	-7.46	0.37	0.00			<0.0001

[£] All variables were adjusted for age.

A significant association between waist to hip ratio (WHR) and any morbidity was observed starting from 0.8 (3rd decile) to 1.9 (10th decile) in women and 1.0 (5th decile) to 2.4 (10th decile) in men. For any 2 co-morbidities, association started from 0.9 (7th decile) to 1.9 (10th decile) in women and 0.9 (3rd decile) to 2.4 (10th decile) in men. For any 3 co-morbidities, the association started from 0.8 (6th decile) to 1.9 (10th decile) for women and 1.0 (4th decile) to 2.4 (10th decile) in men (Table 7.3-11 and Table 7.3-12).

As WHR go larger from 0.78 onwards, the odds for morbidities / co-morbidities increased, from 1.6 to 3.4 for a single morbidity, 1.5 to 2.4 for 2 co-morbidities and 1.8 to 2.4 for 3 co-morbidities in women. In men, similar odds are observed, except for the highest deciles of WHR, where odds are markedly lower than for women, for 3 co-morbidities.

A significant association between any morbidity and waist to height ratio (WHtR) was observed starting from 0.6 (6th decile) to 1.2 (10th decile) for women and 0.5 (4th decile) to 1.63 (10th decile) for men (

Table 7.3-13 and Table 7.3-14). For any 2 co-morbidities, associations started from 0.6 (5th decile) to 1.2 (10th decile) and 0.58 (5th decile) to 1.63 (10th decile) for women and men, respectively. For any 3 co-morbidities, associations started from 0.5 (4th decile) to 1.2 (10th decile) for women and 0.6 (5th decile) to 1.6 (10th decile) for men.

As WHtR go larger from 0.60 onwards, the odds for morbidities / co-morbidities increased, from 1.4 to 2.6 for a single morbidity, 1.5 to 3.5 for 2 co-morbidities and 1.3 to 3.3 for 3 co-morbidities in women. In men, similar odds are observed, except for the highest deciles of WHtR, where odds are markedly higher than for women, for any one or more co-morbidities.

Table 7.3-11: Risk of metabolic diseases associated with increasing WHR in Saudi women, based on regression (adjusted for age)

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WHR Decile1	0.71						<0.0001						<0.0001						<0.0001
WHR Decile2	0.75	0.13	0.12	1.14	0.90	1.44	0.270	-0.46	0.16	0.63	0.46	0.86	0.003	-0.35	0.33	0.70	0.37	1.35	0.287
WHR Decile3	**0.78**	**0.48**	**0.13**	**1.62**	**1.26**	**2.08**	<0.0001	0.03	0.14	1.03	0.78	1.36	0.849	0.10	0.29	1.11	0.63	1.95	0.726
WHR Decile4	0.81	0.37	0.13	1.44	1.12	1.86	0.004	0.01	0.14	1.01	0.76	1.33	0.964	0.14	0.28	1.15	0.66	1.98	0.627
WHR Decile5	0.84	0.36	0.13	1.43	1.10	1.85	0.007	0.20	0.14	1.22	0.93	1.60	0.150	0.37	0.26	1.44	0.86	2.42	0.164
WHR Decile6	**0.86**	0.58	0.14	1.79	1.36	2.35	<0.0001	0.19	0.14	1.21	0.92	1.59	0.163	**0.58**	**0.26**	**1.78**	**1.08**	**2.95**	**0.024**
WHR Decile7	**0.89**	0.69	0.15	2.00	1.50	2.68	<0.0001	**0.43**	**0.14**	**1.53**	**1.17**	**2.00**	**0.002**	0.58	0.25	1.79	1.09	2.95	0.022
WHR Decile8	0.92	0.85	0.16	2.34	1.72	3.19	<0.0001	0.63	0.14	1.88	1.44	2.45	<0.0001	0.84	0.25	2.32	1.43	3.77	0.001
WHR Decile9	0.95	1.13	0.17	3.08	2.22	4.29	<0.0001	0.68	0.14	1.97	1.50	2.57	<0.0001	0.87	0.25	2.38	1.46	3.86	<0.0001
WHR Decile10	1.89	1.23	0.18	3.42	2.40	4.87	<0.0001	0.87	0.14	2.39	1.82	3.14	<0.0001	0.90	0.25	2.45	1.51	3.98	<0.0001
Age		0.04	0.00	1.04	1.04	1.05	<0.0001	0.08	0.00	1.08	1.08	1.09	<0.0001	0.07	0.00	1.07	1.06	1.08	<0.0001
Constant		-0.42	0.12	0.66			<0.0001	-4.23	0.14	0.01			<0.0001	-5.83	0.26	0.00			<0.0001

[£] All variables were adjusted for age.

Table 7.3-12: Risk of metabolic diseases associated with increasing WHR in Saudi men, based on regression (adjusted for age)

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WHR Decile1	0.83						<0.0001						<0.0001						<0.0001
WHR Decile2	0.90	0.01	0.14	1.01	0.77	1.32	0.944	0.19	0.16	1.21	0.88	1.67	0.244	0.32	0.33	1.38	0.72	2.61	0.329
WHR Decile3	**0.95**	0.15	0.14	1.16	0.87	1.54	0.303	**0.52**	**0.16**	**1.69**	**1.24**	**2.30**	**0.001**	0.33	0.32	1.39	0.74	2.59	0.307
WHR Decile4	**1.01**	0.21	0.16	1.24	0.91	1.68	0.176	0.69	0.16	1.99	1.46	2.70	<0.0001	**0.96**	**0.29**	**2.62**	**1.49**	**4.62**	**0.001**
WHR Decile5	**1.03**	**1.35**	**0.23**	**3.85**	**2.45**	**6.04**	<0.0001	1.02	0.16	2.78	2.04	3.80	<0.0001	0.97	0.29	2.63	1.50	4.61	0.001
WHR Decile6	1.05	1.03	0.20	2.81	1.90	4.16	<0.0001	1.11	0.16	3.02	2.21	4.13	<0.0001	1.22	0.28	3.38	1.94	5.90	<0.0001
WHR Decile7	1.07	1.66	0.23	5.27	3.36	8.27	<0.0001	0.98	0.16	2.67	1.96	3.64	<0.0001	1.02	0.29	2.78	1.58	4.89	<0.0001
WHR Decile8	1.11	0.90	0.18	2.46	1.73	3.49	<0.0001	0.84	0.16	2.32	1.70	3.15	<0.0001	1.28	0.28	3.59	2.05	6.26	<0.0001
WHR Decile9	1.17	1.19	0.18	3.30	2.32	4.68	<0.0001	0.56	0.16	1.74	1.28	2.38	<0.0001	0.90	0.29	2.46	1.38	4.39	0.002
WHR Decile10	2.37	0.69	0.15	2.00	1.49	2.68	<0.0001	0.53	0.16	1.69	1.23	2.33	0.001	0.23	0.33	1.26	0.66	2.40	0.480
Age		0.05	0.00	1.05	1.04	1.06	<0.0001	0.07	0.00	1.07	1.07	1.08	<0.0001	0.05	0.00	1.06	1.05	1.06	<0.0001
Constant		-0.69	0.14	0.50			<0.0001	-4.19	0.16	0.02			<0.0001	-5.50	0.29	0.00			<0.0001

[£] All variables were adjusted for age.

Table 7.3-13: Risk of metabolic diseases associated with increasing WHtR in Saudi women, based on regression (adjusted for age)

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WHtR Decile1	0.43						<0.0001						<0.0001						<0.0001
WHtR Decile2	0.48	-0.04	0.09	0.96	0.81	1.14	0.668	-0.32	0.15	0.72	0.54	0.97	0.033	0.19	0.33	1.21	0.63	2.33	0.576
WHtR Decile3	0.51	-0.06	0.09	0.94	0.79	1.11	0.454	-0.03	0.14	0.97	0.74	1.27	0.813	-0.17	0.35	0.85	0.43	1.68	0.635
WHtR Decile4	**0.54**	0.06	0.09	1.06	0.89	1.26	0.518	0.15	0.13	1.17	0.90	1.51	0.242	**0.83**	**0.28**	**2.29**	**1.32**	**3.96**	**0.003**
WHtR Decile5	**0.57**	0.13	0.09	1.13	0.95	1.35	0.156	**0.39**	**0.13**	**1.47**	**1.15**	**1.89**	**0.002**	0.58	0.28	1.78	1.02	3.11	0.042
WHtR Decile6	**0.60**	**0.35**	**0.09**	**1.42**	**1.19**	**1.70**	<0.0001	0.59	0.12	1.80	1.41	2.28	<0.0001	0.97	0.27	2.64	1.56	4.46	<0.0001
WHtR Decile7	0.63	0.44	0.09	1.56	1.30	1.87	<0.0001	0.70	0.12	2.01	1.59	2.56	<0.0001	1.02	0.26	2.77	1.65	4.66	<0.0001
WHtR Decile8	0.66	0.55	0.10	1.73	1.43	2.09	<0.0001	0.90	0.12	2.46	1.94	3.11	<0.0001	1.24	0.26	3.47	2.09	5.76	<0.0001
WHtR Decile9	0.7	0.83	0.10	2.30	1.88	2.82	<0.0001	1.12	0.12	3.08	2.44	3.90	<0.0001	1.57	0.25	4.79	2.91	7.87	<0.0001
WHtR Decile10	1.21	0.97	0.11	2.64	2.14	3.26	<0.0001	1.25	0.12	3.51	2.77	4.44	<0.0001	1.69	0.25	5.45	3.32	8.92	<0.0001
Age		0.04	0.00	1.04	1.03	1.04	<0.0001	0.07	0.00	1.07	1.06	1.07	<0.0001	0.06	0.00	1.07	1.06	1.07	<0.0001
Constant		-0.91	0.08	0.40			<0.0001	-4.36	0.13	0.01			<0.0001	-6.52	0.27	0.00			<0.0001

£ All variables were adjusted for age.

Table 7.3-14: Risk of metabolic diseases associated with increasing WHtR in Saudi men, based on regression (adjusted for age)

Body Composition	Decile	Any morbidity						Any 2 co-morbidities						Any 3 co-morbidities					
		B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value	B	SE	OR	CI1	CI2	p-value
WHtR Decile1	0.44						<0.0001						<0.0001						<0.0001
WHtR Decile2	0.49	-0.18	0.10	0.83	0.69	1.00	0.055	-0.18	0.15	0.84	0.62	1.13	0.245	-0.08	0.33	0.92	0.48	1.77	0.811
WHtR Decile3	0.53	0.09	0.10	1.09	0.91	1.32	0.361	-0.09	0.15	0.92	0.69	1.22	0.559	0.30	0.30	1.35	0.75	2.43	0.314
WHtR Decile4	**0.55**	**0.34**	**0.10**	**1.41**	**1.17**	**1.70**	<0.0001	0.24	0.14	1.27	0.96	1.67	0.090	-0.43	0.35	0.65	0.33	1.28	0.212
WHtR Decile5	**0.58**	0.47	0.10	1.60	1.32	1.94	<0.0001	**0.51**	**0.13**	**1.66**	**1.28**	**2.16**	<0.0001	**0.70**	**0.27**	**2.01**	**1.17**	**3.44**	**0.011**
WHtR Decile6	0.60	0.81	0.10	2.24	1.84	2.73	<0.0001	0.65	0.13	1.91	1.48	2.47	<0.0001	0.84	0.26	2.32	1.38	3.90	0.001
WHtR Decile7	0.63	0.94	0.11	2.55	2.07	3.15	<0.0001	0.88	0.13	2.41	1.87	3.11	<0.0001	1.08	0.26	2.93	1.76	4.89	<0.0001
WHtR Decile8	0.66	1.17	0.11	3.21	2.58	4.00	<0.0001	1.22	0.13	3.39	2.64	4.36	<0.0001	1.29	0.25	3.63	2.21	5.96	<0.0001
WHtR Decile9	0.70	1.46	0.12	4.29	3.40	5.41	<0.0001	1.28	0.13	3.59	2.79	4.62	<0.0001	1.54	0.25	4.66	2.85	7.63	<0.0001
WHtR Decile10	1.63	1.46	0.12	4.30	3.42	5.42	<0.0001	1.60	0.13	4.94	3.85	6.35	<0.0001	2.01	0.25	7.44	4.58	12.06	<0.0001
Age		0.04	0.00	1.04	1.04	1.04	<0.0001	0.06	0.00	1.07	1.06	1.07	<0.0001	0.06	0.00	1.06	1.05	1.06	<0.0001
Constant		-1.43	0.09	0.24			<0.0001	-4.39	0.13	0.01			<0.0001	-6.22	0.27	0.00			<0.0001

£ All variables were adjusted for age.

7.3.5 Defining Saudi specific cut-off points for BMI, WC, and waist to hip / height ratio in relation to estimated metabolic risk

This section is defining Saudi specific cut-off points based on Receiver Operator Curves (ROC) for the metabolic diseases defined.

7.3.5.1 Best anthropometric measure to predict health risks

ROC curves of obesity-related anthropometric measures to predict metabolic risks were compared by using the method of DeLong et al. (DeLong, DeLong et al. 1988), which accounts for the correlation among variables. Table 7.3-15 shows the diagnostic performance of anthropometric measures in predicting (co-)morbidities (hypertension, T2DM, dyslipidemia, any morbidity, any 2 co-morbidities and any 3 co-morbidities).

In women, WC (cm) provided the highest Area Under Curve (AUC) in predicting hypertension (0.66), T2DM (0.71) and dyslipidemia (0.62) compared to other anthropometric measures. BMI provided the lowest AUC in predicting hypertension (0.65), T2DM (0.66) and dyslipidemia (0.54). Also, WC provided the highest level of AUC in predicting any single morbidity (0.69), any 2 comorbidities (0.73) and any 3 comorbidities (0.72) compared to other anthropometric measures. BMI provided the lowest AUC in predicting any single morbidity (0.65), any 2 comorbidities (0.67) and any 3 comorbidities (0.67).

In men, the picture is fairly similar: WC provided the highest AUC in predicting T2DM (0.64), dyslipidemia (0.64), but not hypertension (0.64) compared to other anthropometric measures. BMI provided the lowest AUC for T2DM (0.62), dyslipidemia (0.58), hypertension (0.65). WC also provided the highest AUC for any single morbidity (0.69), any 2 comorbidities (0.68) and any 3 comorbidities (0.69) compared with other anthropometric measures. BMI provided the lowest AUC for any morbidity (0.65), any 2 comorbidities (0.65) and any 3 comorbidities (0.67).

Figure 7.3-1 and Figure 7.3-2 show the receiver operating characteristic curves (ROC) for different anthropometric measures to predict the presence of hypertension, T2DM, dyslipidemia, any morbidity, any 2 comorbidities, and any 3 comorbidities, in women and men.

Based on the ROC analyses, calculated cut-off points for WC in Saudi women range from 90 to 92 cm and 94 to 99 cm for men. The new WC cut-off for women is higher than the traditional cut-off (88 cm) but the new WC cut-off for men is lower than the traditional cut-off (102 cm). Similarly, the calculated BMI cut-off points for Saudi women range from 28.2 to 29.7 (kg/m^2) and 25.9 to 27.7 (kg/m^2) for men. The new BMI cut-offs for both gender are lower than the traditional cut-off (30 kg/m^2) with the men, having slightly lower cut-off than women. Similarly, the calculated WHtR cut-off points for Saudi women range from 0.57 to 0.59 and 0.56 to 0.59 for men. The new WHtR cut-offs for both gender are higher than the traditional cut-off (0.5). Similarly, the calculated WHR cut-off points for Saudi women range from 0.82 to 0.85 and 0.98 to 1.0 for men. The new WHR cut-off for women is nearly similar to the traditional cut-off (0.85) but the new WC cut-off for men is higher than the traditional cut-off (0.90).

Table 7.3-15: Diagnostic performance of anthropometric measures in predicting co-morbidity* (hypertension, T2DM, dyslipidemia, any morbidity, any 2 co-morbidities and any 3 co-morbidities) using optimal anthropometric cut-off values based on the shortest distance in ROC curves in Saudi adults (n=23,968). [$]

Metabolic Risks		BMI (kg/m^2) (n=22,416)				WC (cm) (n=21,062)				WHR (n=12,552)				WHtR (n=20,854)			
		AUC	SE	CI	Cut-off	AUC	SE	CI	Cut-off	AUC	SE	CI	Cut-off	AUC	SE	CI	Cut-off
Hypertension*	♀	0.648	0.008	0.637-0.660	29.0	**0.663**	0.008	0.652-0.674	90.5	0.621	0.008	0.610-0.633	0.82	**0.652**	0.008	0.641-0.664	0.58
	♂	**0.655**	0.008	0.642-0.668	27.7	**0.638**	0.009	0.624-0.650	99	0.509	0.009	0.495-0.522	0.98	0.631	0.008	0.618-0.644	0.59
T2DM*	♀	0.661	0.007	0.650-0.672	29.2	**0.706**	0.007	0.695-0.717	90.6	0.689	0.007	0.678-0.700	0.85	**0.693**	0.006	0.682-0.704	0.58
	♂	0.616	0.008	0.603-0.629	26.5	**0.637**	0.008	0.624-0.650	97	0.567	0.008	0.553-0.580	1.0	**0.628**	0.007	0.615-0.641	0.59
Dyslipidaemia*	♀	0.573	0.008	0.561-0.585	29.0	**0.617**	0.008	0.605-0.628	89.8	0.598	0.008	0.586-0.609	0.83	**0.604**	0.008	0.592-0.616	0.58
	♂	0.579	0.009	0.565-0.592	25.9	**0.638**	0.009	0.624-0.651	94	0.610	0.009	0.597-0.623	1.0	**0.625**	0.009	0.612-0.638	0.56
Any morbidity*	♀	0.645	0.009	0.633-0.656	29	**0.686**	0.008	0.675-0.697	90.1	0.656	0.009	0.645-0.667	0.83	**0.663**	0.008	0.652-0.674	0.57
	♂	0.65	0.01	0.637-0.663	25.9	**0.691**	0.01	0.678-0.703	96.1	0.634	0.01	0.621-0.647	0.99	**0.676**	0.01	0.663-0.688	0.58
Any 2 co-morbidities*	♀	0.673	0.007	0.661-0.684	28.2	**0.726**	0.006	0.715-0.737	90.1	0.691	0.007	0.680-0.702	0.83	**0.711**	0.006	0.700-0.722	0.58
	♂	0.649	0.007	0.636-0.662	26.4	**0.677**	0.007	0.664-0.689	98.3	0.569	0.008	0.556-0.583	0.99	**0.667**	0.007	0.654-0.679	0.59
Any 3 co-morbidities*	♀	0.667	0.01	0.656-0.678	29.7	**0.720**	0.009	0.709-0.730	92.1	0.692	0.01	0.681-0.703	0.85	**0.711**	0.009	0.700-0.722	0.59
	♂	0.669	0.01	0.656-0.682	27.5	**0.692**	0.01	0.679-0.704	98.1	0.571	0.01	0.558-0.585	0.98	**0.679**	0.01	0.667-0.692	0.59

[$] The above table was constructed from the receiver-operating characteristic (ROC) analysis using BMI (kg/m^2), WC (cm), WHR and WHtR as covariate and any morbidity, any 2 co-morbidities or any 3 co-morbidities as an outcome.

AUC: Area under curve; BMI: body mass index; WC: Waist circumference; WHR: Waist to hip ratio; WHtR; Waist to height ratio.

*Value was significant ($p<0.05$).

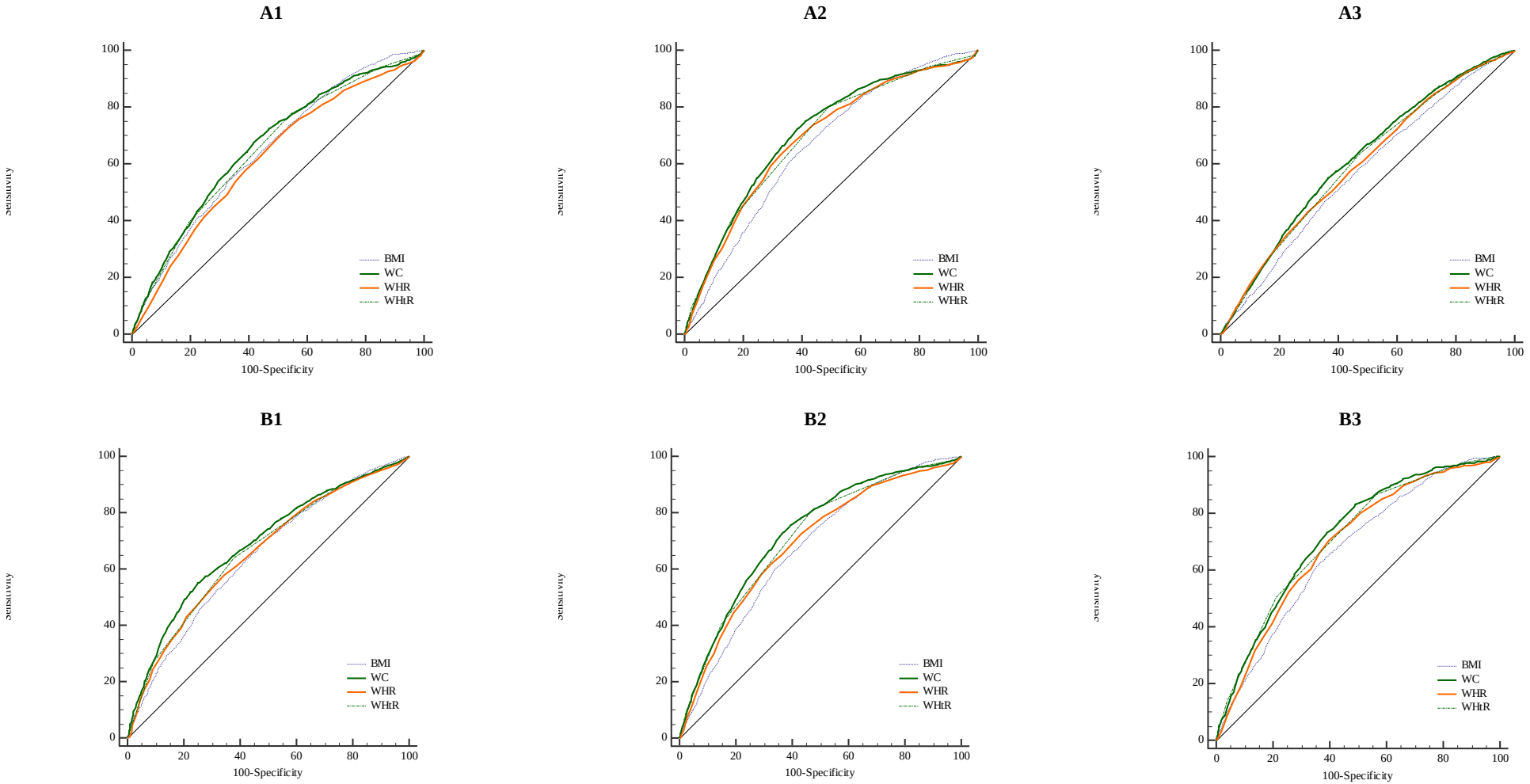


Figure 7.3-1: Receiver operating characteristic curves (ROC) for BMI, WC, WHR and WHtR to predict the presence of hypertension (A1), T2DM (A2), dyslipidemia (A3), any morbidity (B1), any 2 comorbidities (B2), and any 3 comorbidities (B3), in women.

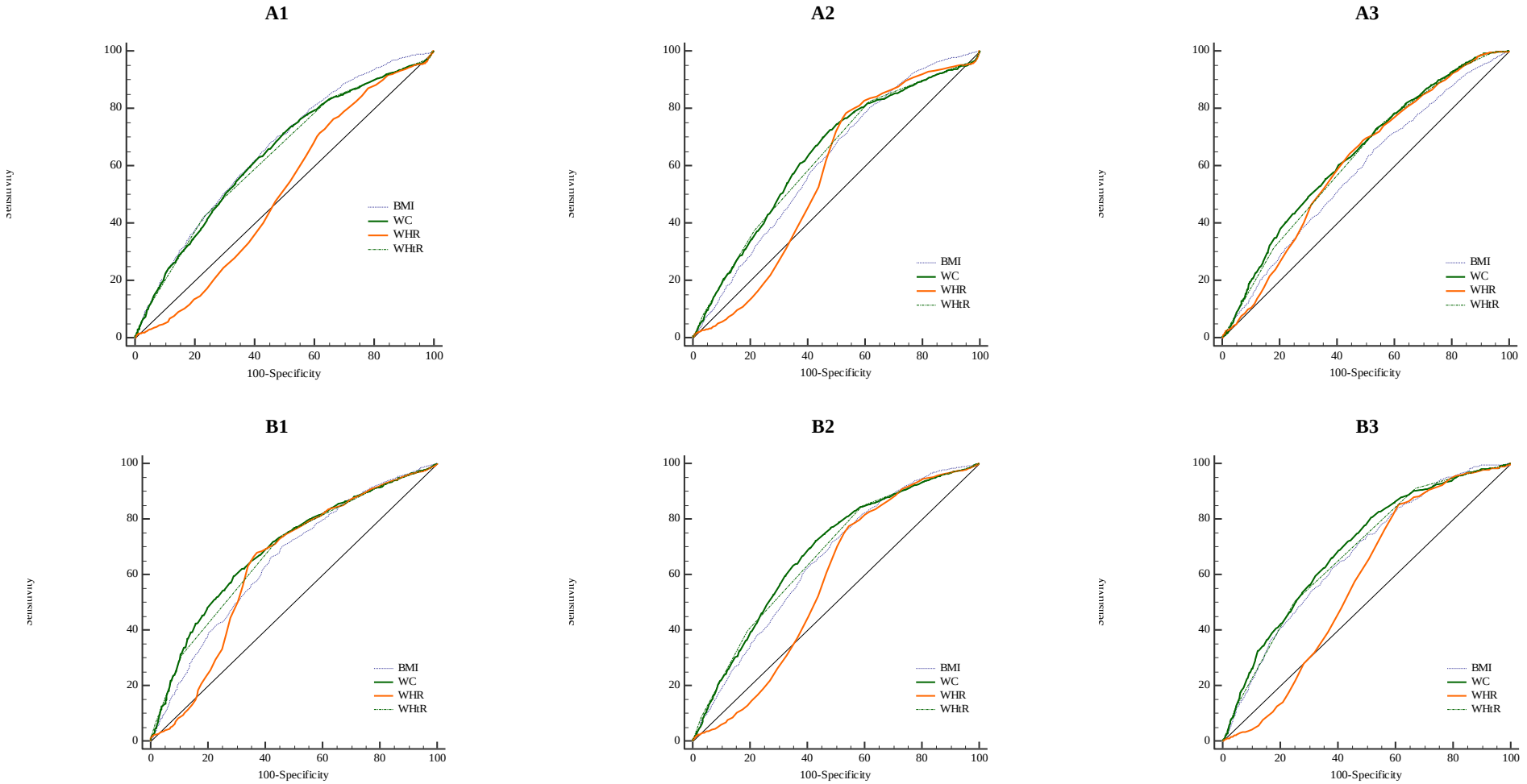


Figure 7.3-2: Receiver operating characteristic curves (ROC) for BMI, WC, WHR and WHtR to predict the presence of hypertension (A1), T2DM (A2), dyslipidemia (A3), any morbidity (B1), any 2 comorbidities (B2), and any 3 comorbidities (B3), in men.

7.4 Discussion

7.4.2 Combining WC and BMI to predict disease risk

Almajwal *et al.*, (2009) suggested combining WC to BMI to predict the metabolic risks more efficiently than BMI alone in Middle East populations including SA (Almajwal, Al-Baghli et al. 2009). In addition, Zhu et al. (2004) suggested including WC with BMI to predict the metabolic risks more efficiently than BMI alone in Caucasian people (Zhu, Heshka et al. 2004). This suggestion were adopted by different clinical guidelines (e.g. the National Institute for Health and Clinical Excellence (NICE), NHLBI Obesity Education Initiative (NIH-NHLBI), and Scottish Intercollegiate Guidelines Network (SIGN)) to combine WC with BMI to predict the metabolic risks more efficiently using health-risk scores (NIH-NHLBI 2000; NHS-NICE 2006; SIGN 2010; NHMRC 2013).

The findings of this study are in agreement that the risk of developing any one (or more) comorbidity increased positively with increasing deciles of BMI and WC, from a tip-up point onwards. However, when BMI was combined to WC in regression models, the predictive value for any one (or more) risk factor went down significantly in both sexes. This indicates that adding WC to BMI is not a solution for the poor performance of BMI. Two other studies are consistent with these findings: Lee *et al.* (2008) conducted a meta-analysis of 10 studies including 88,514 individuals, to determine which of the four indices (BMI, WC, WHR and WHtR) is the best predictor of major cardiovascular risk factors (hypertension, T2DM and dyslipidaemia (Lee, Huxley et al. 2008). The study results showed that the combinations of BMI and WC, WHR, or WHtR, did not increase the discriminatory capability of BMI for hypertension, T2DM and dyslipidaemia. Janssen et al (2004) conducted a study using the data of 14,924 adult individuals from the third National Health and Nutrition Examination Survey (NHANES III) in United States (Janssen, Katzmarzyk et al. 2004). This study found that WC but not BMI explains obesity related health risk. It also confirmed that overweight (BMI 25-29.9 kg/m^2) and obese (BMI≥30 kg/m^2) subjects were more likely to have hypertension, dyslipidaemia, and the metabolic syndrome than were normal weight subjects (BMI< 25 kg/m^2). However, after adjustment for WC category (normal or high; WC values ≥102 and ≥88 cm for men and women, respectively), the odds of comorbidity did not improve but remain high in overweight and obese subjects compared to normal-weight subjects. After adjustment for WC as a continuous variable, the likelihood of having metabolic syndrome, hypertension and

dyslipidaemia was similar in all groups. When WC and BMI were used as continuous variables in the same regression model, WC alone was a significant predictor of comorbidity (the metabolic syndrome, hypertension and dyslipidaemia) (Janssen, Katzmarzyk et al. 2004).

7.4.3 Best predictors of metabolic diseases among anthropometric measures using a greater area under the curve (AUC)

Which anthropometric measure of obesity should be used for predicting metabolic diseases is widely debated. The methods described by DeLong et al. are usually used to estimate the AUC and test the difference in the AUC between different measures using ROC curves analysis (DeLong, DeLong et al. 1988). Any measure with the highest level of Area Under Curve (AUC) is considered to be the measure with the best prediction power. The results of this study show that WC provided the best prediction power of any one (or more) risk factor in both sexes, of all individual risk factors for both sexes except of hypertension among men. WHtR alone performed almost equally well as WC. However, BMI and WHR were markedly poorer predictors of these risk factors. These results are consistent with several multi-ethnic and Arabic ethnic studies.

In the Arab region, Bener et al. (2013) found in a cross-sectional study in Qatar (n=1,552) that WC is the best predictor of metabolic syndrome (Bener, Yousafzai et al. 2013). Similar results were observed for WC to identify metabolic syndrome risks in Egypt (n=3,209) (Assaad-Khalil, Mikhail et al. 2015). Again WC was better than BMI for identifying subjects with hypertension in a Egyptian population (n=5,550) (El Din, Zaki et al. 2014). In Tunisia, Bouguerra (2007) also found WC a better predictor of high blood pressure, diabetes and dyslipidemia than BMI (n=3,435) (Bouguerra, Alberti et al. 2007). In Iraq, Mansour et al. (2007) (n=12,986) showed that BMI was the least reliable index for identifying T2DM and hypertension in Iraqi people compared to WC, WHR, and WHtR (this agrees with the results of this current study) and the authors also found that WHtR was the best predictor for hypertension while WHR was the best predictor for T2DM than BMI, WC, and WHtR (Mansour and Al-Jazairi 2007). Al-Lawati et al. (2008) in an Omani population (n=1,420) indicated that WHR and WC better predict CVDs risk than BMI (Al-Lawati, Barakat et al. 2008; Al-Lawati and Jousilahti 2008). In Jordan, Al-Odat et al. (2012) (n=500) found that WHR was the best predictor of metabolic syndrome followed by WHtR in men whereas WHR, WHtR and WC were almost equal in women, followed by

BMI (Al-Odat, Ahmad et al. 2012). However, the sample size of the study is very small to predict the anthropometric measures' effects. The comparison between the cut-off values of the findings of this current study and other results of Arab countries are shown in Table 7.4-1.

A meta-analysis (10 studies) including 88,514 individuals from different ethnicity to determine which of the four indices (BMI, WC, WHR and WHtR) is the best predictor of major cardiovascular risk factors (hypertension, T2DM and dyslipidaemia) (Lee, Huxley et al. 2008). The study results showed that WHtR was the best discriminator for hypertension (AUC=0.684 for men and 0.732 for women), diabetes (AUC=0.726 for men and 0.756 for women), and dyslipidaemia (AUC=0.653 for men and 0.663 for women) in both sex followed by WC. Those findings are in agreement with the results of this study showing that WHtR performs equally well with WC in predicting metabolic diseases. Also, this meta-analyses found that BMI was the poorest predictor for hypertension (AUC=0.641 for men and 0.693 for women), T2DM (AUC=0.672 for men and 0.693 for women) and dyslipidaemia (AUC=0.647 for men and 0.639 for women). Furthermore, other meta-analysis from the Diabetes Epidemiology: Collaborative Analysis of Diagnostic Criteria in Asia Study (DECODA) involved data from 16 cross-sectional studies found a stronger association between T2DM and WHtR followed by WC than BMI and WHR in both men and women (Nyamdorj 2008).

7.4.4 Optimal cut-points for anthropometric measures to predict metabolic diseases

This study also calculates new cut-off points for the anthropometric measures on the basis of the equivalence of sensitivity to specificity for different anthropometric measures in predicting metabolic diseases. The new cut-off points for WC range between 90 to 92 cm for women and 94 to 99 cm for men. In comparing with Caucasians' cut-offs for WC, the new cut-off point in women is higher than the cut-off in Caucasians (88 cm) whereas the new cut-off point in men is lower than those for Caucasians (102 cm). When comparing with WC cut-off points in some Arab populations; these results were relatively similar to those in Egypt, Lebanon and Qatar (Chedid, Gannagé-Yared et al. 2009; Bener, Yousafzai et al. 2013; El Din, Zaki et al. 2014). However, lower cut-off points were found in studies from Oman and Tunisia (Bouguerra, Alberti et al. 2007; Al-Lawati, Barakat et al. 2008; Al-Lawati and Jousilahti 2008) (Table 7.4-1). These differences between WC cut-offs

could be related to the small sample size in these studies, or characteristics of the studied risk factors, for instance the suggested cut-offs in Oman were based on the Framingham risk score (Al-Lawati, Barakat et al. 2008). To the knowledge of the researcher, this is the first study assessing cut-off points based on metabolic diseases in SA. However, it has been claimed that ROC is not the appropriate analysis in health promotion as it should trigger is weight control. It has almost no adverse effects, so there is no hazard if the threshold for action is below the ROC tip-point. False-positives (Type I error) do not matter (Tanamas, Lean et al. 2015). However, including false-positives may cause unnecessary and costly diagnostic testing in clinical or research practice.

Table 7.4-1: Comparisons between obesity indices cut off points from cross-sectional studies in selected local, regional and Arab countries and the suggested cut-off points obtained in this study.

Survey	Country	Age	Sample size (n)	Cut-off								Risk factors
				BMI		WC		WHR		WHtR		
				Women	Men	Women	Men	Women	Men	Women	Men	
(Assaad-Khalil, Mikhail et al. 2015)	Egypt	18-80	3209	ND	ND	96.25	100.5	ND	ND	ND	ND	Presence of ≥2 MS to IDF
(El Din, Zaki et al. 2014)	Egypt	20-75	5550	30.1	28	87.8	95.8	0.81	0.92	0.56	0.57	Presence of hypertension
(Bener, Yousafzai et al. 2013)	Qatar	>20	1552	28.4-30	28-30	91-88	99.5-102	0.88	0.90	0.63-0.5	0.58-0.5	Presence of ≥2 MS to IDF
(Al-Odat, Ahmad et al. 2012)	Jordan	20–85	500	30.3	28.4	95.6	97.8	0.84	0.89	0.61	0.61	Presence of ≥2 MS to IDF
(Ibrahim, Elamragy et al. 2011)	Egypt	≥25	2,313	ND	ND	91.5	93.5	ND	ND	ND	ND	Presence of RFs among Normotensives
				ND	ND	92.5	93.5	ND	ND	ND	ND	Presence of RFs among Hypertensives
(Almajwal, Al-Baghli et al. 2009)	SA	≥30	195,851	31.5	28.5	ND	ND	ND	ND	ND	ND	Presence of T2DM
				31.5	29	ND	ND	ND	ND	ND	ND	Presence of hypertension
				30.5	28.5	ND	ND	ND	ND	ND	ND	Presence of T2DM or hypertension
				31.5	29.5	ND	ND	ND	ND	ND	ND	Presence of T2DM and hypertension
(Chedid, Gannagé-Yared et al. 2009) *	Lebanon	18-30	381	27.5	27.5	91	99.5	ND	ND	ND	ND	Presence of ≥2 MS to IDF
(Al-Lawati and Jousilahti 2008)	Oman	≥20	1420	26.8	23.2	84.5	80	0.91	0.91	ND	ND	Presence of ≥2 CVD risk factors (hyperglycemia, hypertension and dyslipidemia)
(Al-Lawati, Barakat et al. 2008)				22.9	22.6	84.5	78.5	0.98	0.96	ND	ND	The Framingham risk score (Anderson et al., 1991)
(Bouguerra, Alberti et al. 2007)	Tunisia	≥20	3435	27	24	85	85	ND	ND	ND	ND	Any presence of high blood pressure, hyperglycaemia, high blood cholesterol and hypertriglyceridemia
(Mansour and Al-Jazairi 2007)	Iraq	30-62	12,986	26.1	25.4	91	90	0.91	0.92	0.56	0.52	Presence of T2DM
				26.5	24.9	95	95	0.91	0.92	0.59	0.55	Presence of hypertension
(Mansour, Al-Hassan et al. 2007)	Iraq	≥18	1,000	ND	ND	99	97	ND	ND	ND	ND	Presence of ≥2 MS to IDF
Present study *	SA	≥18	23,968	29	27.7	90.5	99	0.82	0.98	0.58	0.59	Presence of hypertension
				29.2	26.5	90.6	97	0.85	1.0	0.58	0.59	Presence of T2DM
				29	25.9	89.8	94	0.83	1.0	0.58	0.56	Presence of dyslipidaemia
				29.1	**26.7**	**90.3**	**96.7**	**0.83**	**0.99**	**0.58**	**0.58**	**Average**
				29	25.9	90.1	96.1	0.83	0.99	0.57	0.58	Presence of any-comorbidity
				28.2	26.4	90.1	98.3	0.83	0.99	0.58	0.59	Presence of any 2 comorbidities
				29.7	27.5	92.1	98.1	0.85	0.98	0.59	0.59	Presence of any 3 comorbidities
				29.0	**26.6**	**90.8**	**97.5**	**0.84**	**0.99**	**0.58**	**0.59**	**Average**
Present study $	SA	≥18	23,968	23.9	24.8	93	93	0.78	1.03	0.60	0.55	Presence of any-comorbidity
				23.9	23.2	89	97	0.89	0.95	0.57	0.58	Presence of any 2 comorbidities
				23.9	23.2	89	97	0.86	1.01	0.54	0.58	Presence of any 3 comorbidities
				23.9	**23.7**	**90.3**	**95.7**	**0.84**	**1.00**	**0.57**	**0.57**	**Average**

AUC: Area under curve; CSS: Cross sectional; WC: waist circumference; WHR: Waist to hip ratio; WHtR: Waist to height ratio; IDF: The International Diabetes Federation 2005; MS: Metabolic syndrome; RFs: cardiometabolic risk factors: diabetes mellitus, decrease in HDL-C and increase in LDL-C, triglycerides and left ventricular mass index by echocardiography.

According to IDF (Alberti, Zimmet et al. 2006), a participant has the MS if WC ≥94 cm in men and ≥80 cm in women) plus any two of these risk factors: (a) FPG ≥ 100mg/dL (5.6mmol/L) or previously diagnosed impaired fasting glucose (b) blood pressure ≥130/85mmHg or treatment for hypertension; (c) Triglyceride ≥ 150mg/dL (1.7mmol/L); (d) HDL Cholesterol:Men < 40mg/dL (1.03mmol/L);Women < 50mg/dL (1.29mmol/L) or treatment for low HDL; * Combined surveys in Saudi Arabia using ROC curve analysis; $ Combined surveys in Saudi Arabia using logistic regression analysis.

7.2.2 Trends of prediction of metabolic diseases by anthropometric and body composition measures

This study attempted to identify cut-off values based on the observed significant association between deciles of anthropometric measures and risk factors. Multiple regression analyses show that the risk of any one morbidity (or more) was significantly increased at BMI deciles as low as 23.9 in women and 23.2 to 24.8 (kg/m^2) in men, and was not increased progressively as BMI deciles increased. These findings are consistent with a large (197,681) study in Saudi Arabia. Almajwal et al. found that despite a significant increase in odds ratio of hypertension and diabetes from BMI values as low as 21-23, this did not improve the diagnostic performance of BMI measurements (Almajwal, Al-Baghli et al. 2009). These finding are also consistent with a study in Asian population in Hong Kong which reported an increase of T2DM and hypertension from a BMI value of 22 (kg/m^2) onwards (Ko, Chan et al. 1999). A meta-analysis study in a Chinese adult population (n=239,972) found that the prevalence of hypertension, diabetes, dyslipidaemia, and clustering of risk factors all increased with increasing BMI starting at 24 (kg/m^2) (Bei-Fan 2002). A study in Hong Kong on a Chinese population also showed increase of diabetes and hypertension prevalence from a BMI value of 22 (kg/m^2) upwards (Ko, Chan et al. 1999). However, the use of these low cut-off values leads to high values of sensitivities and false-positive rates (Type I error) which may cause unnecessary and high cost diagnostic testing in clinical or research practices, in addition to the weakness performance of BMI as discussed earlier.

There are some reasons explaining the weakness of BMI as a tool to classify obesity in the SA population. First, BMI does not represent body fat in different ethnic groups and populations (Wang, Thornton et al. 1994; Deurenberg-Yap, Schmidt et al. 2000; Prentice and Jebb 2001). Second, BMI includes body muscle mass which has a contradictory effect when compared with body fat, as shown in regression and correlation analysis in this study and in other studies (Ferreira, Snijder et al. 2004; Leenders, Verdijk et al. 2013; Park and Yoon 2013; Kim, Park et al. 2014; Sampaio, Sampaio et al. 2014). This is supported by the findings of a recent cohort study (n=54,420) in Canada, which found that low BMI and high body fat percentage are independently associated with increased mortality (Padwal, Leslie et al. 2016). Previous studies in Arab populations indicated that BMI has poor prediction power for health risks, as discussed earlier.

7.2.3 Strengths and limitations

This study is a cross-sectional study which limits the ability to draw causal inferences from the relationships observed. However, it includes a large random sample obtained using clustering and stratification techniques based on National Saudi census data (Chapter 5). Subjects with Type 1 diabetes were excluded in this study as in type 1 diabetes mellitus the primary pathology is loss of β-cells function, rather than increased insulin resistance. Therefore, individuals with type 1 diabetes mellitus may be less sensitive to changes in body fat, and their inclusion would likely weaken anthropometric associations with hyperglycemia (Srikanthan and Karlamangla 2011).

Antihypertensive drugs (including diuretics, beta blockers, Angiotensin-converting enzyme (ACE) inhibitors, Angiotensin II receptor blockers (ARBs), Calcium channel blockers, and renin inhibitors) may affect blood pressure and salt metabolism in human body (Sciarretta, Palano et al. 2011; Thompson, Hu et al. 2011). In the present study, subjects who were diagnosed with hypertension and subjects were using antihypertensive drugs were considered as having hypertension and included in the analyses.

7.3 Conclusion

The current study shows that adding WC to BMI does not improve the prediction power of all individual risk factors or any morbidity (or more) in both sexes. It also shows that the waist circumference (WC) alone is the best overall predictor of metabolic diseases, whereas waist-to-height ratio (WHtR) performs reasonably well as WC. Body mass index (BMI) and Waist-to-hip ratio (WHR) are poor measures to predict metabolic diseases and should not be used as surrogate measures of obesity. The prediction trend of BMI is not consistent in predicting metabolic diseases and starts as low as ~23 (kg/m^2) in sexes. This study suggests that a WC of 90 cm in women and 97 cm in men represents a more appropriate cut-off point for the definition of adiposity than the definitions currently used. Further prospective long term studies with imaging techniques are required in SA and the Eastern Mediterranean region to validate these findings.

Chapter eight

Knowledge and perceptions of Saudi adults towards food and health

8.1 Introduction

As outlined in Chapter 1 (Section 1.4), appropriate lifestyle modifications such as diet, physical activity and weight loss, have significant impact on preventing or delaying the onset of NCDs in high risk people. For instance, a meta-analysis of eight randomised controlled trials found that lifestyle modification including dietary modification only or dietary modification with exercise, significantly reduced mean values for systolic and diastolic BP, triglycerides, WC, and fasting blood glucose (by -6.4, -3.3 (mm Hg), -12.0 (mg/dl), -2.7 (cm), and -11.5 (mg/dl), respectively) compared with the control group (Yamaoka and Tango 2012).However, in order to successfully design, implement and evaluate intervention efforts health-care practitioners and national policy makers require reliable data regarding the distribution and determinants of NCD related health risk associated behaviour, such as knowledge, perceptions and factors influencing food choices and behaviour in the community (Alwan 1997; Conner, Norman et al. 2002; Paquette 2005).

Nutritional knowledge is one of the main influential factors to improve behaviour of healthy eating and lifestyle towards health and overall wellbeing (McCullough, Feskanich et al. 2002; Kolodinsky, Harvey-Berino et al. 2007). In England, Wardle et al. (2000) revealed that people in the highest knowledge quintile were almost 25 times more likely to meet current recommendations for fruit, vegetable and fat intake compared to those in the lowest quintile (Wardle, Parmenter et al. 2000). Several studies have examined specific aspects of lifestyle and dietary behaviours amongst the Saudi population (Epuru and AlMuqrn ; Bani and Hashim 1999; Khattab, Abolfotouh et al. 1999; Al-Rethaiaa, Fahmy et al. 2010; ALFaris, Al-Tamimi et al. 2015). However, the vast majority of these studies did not assess the influencing factors on food choices and dietary behaviour. Several psychosocial factors such as attitude toward behaviour (ATT), social norms (SN), perceived behavioural control (PBC) and actual barriers to behaviour (ABB) have lead to the foundation of a behavioural intention to engage (or not) with certain behaviour. These factors can be estimated using the Theory of Planned Behaviour (TPB) (Ajzen 1988; Ajzen 1991), a model frequently used to examine factors influencing behaviours and behavioural intentions (Ajzen 1991; Conner and Sparks 2005).

The study hypothesis is that lack of knowledge about nutritional balanced diet is a significant barrier affecting intention toward adopting a nutritionally balance diet. Thus, this study aims to answer the following research questions:

-Are Saudi adults aware of the existing nutrition and health guidelines and does their awareness best predict best the psychosocial constructs to eat a nutritionally balanced diet?

-Is nutritional knowledge the best predictor of intention to eat a nutritionally balanced diet among the psychosocial constructs using TPB?

8.2 Methodology and materials

8.2.1 Population

A cross-sectional study was conducted on a sample of Saudi men and women aged 18 years and older. No expatriates were included in this study. Participants were recruited via advertising on social media (Twitter and Facebook) and by snowball recruitment, in December 2015 and January 2016. The sample size of the study was calculated based on the records of the 2010 census (Ministry of Economy and Planning 2010). In a total of 13,226,393 Saudi adults in SA aged 18 years and over (6,521,284 women and 6,705,109 men), with absolute precision on either side of the proportion (the margin of error) 0.05 (5%), 95% confidence interval and variance in population 0.5 (50% - having sufficient nutritional knowledge), study calculations resulted in a sample size of 384 individuals (Lwanga S and S 1991; CRS 2015). Based on pretesting sample, the completion rate of the questionnaire was 42% (Section 3.2.4). Therefore, the final sample size is 1090 which is able to represent the Saudi population.

The study was conducted in accordance with the Declaration of Helsinki. All participants provided online informed consent to participate in the study. All procedures were approved by the University of Glasgow, College of Medicine, Veterinary Medicine and Life Sciences (MVLS) Ethics Committee.

8.2.2 Demographic characteristics

Items were included in the questionnaire (Appendix 6) to assess the socio-demographic and personal characteristics of the participants (e.g., age, gender, monthly income, occupational status, education level, marital status and living status (Section 1).

Demographic data collected included

- Age (divided into two categories: ≤45 and >45 years)
- Sex (male and female)
- Marital status (never married, married, divorced, and widowed
- Educational status: (low (secondary school or below), medium (college or bachelor degree) and high (master degree or higher))
- Occupational status (employees, students, stay at home, unemployed or retired)
- Health insurance (covered or not covered)
- Socio-economic status score based on participants education (low, medium and high) and monthly individual income (low (≤3,500 SR), medium (>3,500 SR and < 8,500 SR) and high (≥8,500 SR), generating a score of 1, 2 or 3).

Socioeconomic status scores, ranging from 2 to 6, were categorised as low (2-3), medium (4-5) and high (6) base on previous studies conducted in SA (Al-Numair 2006). Participants were also divided to three categories: low education level (secondary and less); high education level (college or higher) with medical background (participants with secondary or less education and with medical background were included); and high education level (college or higher) without medical background. More details of questionnaire items are in Appendix 6.

8.2.3 Factors influencing food choice, and the Theory of Planned Behaviour (TPB)

The questionnaire items (Appendix 6) used were based on the TPB assessing: attitudes towards behaviour (ATT), subjective norms (SN), perceived behavioural control (PBC), knowledge as actual barriers to behaviour (ABB), and socio-demographic and personal factors which may influence the intention of population toward adopting a nutritionally balanced diet. More details of questionnaire items are in Appendix 6.

The five main constructs proposed to predict these factors were included in the questionnaire, as summarised in Table 8.3-4. Unipolar five-points Likert scales (+1 to +5) were used to answer survey questions, with answers including "strongly agree", "agree", "neutral", "disagree", or "strongly disagree". Positively scaled questions' responses were coded from 1 to 5 (strongly disagree to strongly agree) and for negatively scaled questions' responses were coded from 5 to 1 (strongly disagree to strongly agree).

ATT was assessed using 14 different belief items. The scale includes statements regarding the health benefits, body appearance change, taste, nutrient value, and cost of nutritionally balanced diets (Table 8.3-4, Section 2).

SN was assessed using 13 items consisting of statements concerning the perceived beliefs of family members, friends, doctors, culture, official resources, and newspapers, magazines and TV programs (Table 8.3-4, Section 3).

PBC was assessed using 12 control beliefs regarding statements about time, cost and taste of a balanced diet, food preferences, having a balanced diet, availability of a balanced diet at work, consuming a balanced diet when busy or when away from home, and family sharing effects (Table 8.3-4, Section 4).

The participants' knowledge regarding a nutritionally balanced diet was assessed as ABB using 25 items (Table 8.3-4, Section 5). Participants' knowledge was assessed regarding: fruits, vegetables, fish (white vs. oily), fat, sugar, salt, healthy weight and low salt diet vs. chronic diseases, fizzy drinks, tea and coffee vs. water, and monosodium glutamate (MSG) and sea salt vs. table salt (true / false / not sure and open questions). Knowledge items scored as follows: correct response=1; incorrect response=0; not sure =0. The not sure / do not know category was included to overcome bias from guessing based on previous research (Parmenter and Wardle 1999).

Items from the knowledge section (ABB) evaluated three domains: (a) knowledge about consumption of nutritionally balanced diet and its relation to NCDs; (b) knowledge about nutritionally balanced diet recommendations; and (c) knowledge about nutritionally balanced diet content. Knowledge assessment questions were developed based on the

Saudi national guidelines ("Dietary Guidelines for Saudis: Healthy Food Palm" in 2012 (MOH 2012) and "Diet and Physical Activity Strategy (DPAS)" in 2014 (MOH 2014).

Finally, intention to eat a nutritionally balance diet was assessed using four items (Table 8.3-4, Section 6).

8.2.4 Questionnaire pre-testing

The first version of the questionnaire was tested among 40 Saudi students aged 18-59 years old living in the city of Glasgow, United Kingdom and Saudi citizens living in Riyadh city, Saudi Arabia. Participants in the pretest were similar to those who were included in the actual survey. Each subject was asked to answer all questions provided. The participants were instructed to report on the following: questions difficulty, ambiguity, and time taken to fill in the questionnaire. The mean time taken was 29 minutes (SD ±12 minutes). The completion rate of the participants was also assessed (42%) (Quigley 1997; Teufel 1997; O'Leary 2005; SA McNaughton 2005; Malhotra 2006; McNaughton 2007). The completion rate was 42%.

8.2.5 Population awareness of nutrition and health guidelines and its related factors

Population awareness of nutritional information sources such as the "Healthy Food Palm" (MOH 2012) and the "Diet and Physical Activity Strategy" (MOH 2014) were assessed by asking them the following:

"Have you heard about or read the following guidelines?

(1) Dietary Guidelines for Saudis: "Healthy Food Palm"

(2) Diet and Physical Activity strategy (DPAS)

(3) Other guidelines such as Eat Well Plate or Food Guide Pyramid etc;

If yes, are you following any one of them and what is your opinion about it/them?"

Each participant was also asked about perceptions towards existing governmental policies and guidelines designed to promote health through diet, foods and physical activity in SA. As the current guidelines used by the government are fairly recent, the participants were

also asked about the UK "Eat Well Plate" (FSA 2013) and US "Food Guide Pyramid" (USDA 2005). The term "nutritionally balanced diet or healthy eating" has been defined in this study as being a diet low in fat and salt, and high in fruit and vegetable, based on current dietary recommendations.

8.2.6 Perceived usual diet, dietary supplements use, health, physical activity, smoking status, and anthropometric measurements

Participants were asked to report their usual diet, vitamin, mineral or other nutritional supplements intake (alongside with a rationale for intake), physical activity status (fairly inactive, moderately active, or very active), smoking (never, past or current). Participants also reported on their current health status and medical conditions or illnesses lasting or expected to last for 12 months or more. Options of 12 common chronic diseases were available, with opportunity to report any other diseases diagnosed by healthcare professionals. Similarly, participants reported on medical conditions or illnesses lasting or expected to last for 12 months or more for close family members.

Participants were asked whether they knew their anthropometric measurements or not, and asked to report their weight (kg), height (cm), waist circumference (WC, cm) and hip circumferences (HC, cm). BMI was calculated as weight in kilograms divided by the square of height in meters (WHO 2014). For more details on anthropometry definitions, refer to **Chapter 5 section 5.2.2.2.**

8.2.7 Statistical analysis

Continuous variables of body composition were shown as median and interquartile range (IQR) using descriptive statistics. Mann-Whitney and Kruskal-Wallis H tests were used to determine differences between continuous and ordinal variables. Descriptive statistics were used to examine socio-demographic characteristics and study variables. The Chi-Squared (χ^2) test was used to determine differences in proportions among categorical variables.

Multiple and linear regression analyses was used to determine whether ATT, SN, PBC and knowledge variables predict the participants' intentions toward nutritionally balanced diet.

Multiple regression analysis was used to determine whether external variables predict the influencing factors (ATT, SN, PBC and knowledge). External variables including age, gender, socio-economic status, family members (no.), children (no.), care of elder person, BMI, physical activity (PAL), medical background, being outside SA more than 3 months, grocery shopper, smoking, having a chronic illness, and being aware of health and nutrition policies were included into the model as they were potentially related to these influencing factors (ATT, SN, PBC and knowledge).

The Cronbach α test was performed to assess internal consistency (index of intra-item homogeneity) (Cronbach 1951; Santos 1999). The Cronbach α varies between 0 and 1 and the higher the value is considered to be more reliable. If the Cronbach α scores between 0.61–0.80, indicate a substantial reliability and if the scores between 0.81-1.0, indicate an almost perfect reliability (Streiner, Norman et al. 2014). Furthermore, the difficulties of knowledge item were evaluated as suggested by Streiner and Norman (Streiner, Norman et al. 2014). The percentage of correct answers for each item was calculated. The percentage of correct answers for each item should fall between 20 and 80%. Any item is considered too difficult if the percentage of correct answer less than 20% but if the correct item is more than 80%, it is considered too easy.

8.3 Results

8.3.1.1 Socio-demographic

A total of 1,045 individuals, 466 women (45%) and 579 men (55%), participated in the study. Most were from central (69%) and western (17%) regions of SA. This sample size affords a confidence interval (margin of error) of ±3% for data reported, at the 95% confidence level (CRS 2015). The median age of participants was 33 (IQR 27-40) years and most participants (n=916, 88 %) were younger than 45 years. Most participants (n=540, 52%) fell into the medium level of socioeconomic status and 42% (n=434) of them were insured by a private health insurance company. One third of participants (n=332, 32%) also had a food, nutrition or health education background with n=62 were current students. Most participants were employed (n=683, 65%) and married (n=689, 66%) (Table 8.3-1). Moreover, one third of the participants (n=326, 31%) lived / had lived outside Saudi Arabia for an extended period of time (i.e. three months or more).

Table 8.3-1: Socio-demographic characteristics of the study participants (n=1045)

Characteristics	***All (1045) n. (%)***	***Female (n=466) n.(%)***	***Male (n=579) n. (%)***
Age (year)			
<45	913 (87)	419 (90)	494 (85)
>45	132 (13)	47 (10)	85 (15)
Total	1045	466 (45)	579 (55)
Median Age (IQR)	33 (27-40)	30 (24-28)	35 (29-40)
Education			
Secondary school or below	151 (15)	88 (19)	63 (11)
College (Diploma) or Bachelors	617 (59)	271 (58)	346 (60)
Master degree or higher	277 (26)	107 (23)	170 (29)
Marital Status			
Never Married	326 (31)	195 (42)	131 (23)
Married	689 (66)	249 (53)	440 (76)
Divorced	27 (2.7)	19 (4)	8 (1)
Widowed	3 (0.3)	3 (1)	0 (0)
Income [a]			
<3,500	262 (25)	217 (47)	45 (8)
3,500- 8,500	174 (17)	77 (16)	97 (17)
>8,500	609 (58)	172 (37)	437 (75)
Occupational status			
Employed	683 (65)	192 (41)	491 (85)
Student	176 (17)	122 (26)	54 (9)
Household (house wife/husband)	103 (10)	103 (22)	0 (0)
Unemployed	48 (4.6)	36 (8)	12 (2)
Retired	35 (3.4)	13 (3)	22 (4)
Socio-economic Status			
Low (2-3)	272 (26)	207 (44)	65 (11)
Medium (4-5)	540 (52)	182 (39)	358 (62)
High (6)	233 (22)	77 (17)	156 (27)
Medical Education background	332 (32)	165 (35)	167 (29)
Grads and medical education background			
(A) Low education level [b, c]	134 (13)	75 (16)	59 (10)
(B) High education level with medical education background [d]	332 (32)	165 (35)	167 (29)
(C) High education level without medical education background [e]	579 (55)	226 (49)	353 (61)
Lived outside SA for 3 months and more	321 (31)	92 (20)	229 (40)

IQR: Interquartile range; [a] Individual income in Saudi Riyals (SR) per month;
[b] Participants with secondary school or less. [c] Participants with medical education background were moved to "B" category. [d, e] Participants with College school or higher.

8.3.1.2 Usual diet, dietary supplements, health, physical activity and smoking status

Over two thirds (68%, n=712) were not following any special diet, with one quarter (n=273) regularly taking vitamin, mineral or other nutritional supplements. Supplement intake did vary between women (n=157, 34%) and men (n=111, 19%) (χ^2=28.5, p<0.0001). Most (n=747, 72%) agreed that their health status was good in general, and only a quarter

(n=226) reported a medical conditions or illnesses lasting or expected to last for 12 months or more (women, n=112, 24%; men n=114, 20%). However, a majority (n=658, 63%) stated that someone close to them had medical conditions or illnesses lasting or expected to last for 12 months or more, with a third experiencing diabetes and hypertension through a person close to them.

Lifestyle factors included a majority being physically inactive (not doing physical activity or walking only, n=628, 60%) with over a third of the male population smoking (versus a minority of women – 1%). The overall prevalence of (self-reported) overweight and obesity based on BMI was 63% (35% and 28%, respectively).

8.3.2 Influencing factors in the Theory of Planned Behaviour (TPB) construct

8.3.2.1 Internal consistency of TPB components

The overall internal consistency for ATT, SN, PBC, and intensions towards balanced and healthy diet was valid, with Chronbach's alpha scales ranging between 0.522 and 0.747 (Table 8.3-2 and Table 8.3-4). As such, all construct were included in the analysis. Knowledge items were evaluated in term of difficulty, with five items out of 25 items (20%) identified as too difficult, and seven items (28%) as too easy (Table 8.3-3). External variables, such as age, gender, socio-economic status, number of family members or children, care of elderly person, BMI, PAL, medical background, being outside SA more than 3 months, being the main grocery shopper, smoking, having a chronic illness, and being aware of health and nutrition policies were all included into the model, as they were potentially related to these determinants.

Table 8.3-2: The main TPB constructs and Cronbach α for internal consistency (n=1045).

Constructs Items	Scoring	Questions (no.)	α
Attitude towards behaviour (ATT)	1-5	14	0.678
Subjective norms (SN)	1-5	13	0.649
Perceived behavioural control (PBC)	5-1	12	0.747
Actual barriers to behaviour (ABB)	True/False and open questions	25	0.617
Intentions to change or retain diet	1-5	4	0.522

Table 8.3-3: The percentage of correct answers in knowledge items among the study population (n=1045)

Knowledge questions	*Correct answers (%)*
1. Starchy foods such as bread, cereals, rice, pasta and potatoes should be the main component of a nutritionally balanced diet	42.7
2. What percentage of the food we eat should be made up of starchy foods (e.g.: bread, cereals, rice, pasta, potatoes)	33.3
3. It is more important to eat a wide variety of vegetables than fruits	63.9
4. How many portions of fruit should we eat each day	50.2
5. How many portions of vegetables should we eat each day	38.1
6. Eating white fish is just as important for health as eating oily fish such as salmon	7.8
7. How many portions of fish should we eat each week	29.9
8. How many of these should be oily fish	53.8
9. We should try to eliminate as much fat as possible from our diet	82.1
10. A diet with lots of high sugar foods is ok as long as it is low in calories	80.2
11. What is the maximum recommended intake of sugar for adults, in grams/day	4.8
12. What is the maximum recommended intake of salt for adults, in grams/day	9.7
13. Most of the salt in our diet comes from what is added to food at the table	34.3
14. Most of the salt in our diet comes from what is added to food at the cooking	77.8
15. Most of the salt in our diet comes from processed or canned foods	53.7
16. Sodium is a component of table salt	90.5
17. Fizzy drinks contribute to daily fluid intake just as much as water	93.4
18. Tea and coffee contribute to daily fluid intake just as much as water	82.5
19. Maintaining a healthy weight is important to reduce the risk of developing some types of cancer, high blood sugar and high blood pressure	94.1
20. Reduce or avoid eating food products with a high content of salt and sodium is very important to reduce the risk of developing high blood pressure	92.3
21. Reduce or avoid eating food products with a high content of salt and sodium is very important for reducing the risk of strokes, heart disease and heart attacks.	73.1
22. Monosodium glutamate (Aginamoto-MSG) is considered as a healthy choice to table salt	68.9
23. Sea salt is considered as a healthy choice to table salt	9.7
24. Spices and some flavourings such as lemon are considered as a healthy choice to table salt	77.8
25. Vitamin/mineral supplements are an important part of a healthy diet	19.3

Table 8.3-4: Questions covered in the main TPB constructs, mean scores and standard deviations (sd), and Cronbach's α (n=1045).

Constructs Items	*Mean (SD)*
Attitude towards behaviour (ATT) (scores 1-5) (α=0.678)	
1. What I eat now plays an important part in reducing my risk of developing chronic diseases in later life (e.g.: cancer, heart disease, diabetes or stroke).	3.9 (1.0)
2. The way I eat can change my well-being in the short term	3.8 (0.98)
3. The way I eat can change my appearance	4.2 (0.90)
4. Changing the way I eat will have an impact on my immediate well-being	4.3 (0.88)
5. Changing the way I eat will reduce my risk of developing chronic diseases in later life	4.2 (0.88)
6. Good health is just a matter of luck (Reverse)	4.3 (0.76)
7. It's important to me to just enjoy my food, regardless of whether it's good for me (Reverse)	3.7 (1.1)
8. It's important to me to eat a broad range of food rich in nutrients and in the correct amounts	4.1 (0.87)
9. The kind of food I eat does not matter, it's just fuel and fills my empty stomach (Reverse)	3.8 (1.1)
10. Being aware of what you eat is only important if you want to lose weight (Reverse)	3.7 (1.3)
11. I'm not sure if I eat a balanced diet with the right nutrients so I take supplements as an insurance (Reverse)	3.5 (1.19)
12. Taking supplements reduces my risk of having a heart attack or stroke (Reverse)	3.2 (1.1)
13. As long as I take supplements, I don't need to worry about what I eat and its effect on my health (Reverse)	4.0 (0.84)
14. I spend as little as possible on food	2.2 (0.95)
Subjective norms (SN) (scores 1-5) (α=0.649)	
1. I am interested in reading articles about food and health	3.6 (1.0)
2. Watching TV shows about food and health influences the food choices I make	3.6 (0.98)
3. I need to change the way I eat because my partner/husband/wife is concerned about my health	3.0 (1.10)
4. I take more interest in food and health now that I have children	3.5 (1.1)
5. I take more interest in food and health since someone close to me got ill	3.1 (1.1)
6. I always check nutritional information labels before I buy any food	3.5 (1.2)
7. Information about food and health from official sources influences my food choices (e.g. Department of Health, Saudi FDA, doctor, public health adverts).	4.0 (0.92)
8. Information about food and health in the media influences my food choices (e.g.: magazines, newspapers, online, TV).	3.6 (0.97)
9. When eating out, my choice of food is influenced by nutritional information provided (e.g.; on menus in restaurants and cafes)	3.5 (0.98)
10. When in the supermarket, I will always buy special offers regardless of the nutritional content of the food (Reverse)	3.8 (0.99)
11. I mainly buy from the value brand/essentials ranges (Reverse)	3.9 (0.9)
12. I was brought up to always finish the food on my plate and still do (Reverse)	2.5 (1.2)
13. I'd never use a food bank because of what other people would think of me (Reverse)	3.1 (1.3)

*Continued overleaf

Constructs Items	*Mean (SD)*
Perceived behavioural control (PBC) (scores 5-1) (α=0.747)	
1. I'd like to pay more attention to food and health but my lifestyle doesn't allow for it (Reverse)	2.3 (1.1)
2. There are no nutritionally balanced options available for lunch when I'm at work (Reverse)	2.2 (1.1)
3. I don't have time to eat a nutritionally balanced diet, I just "grab and go" (Reverse)	3.2 (1.2)
4. Nutritionally balanced foods are so much more expensive (Reverse)	2.6 (1.2)
5. I like my food too much to worry about food and health (Reverse)	2.6 (1.1)
6. Nutritionally balanced food is boring and tasteless (Reverse)	3.3 (1.2)
7. There are no nutritionally balanced options available when I eat out (Reverse)	2.5 (1.1)
8. I go through phases of eating a nutritionally balanced diet and then I give in to temptation (Reverse)	3.0 (1.1)
9. I can only eat a nutritionally balanced diet when I want to lose weight (Reverse)	2.2 (0.96)
10. I can't say no to my children when they want to eat snacks between meals (Reverse)	2.8 (1.1)
11. I usually finish what my child/children leave on their plate(s) (Reverse)	3.3 (1.1)
12. If my partner/friends/children are having dessert, I usually have one too, even if I'm full (Reverse)	3.0 (1.2)
Knowledge = Actual barriers to behaviour (ABB) (True/False and open questions) (α=0.617)	
1. Starchy foods such as bread, cereals, rice, pasta and potatoes should be the main component of a nutritionally balanced diet (b)	0.43 (0.49)
2. What percentage of the food we eat should be made up of starchy foods (e.g.: bread, cereals, rice, pasta, potatoes) (b)	0.33 (0.47)
3. It is more important to eat a wide variety of vegetables than fruits (b)	0.64 (0.48)
4. How many portions of fruit should we eat each day (b)	0.50 (0.50)
5. How many portions of vegetables should we eat each day (b)	0.38 (0.49)
6. Eating white fish is just as important for health as eating oily fish such as salmon (b)	0.08 (0.27)
7. How many portions of fish should we eat each week (b)	0.30 (0.46)
8. How many of these should be oily fish (b)	0.54 (0.50)
9. We should try to eliminate as much fat as possible from our diet (b)	0.82 (0.38)
10. A diet with lots of high sugar foods is ok as long as it is low in calories (c)	0.80 (0.40)
11. What is the maximum recommended intake of sugar for adults, in grams/day (b)	0.05 (0.21)
12. What is the maximum recommended intake of salt for adults, in grams/day (b)	0.10 (0.30)
13. Most of the salt in our diet comes from what is added to food at the table (c)	0.34 (0.47)
14. Most of the salt in our diet comes from what is added to food at the cooking (c)	0.78 (0.42)
15. Most of the salt in our diet comes from processed or canned foods (c)	0.54 (0.50)

*Continued overleaf

Constructs Items	*Mean (SD)*
16. Sodium is a component of table salt (c)	0.91 (0.29)
17. Fizzy drinks contribute to daily fluid intake just as much as water (c)	0.93 (0.25)
18. Tea and coffee contribute to daily fluid intake just as much as water (c)	0.82 (0.38)
19. Maintaining a healthy weight is important to reduce the risk of developing some types of cancer, high blood sugar and high blood pressure (a)	0.94 (0.24)
20. Reduce or avoid eating food products with a high content of salt and sodium is very important to reduce the risk of developing high blood pressure (a)	0.92 (0.27)
21. Reduce or avoid eating food products with a high content of salt and sodium is very important for reducing the risk of strokes, heart disease and heart attacks (a)	0.73 (0.44)
22. Mono sodium glutamate (Aginamoto) is considered as a healthy choice to table salt (c)	0.69 (0.46)
23. Sea salt is considered as a healthy choice to table salt (c)	0.10 (0.30)
24. Spices and some flavourings such as lemon are considered as a healthy choice to table salt (c)	0.78 (0.42)
25. Vitamin/mineral supplements are an important part of a healthy diet (c)	0.19 (0.40)
Intentions to change or retain diet (scores 1-5) (α=0.522)	
1. I am happy that I currently eat a nutritionally balanced diet and have no plan to change it	3.0 (1.1)
2. I know my diet isn't as balanced as it should be. I don't see this as a problem and I'm not planning to change it (Reverse)	3.6 (1.1)
3. I intend to make changes to my diet to eat more nutritionally balanced diet	3.9 (0.94)
4. I have already made changes to my diet to eat more nutritionally balanced diet	3.1 (1.0)

(a) Knowledge about consumption of nutritionally balanced diet and its relation to NCDs;
(b) Knowledge about nutritionally balanced diet recommendations; and
(c) Knowledge about nutritionally balanced diet content.

8.3.2.2 Impact of external determinants on the TPB constructs

Fifty-eight percent (n=608/1041) scored high on ATT toward nutritionally balanced diet. Only 37% (n=390/1043) scored high on SN toward nutritionally balanced diet. Only 9% (n=91/1042) scored high on PBC toward nutritionally balanced diet. Knowledge as a barrier was identified in 60% (n=623/1045) who answered less than 15 out of 25 knowledge questions correctly (score below 60%). Nearly half of the population (49%, n=511/1042) scored high on intention to adopt a more nutritionally balanced diet (Table 8.3-5).

Table 8.3-5: Median and Interquartile range (IQR) for each construct for the study sample by gender (n=1045).

TPB Construct [a]	*Median (IQR)*	*Minimum-Maximum* [b]
ATT	50 (45-55)	21-66
SN	44 (39-48)	1-60
PBC	31 (26-36)	7-54
ABB = Knowledge	14 (12-16)	0-21
Intention	13 (12-15)	1-20

[a] As sum of each TPB Construct.
[b] for population
IQR: Interquartile range; ATT: Attitude Toward Behaviour; SN: Social Norms; PBC: Perceived Behavioural Control; ABB: Actual Barrier to Behaviour.

Fourteen predictor variables were included in the regression analyses, for each construct; 7 out of 14 predictors influenced ATT: awareness of existing nutrition and health guidelines was the strongest (B=3.53; p<0.0001) whilst BMI was the weakest (B=-0.079; p=0.048). Overall these determinants explained 16% of the variance in ATT towards adopting a balance diet (Table 8.3-6).

Seven factors out of 14 influenced SN. Awareness was also the strongest predictor of SN (B=2.1; p=0.001) whilst age was the weakest (B=0.09; p=0.024). Overall these determinants explained 14% of the variance in SN towards balance diet.

Seven factors out of 14 influenced PBC. Physical activity was the strongest predictor of PBC (B=2.2; p<0.0001) whilst age was the weakest predictor (B=0.18; p<0.0001); and the

overall these determinants explained 19% of the variance in PBC towards balance diet (Table 8.3-6 and Figure 8.3-1).

Seven factors out of 14 influenced Knowledge. Awareness was also the strongest predictor of knowledge (B=1.6; p=0.018) whilst BMI was the weakest predictor (B=0.034; p=0.024); and the overall these determinants explained 19% of the variance in knowledge towards balance diet (Table 8.3-6 and Figure 8.3-1). The above finding shows that the awareness of existing nutrition and health guidelines was the most motivational factor on the population to take up a more nutritionally balanced diet by having high positive self-performance to perform the behaviours (ATT), by perceived social pressure to engage in the behaviour (SN), and by nutritional knowledge (ABB).

Table 8.3-6: Multiple regression analyses of external factors onto TPB components (n=1042)

	ATT *(R-Square=0.157)* [a]			***SN*** *(R-Square=0.136)* [b]			***PBC*** *(R-Square=0.193)* [c]			***ABB*** *(R-Square=0.191)* [d]		
Variable	***B***	***P-value***	***CI***	***B***	***P-value***	***CI***	***B***	***P-value***	***CI***	***B***	***P-value***	***CI***
Age (years)	0.082	0.056	(-0.002-0.17)	0.085	0.024	0.01-0.32	0.175	<0.0001	0.10-0.25	0.01	0.512	(-0.021-0.042)
Gender (0=F & 1=M)	-1.121	0.072	(-2.34-0.10)	-0.751	0.170	(-1.83-0.32)	-2.095	<0.0001	(-3.19--1.00)	-1.05	<0.0001	(-1.50--0.60)
Socio-economic Level	0.598	0.177	(-0.27-1.47)	-0.299	0.442	(-1.06-0.46)	0.086	0.828	(-0.69-0.87)	-0.084	0.611	(-0.41-0.24)
Family Member	-0.234	0.344	(-0.72-0.25)	-0.934	<0.0001	(-1.36--0.51)	-0.095	0.670	(-0.53-0.34)	-0.189	0.040	(-0.37--0.01)
Children number	-0.493	0.213	(-1.27-0.28)	0.909	0.009	0.23-1.59	0.771	0.030	0.07-1.47	0.483	0.001	0.19-0.77
Care of elder (0=No & 1=Yes)	-1.23	0.037	(-2.38--0.08)	0.034	0.947	(-0.98-1.05)	-0.862	0.103	(-1.90-0.17)	-0.003	0.989	(-0.43-0.43)
BMI (kg/m^2)	-0.079	0.048	(-0.16--0.001)	-0.034	0.340	(-0.10-0.04)	-0.199	<0.0001	(-0.27--0.13)	0.034	0.024	0.004-0.063
Physical activity level	1.72	<0.0001	1.01-2.43	1.302	<0.0001	0.68-1.93	2.223	<0.0001	1.59-2.86	0.358	0.008	0.09-0.62
Medical Background	2.286	<0.0001	1.11-3.46	1.377	0.009	0.35-2.41	0.993	0.064	(-0.06-2.05)	1.273	<0.0001	0.84-1.71
Outside SA	0.751	0.198	(-0.39-1.90)	-0.827	0.107	(-1.83-0.18)	1.177	0.025	0.15-2.21	-0.299	0.169	(-0.72-0.13)
Grocery shopper	1.685	0.006	0.48-2.90	1.701	0.002	0.64-2.76	1.016	0.066	(-0.07-2.10)	-0.062	0.788	(-0.51-0.39)
Smoker	-1.664	0.015	(-3.01--0.32)	-1.05	0.081	(-2.23-0.13)	-0.654	0.289	(-1.86-0.56)	-0.443	0.082	(-0.94-0.06)
Chronic Diseases	-0.855	0.166	(-2.06-0.35)	-0.573	0.290	(-1.64-0.49)	-0.553	0.318	(-1.64-0.53)	-0.221	0.335	(-0.67-0.23)
Awareness	3.532	<0.0001	2.16-4.90	2.088	0.001	0.89-3.29	1.481	0.018	0.25-2.71	1.595	<0.0001	1.09-2.10

*Value was significant ($p<0.05$).

B: regression coefficient; CI: confidence interval; SE=standard error; ATT: Attitude Toward Behaviour; SN: Social Norms; PBC: Perceived Behavioural Control; ABB: Actual Barrier to Behaviour; BMI: Body mass index; External variables: age, gender, socio-economic status, family members (no.), children (no.), care of elder person, BMI, PAL, medical background, being outside SA more than 3 months, grocery shopper, smoking, having a chronic illness, and being aware of health and nutrition policies.

[a] Dependent variable: ATT; and Independent variables: the External variables

[b] Dependent variable: SN; and Independent variables: the External variables

[c] Dependent variable: PBC; and Independent variables: the External variables

[d] Dependent variable: knowledge; and Independent variables: the External variables.

8.3.2.3 Impact of the TPB constructs on intention

Intention towards a balanced diet was predicted by all four constructs (ATT, SN, PBC and Knowledge), and SN toward adopting a balanced diet was the strongest predictor of participants' intention to adopt a balanced diet (B=0.111; p<0.0001) whilst PCB was the weakest predictor (B=0.026; p=0.028). Overall these determinants explained 25% of the variance in intention towards balance diet (Table 8.3-7 and Figure 8.3-1).

Table 8.3-7: Multiple regression analyses of TPB components onto intentions among study population (n=1,042)

Variable	R-Square	B	SE	Beta	t-value	P-value*	CI
ATT	0.246	0.091	0.011	0.248	7.957	<0.0001	0.069-0.114
SN		0.111	0.013	0.262	8.503	<0.0001	0.086-0.137
PBC		0.026	0.012	0.065	2.198	0.028	0.003-0.049
ABB = Knowledge		0.083	0.028	0.087	2.976	0.003	0.028-0.137

*Value was significant (p<0.05).
B: regression coefficient; CI: confidence interval; SE=standard error; ATT: Attitude toward behaviour; SN: Social Norms; PBC: Perceived Behavioural Control; ABB: Actual Barrier to Behaviour; BMI: Body mass index.
Dependent variable: Intention
Independent variables: ATT, SN, PBC and Knowledge.

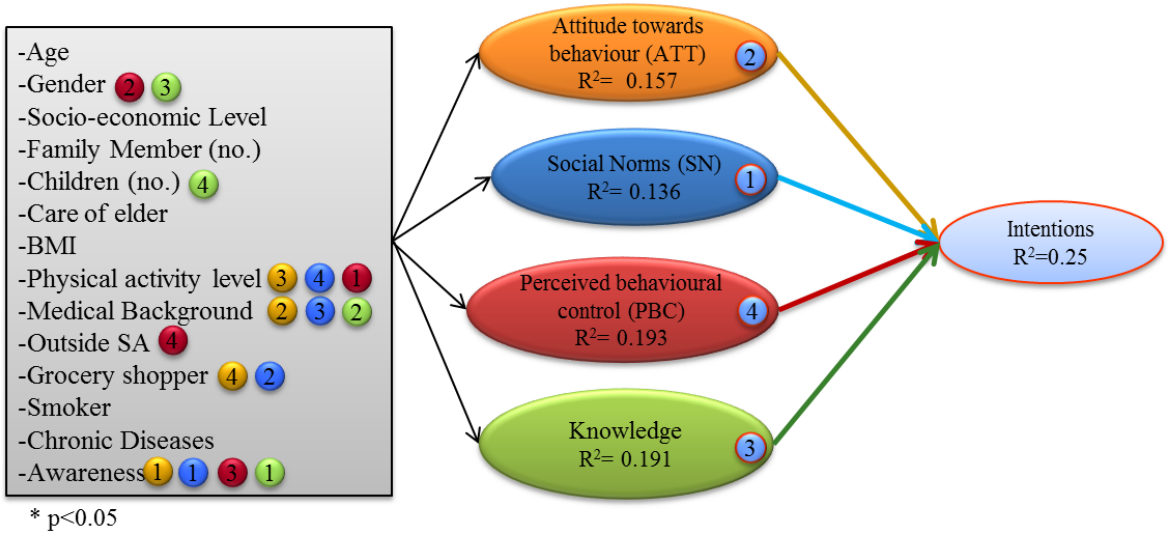


Figure 8.3-1: Path analysis for intentions toward balanced diet for study population (n=1042)

Note: -The colour of the numbers in level 1 matching the colour of construct in level 2
- The colour of number in level 2 matching the colour of intention in level 3
- The numbers are based on ranking of predictors based on beta using multiple regression analyses

8.3.2.4 Population awareness of nutrition and health guidelines and related factors

Only a minority (n=203, 19%) were aware of any (local/ foreign) nutrition & health guidelines (25% women, 15% men). Half of those aware (n=113/203, 56%) were aware of Saudi guidelines (Healthy Food Palm or DPAS) and/ or foreign guidance and 44% (n=90/203) were aware of non-Saudi guidelines ("Eat Well Plate" or "Food Guide Pyramid") only.

Nutrition and health guidelines awareness was higher in those with a medical/ nutrition education than those without medical/ nutrition education (71%, n=144/203, χ^2=178.3, p<0.001) with no difference between genders. Awareness did not differ between those who had lived outside SA for 3 months or more (21%, n=66/321) and those who never left SA (19%, n=137/724) (χ^2=0.381, p=0.537), even when considering students who had never left SA (24%, n=30/125) or those who had lived outside SA for 3 months or more (22%, n=11/51) (χ^2=0.120, p=0.729).

8.4 Discussion

The population in this study can be compared to the adult population Saudi census in 2010 (Ministry of Economy and Planning 2010). The study population was more educated (60% with a degree) compared to 37% of Saudi adults in the Saudi census of 2010 (Ministry of Economy and Planning 2010). With 1,045 participants, this study has a sample size larger than previous studies to assess the relationship between the study variables accurately (Povey, Conner et al. 2000; Psouni, Chasandra et al. 2016). The Cronbach α analysis was used to assess the internal consistency of the items in each TPB component. The analysis indicated an acceptable reliability of the TPB construct except for intention which is poor: 0.52. However, this item was not excluded, as it is testing an important feature explaining potential adoption of a balanced diet.

Results in this chapter highlight that the awareness and knowledge regarding nutrition and health guidelines are playing an important role in motivating SA people to take-up a more nutritionally balanced diet. In the same time, only 45% of the study subjects are

knowledgeable and very few (19%) are aware of any (local/ foreign) nutrition and health guidelines.

3.3.1 TPB model and intention towards adopting a nutritionally balanced diet

As discussed in Chapter 1, most of the Saudi population does not meet dietary guidelines proposed by national or global organizations (Section 1.1), leading to an increased prevalence of NCDs such as T2DM and CVDs. Promoting a nutritionally balanced diet including high fruit and vegetable intake was demonstrated to be effective. TPB is one of the models representing these interventions successfully (Ball, Jeffery et al. 2010; Brouwer and Mosack 2015).

This study shows that all TPB constructs positively predicted intention towards adopting a nutritionally balanced diet. ATT (having high positive self-performance to perform the behaviours), SN (perceived social pressure to engage in the behaviour), and PBC (perceived ease or difficulty of engaging in the behaviour) predicted intention positively. The current study found also that the SN toward balanced diet is the strongest predictor of participants' intension to eat a balanced diet ($B=0.111$; $p<0.0001$) whilst PCB was the weakest predictor ($B=0.026$; $p=0.028$) which means that the intention of a population is mostly affected by the social pressure - such as the concern of the participants' partner/ husband/ wife regarding his/ her health as well as the negative influence of mass media on the person's intention. These results are in agreement with several studies (Ball, Jeffery et al. 2010; McEachan, Conner et al. 2011; Kothe, Mullan et al. 2012; Brouwer and Mosack 2015; McDermott, Oliver et al. 2015).

The results in this study are also consistent with two recent meta-analyses (42 journal articles and four unpublished dissertations) and systematic reviews (McEachan, Conner et al. 2011; McDermott, Oliver et al. 2015). McDermott et al. found that TPB variables (ATT, SN and PBC) had medium to large associations both with intention and discrete food choice behaviour using intervention studies. The ATT had the strongest correlation with intention toward healthy eating ($r = 0.54$) followed by PCB ($r = 0.42$) and SN ($r = 0.37$) while r is the random effects average correlation ($p<0.001$). McEchan et al. found that prospective tests of the TPB model provided strong predictions of intention and

dietary behaviour across a range of health-related behaviours including healthy eating. The authors found that the ATT toward healthy eating had the strongest association with intention (variance: 33.1%), followed by PBC (17.9%) and SN (11.2%). Also, the latter study found that the dietary behaviour was strongly predicted by ATT (23.5%) followed by SN (16.0%), PBC (15.7%) and intention (14.2%).

The variance in the current study was the percentage variance in true score correlation attributable to statistical artefacts. SN and ATT toward healthy food were positively associated with intention toward healthy food consumption among 115 elderly residents Assisted-Living Facilities in Kansas, USA (Liu and Kwon 2013). Kothe et al. conducted an intervention called Fresh Facts intervention, based on the TPB model, to increase fruit and vegetable consumption through email-delivered messages among university students (Kothe, Mullan et al. 2012). The authors found that intention is the most proximal predictor of behaviour; and intention in turn was predicted by three constructs, ATT (evaluation of the behaviour and its expected outcomes), SN (perceived social pressure to engage in the behaviour), and PBC (perceived ease or difficulty of engaging in the behaviour).

8.4.1 Awareness, knowledge and intention towards nutritionally balanced diet

Nutritional knowledge is one of the main influential factors to improve behaviour of healthy eating and lifestyle towards health and overall wellbeing (McCullough, Feskanich et al. 2002). Nutritional knowledge has been related to making more healthful choices; and increased knowledge of dietary guidance has been found to be positively related to more healthy eating behaviours among college students (Kolodinsky, Harvey-Berino et al. 2007).

This study shows that very few SA adults (19%) were aware of any (local/ foreign) nutrition and health guidelines, with women more aware than men. The multiple regression analyses shows that among the external factors the awareness regarding nutrition and health guidelines was the strongest predictor of ATT, SN and knowledge (Figure 8.3-1). As show in previous section that knowledge predicts intention positively.

The results are consistent with existing findings in SA on fruits and vegetables. One cross-sectional study (n=151) conducted among Saudi women in the western part of SA, aimed to explore the influential factors on fruits and vegetables intake including nutritional knowledge, food preferences, and intention to change these preferences (Bakhotmah 2012). Most (85%) intended to increase their fruit and vegetables consumption. Unfortunately, the author did not assess the relationship between the intention of changing behaviour and nutritional knowledge. Al-Otaibi (2014) found that university students consuming ≥5 servings/day of fruit and vegetables in east part of SA (n=960) were more knowledgeable about the fruit and vegetable recommended levels ($P<0.001$). However, the author found that knowledge regarding fruit and vegetables was not a predictor for reaching recommended intake in this population. These findings may be due to different factors. Firstly, this study was conducted only among young adult women who are not usually exposed to health and nutrition education at school or university, except those in medical or health schools. Second, the dietary habits of university student may represent the eating habits in the university campus only where there is a standardised environment.

The study presented in this chapter highlights that the Saudi population is not sufficiently exposed to the current local guidelines regarding health and nutrition. This could be the result of the education curriculum in SA not including any information regarding health and nutrition promotion, and nutrition-related disease prevention. It highlights that the awareness regarding nutrition and health guidelines may play an important role in motivating SA people to take up a more nutritionally balanced diet as it is the strongest predictor of TPB construct. It also highlights that the stakeholders in SA, especially the Ministry of Health, may be using ineffective channels to convey their health and nutrition messages. Moreover, the research highlights that nutritional knowledge may have significant impact on the population intention toward adopting a nutritionally balanced diet and in turn to take up more nutritionally balanced behaviours. Social pressure may have strong impact on the population's intention. More depth studies are needed including prospective studies to assess the association between these influential factors and behaviour.

Povey et al. (2000) found in a prospective study in the UK (n=235) that perceived social support could act as a moderator variable on the relationship between perceived

behavioural control and intention, as well as the relationship between attitude and intention, by (Povey, Conner et al. 2000). Social support "describes the comfort, assistance, and/ or information one receives through formal and informal contacts with individuals or groups" (Courneya and McAuley 1995; Kelsey, Kirkley et al. 1996). Therefore, social support such as nutritional education needs to improve the community intention towards healthy and balanced diet. The previous study supports the study findings that knowledge has strong impact on the population intention toward nutritionally balanced diet.

8.4.2 Strengths and limitations

The number of participants in this study (n=1045) is sufficient since it affords a confidence interval (margin of error) of ±3% for data reported, at the 95% confidence level (CRS 2015). However, the generalizability of the study is limited by the fact that nearly one third of the study population (n=332) had a medical education background (food, nutrition or health education) which may affect the representation of the general population. The study sample from online survey may not be representative for the larger population of adults in Saudi Arabia, especially with illiterate people or ones who do not use internet or social media. However, the prevalence of illiteracy in SA is only 14% based on Saudi census in 2010 (Ministry of Economy and Planning 2010). Internet use in SA has increased from 13% of the total population (3 million) in 2005 to 64% (19.6 million) in 2014 (Al-Tawil 2001; Al-Saggaf 2004; CITC 2014). Simsim MT in 2010 found that 93% of people aged 19 to 25 years, and 70% of people older than 45 years, were using the internet (Simsim 2011). Therefore, this study could be conducted using online resources and social media tools targeting the Saudi Arabian population.

The TPB model is the preferred model to assess the psychosocial model to predict behaviours. Guillaumie et al. (2010) investigated the efficacy of different psychosocial models such as TPB, Social Cognitive Theory, the health belief model, and multicomponent approach combining several theories in predicting fruit and vegetable consumption (Guillaumie, Godin et al. 2010). The authors reported that the TPB is the preferable model to predict fruit and vegetable consumption in adults as it has the highest Random-Effect (R^2 = 0.45) among these models. The Random-Effect was calculated for the prediction of behaviour and intention in relation with fruit and vegetables intake, fruits

intake only, and vegetable intake only based on adjusted R^2 from different studies. It should be acknowledged that there are several barriers (ABB) that may influence intention but that only knowledge was chosen as a barrier. Other barriers can control behaviour such as lack of time or costs (Conner and Sparks 2005). Moreover, the TPB model (along with other social cognition models on behavioural change) cannot fully explain all variances in intention or behaviour. It can be seen that the TPB construct explained only 25% of the variance in intention towards adopting a balanced diet.

Participants were required to spend approximately 25 minutes to fill the study questionnaire which represents a significant burden, and may bias the respondent pool. Unfortunately, it was not possible to count the response rate in this study to know how many withdrew before completion. Also, this study did not assessed the usual dietary intake of the study population since it would increase their burden. However, information on people behaviour is very important because the population intention is not reperesenting the real practice. Therefore, future research should include the usual dietary intake to complete the TPB model and assess the influential impact of intention on real behaviour (dietary intake). Finally, body measurements and physical activity in this study were self-reported. It is possible that some participants were not willing to share their body measurements or did not know them. So, these results could be under or overestimated. Future studies should overcome these issues by performing a physical measurement instead of reporting.

8.5 Conclusion

Acknowledging the cross-sectional study design, very few SA adults are exposed to health and nutrition advice through the national nutrition and health guidelines. Awareness regarding nutrition and health guidelines may play an important role in motivate SA people to take up a more nutritionally balanced diet as it is the strongest predictor of TPB construct. The perceived social pressure to engage in behaviour toward a more nutritionally balanced diet (SN) may have an impact on population intention it was the strongest predictor of participants' intention. Overall, a focus on nutrition and health education interventions may benefit the Saudi population. However, more work is required on the impact of education of uptake of new behaviours and their maintenance in time. The

results of this study should be useful to design interventions to promote a more balanced diet in the Saudi population. These finding urge the stakeholders and policy makers in SA, especially the Ministry of Health and Ministry of Education, to update their awareness strategies and evaluate the channels used to convey the health and wellbeing messages in SA. In future research, more barriers influencing the population intention toward nutritionally balanced diet such as lack of time and cost should be investigated and tested in the TPB model. Future research should include data on usual dietary intake to complete the TPB model assessment.

Chapter nine

General discussion and implications for stakeholders

This thesis has focused on prevention and management of NCDs in Saudi Arabia (SA), with special emphasis on salt intake, body composition and nutritional knowledge / awareness. The last decade has witnessed a significant increase in NCDs, mainly attributable to behavioural and environmental factors. These factors include decreased physical activity, alcohol overuse, exposure to tobacco smoke, and poor diet including high salt and energy intake and low intake of fruit and vegetables (Lim, Vos et al. 2013; Johnson, Raj et al. 2015). While diet, adiposity and low muscle mass are important contributors for NCDs, there are a very limited number of in-depth studies focusing on body composition, diet and nutrition in SA. The steep population increase in SA (~75% in just over 10 years) and a young population (60% aged under 30) implies that the burden of NCDs will increase significantly in few years (Ministry of Economy and Planning 2010). Therefore, there is an urgent need for assessment of data to inform future public health intervention and long term risk management.

9.1 Research questions

This section summarises the Research Questions raised following the introduction and general methodology chapter (Chapter 2), and outlines the answers provided in this thesis.

Is a Saudi-specific food frequency questionnaire a reliable and valid tool to assess salt intake? (**Chapter 3**)

The relationship between chronic high salt intake and CVDs is well established (Elliott, Stamler et al. 1996; Lewington, Clarke et al. 2002; Gu, Young et al. 2009; Soga and Pandey 2011), and so the benefits of reducing salt intake on prevention of CVDs (He and MacGregor 2002; He, Li et al. 2013; Cook, Appel et al. 2014). However, salt intake has not been assessed in SA, nor have the main dietary sources of salt. The culture-specific aspects of the diet imply that a local assessment is required to provide relevant information for future interventions.

Chapter 3 showed that the newly developed food frequency questionnaire (FFQ) specifically designed for the SA population had moderate validity. These results are similar or better than previous studies (McKeown, Day et al. 2001; Gunes, Imeryuz et al. 2015). While no other studies are available to compare, the SA-FFQ also has a high validity coefficient using the Triad / Triangulation method (Yokota, Miyazaki et al. 2010).

The Saudi-FFQ performed well against both urinary salt excretion and 24-HDR for classification of intakes to tertiles, consistently with previous studies (Lassale, Guilbert et al. 2009; Zhuang, Yuan et al. 2012; Gunes, Imeryuz et al. 2015). Indeed, the Saudi-FFQ classified 83-85% of participants either in the same or adjacent tertile for salt intake against both other methods (urinary or recall). However, same tertile classification was weaker (45-52%).

The weighed Kappa statistic tests indicated fair agreement (0.36-0.37), superior than other studies where Kappa values for salt estimated by FFQ ranged from 0.20 to 0.29 against 24-HDR and from 0.18 to 0.31 against 24-hour urinary excretion (Lassale, Guilbert et al. 2009; Zhuang, Yuan et al. 2012; Gunes, Imeryuz et al. 2015). The lower Kappa statistics could be explained by small sample sizes of these studies.

Considering the moderate bias (2.3 gram) and large limits of agreement (-5.4 – 10.0), the Saudi-FFQ is a method suitable at population level, but remains a compromise over the gold standard 24hr urine collection, which would be impractical in a large population.

This newly developed FFQ is unique as it is designed specifically to the Saudi population as foods are culture-specific (Cade 2002). The Kuwaiti Semi-Quantitative FFQ (Dehghan 2005) was used to design the present study questionnaire. The food list were taken from a single 24h food recall (Al-Nozha M 1996). A dietary analysis database was developed especially to fulfil the objectives of present study using data from the Saudi food composition tables (Al-Nozha M 1996; KFSH&RC 2002).

With a validated FFQ, further questions could be raised regarding the salt intake in the Saudi population, using Riyadh as a sampling unit:

Does salt intake vary with socio-demographic characteristics; is salt intake related to blood pressure intake in SA; and what are the main sources of dietary salt in Saudi Arabia?

Chapter 4 showed that the Riyadh population consumes a high amount of salt (8.7 g/day), higher than the recommended level of salt (>5 g/d for salt). This is in line with previous work among South Indian and UK population (8.5 and 8.1 g/d, respectively) (Radhika, Sathya et al. 2007; Sadler 2012). Very few (18%) in this current study population met the national and WHO recommendation for salt intake (<5 g salt/day) (WHO/FAO 2003;

MOH 2012). Salt intake among Saudi adults is about 0.8–7 g salt/day above current recommendations. These findings are consistent with Trials of Hypertension Prevention (TOHP) findings which revealed that only 10% of subjects were consuming <5.75 g salt/day (Cook, Appel et al. 2014). The global mean salt intake is 10.1g salt/day (95% CI: 9.9 to 10.2) which is nearly twice the WHO recommended limit (<5g salt/day) (Powles, Fahimi et al. 2013). On average, salt intake in East Asia, Central Asia and Eastern Europe (mean >10.5 g/day), and Middle East, Central Europe and North Africa regions (9.8–10.5 g/day) is higher than Western Europe, North America and Australia/New Zealand (8.5 to 9.5 g/day) (Powles, Fahimi et al. 2013). Chapter 4 also outlines a relationship between increase salt intake and systolic blood pressure. These results are in consistent with several cross-sectional studies in India, UK and China, (Elliott, Stamler et al. 1996; Radhika, Sathya et al. 2007; Anderson, Appel et al. 2010). However, when the salt intake adjusted for WC, BMI and age (independently and together), the relationship disappeared. This may be explained by the stronger predictive values of both age and adiposity (Overlack, Ruppert et al. 1995).

This study found also that the main sources of dietary salt came from "vegetables" and un-processed foods, unlike other countries. Traditionally, people in SA add salt to both green salad and cooked vegetables. The main source of salt other populations are different than the current study as the Chinese diet was added salt during cooking (78%), followed by soy sauce (7%) whereas breads, grains and cereals (34%), followed by red meats, poultry and eggs (20%) were the main sources of salt in the UK (Zhou, Stamler et al. 2003; Anderson, Appel et al. 2010; Batcagan-Abueg, Lee et al. 2013). Li et al. (2015) in found that in a Chinese population that the main source of salt intake was added salt (79%), followed by salty vegetables (14%), soy sauce (3%), MSG (2%) and other sauce (2%) (Li, Qin et al. 2015). However, the Saudi Food Composition Tables (SFCT) included "ready to eat" foods which contain discretionary salt in SFCT analyses (Al-Nozha M 1996) used in the present study. These findings raise a concern regarding the encouragement to increase intake of vegetables without including advice regarding cooking advice, in light of the risk of higher salt intake in SA. It would be worthwhile to consider education strategies towards the use of alternative ingredients or dressings in salad and cooked vegetables.

The current study shows positive increase of salt intake with improving socio-economic levels particularly, with individual income. However, these results are not in agreement with several studies in Japan, UK and Northern Ireland (Purdy, Armstrong et al. 2002; Miyaki, Song et al. 2013; Ji and Cappuccio 2014). Riyadh city is the capital city of SA.

Therefore, the urban context possibly explains the higher wealth than other cities in SA. Data could be as a result of high access to different foods with income increase.

Beside salt intake, a most noticeable feature of the Saudi population is its rising waistline and body mass. As such, the following questions focused on measures of body composition in SA:

Are body composition measures influenced by age and does BMI agree with WC for predicting NCDs; and does SMI represent the muscle mass status in the body?

In Chapter 5, five cross-sectional surveys were merged together to provide a powerful and representative dataset for understanding adiposity in SA. The study shows that ~43% of older people (aged >45) and 14% of the whole SA population have an elevated WC despite a normal BMI (18.5–25). BMI becomes especially weak with increased age, which is a concern in a population with a high forecasted aged population in the next few decades. A quarter of women and a third of men with a large waist (risk 2) would not have been identified as high-risk because they have a BMI <30 kg/m^2. These finding are with agreement with a study in Scotland and England which found that approximately 41% of older adults with normal BMI (65 years and over, BMI=18.5–25 kg/m^2) had a large waist (WC>94cm for men, WC>80cm for women) (Vlassopoulos, Combet et al. 2013). Also, this study in agreement with the Australian Diabetes, Obesity, and Lifestyle (AusDiab) study which indicated that 40% of individuals with BMI<30 kg/m^2 had a large waist (WC >88cm for females and WC >102cm for males) (Tanamas, Shaw et al. 2014).

The present study also shows that the Saudi population tends to be fatter later in life, with WC rising more persistently than BMI. However, these findings are based on cross-sectional study designs which do not allow for comment on the impact of age on body composition variables. The study observed a positive association between SMI and BMI measures raised a concern regarding the suitable use of these indices in predicting low muscle mass and its related diseases. These results are in line with three cross-sectional studies on Japanese, Korean and US populations as these studies revealed a strong relationship between SMI and BMI (Janssen, Heymsfield et al. 2000; Park and Yoon 2013; Sampaio, Sampaio et al. 2014).

These finding raise a concern regarding the suitable use of SMI in predicting low muscle mass and its related complications. Therefore, further research is required to identify if

body composition measures including adiposity and muscle mass, can predict accurately health metabolic risks in SA (and the appropriate thresholds for these measures). As such, the following question was asked:

Is muscle mass, defined as %SMM, a suitable metric to estimate metabolic disease risk compared to SMI?

Chapter 6 showed that low muscle mass (SMM) is a predictor of metabolic diseases, when SMM is corrected for weight (%SMM). In addition, the corrected SMM for squared height (SMI) was a poor predictor of metabolic diseases. These finding are in agreement with two recent cross-sectional studies (Srikanthan and Karlamangla 2011; Park and Yoon 2013). SMM was estimated using equations included simple anthropometric and demographic measures (Al-Gindan, Hankey et al. 2014) which may raise a concern about using these equations. However, these equations had good prediction power with MRI validation groups (validation: R^2 =0.79, SEE=2.7 kg in men; R^2 =0.59, SEE=2.1 kg in women).

This thesis also assessed the predictive capability of SMI and %SMM using ROC curves (DeLong, DeLong et al. 1988). %SMM had better predictive capability for metabolic diseases compared to SMI (kg/m^2) and absolute SMM (kg). New cut-off points for %SMM for metabolic diseases were defined, ranging from 29 to 32% for men and 26 to 28% for women. The median of %SMM in women is 27% (IQR 24-30%) while the median of %SMM in men is 30% (IQR 28-34%).

This study is the first to set up new cut-off points for %SMM using ROC analyses. It also concluded that SMI should not be used as a surrogate measure of muscle mass as it is positively correlating with adiposity measures and positively predicting metabolic risks. While muscle mass was defined using an equation and simple anthropometric measures, these may not always be available depending on the epidemiological survey. As such, this study focused on BMI and WC and their predictive value in the context of metabolic diseases:

Is BMI alone or a combination of BMI and WC the better metric to estimate the likelihood of having metabolic diseases?

Chapter 7 shows that combining WC and BMI does not improve their value as predictors of metabolic diseases. This is in agreement with other two studies as both studies assessed performance of BMI in predicting metabolic diseases before and after adding WC in the prediction model (Janssen, Katzmarzyk et al. 2004; Lee, Huxley et al. 2008). Both studies found that adding WC to BMI does not improve their value as predictors of metabolic diseases.

The predictive value of BMI, WC, WHR and WHtR was assessed using ROC curves analyses (DeLong, DeLong et al. 1988). WC is the best overall predictor of metabolic diseases, whereas waist-to-height ratio (WHtR) performed nearly as well as WC. These finding are in agreement with several studies in the Arab region (Bouguerra, Alberti et al. 2007; Bener, Yousafzai et al. 2013; El Din, Zaki et al. 2014; Assaad-Khalil, Mikhail et al. 2015) and two multi-ethic meta-analysis studies in 2008 (Lee, Huxley et al. 2008; Nyamdorj 2008). These studies found that WC is the superior measure in prediction metabolic disease as WC has the highest AUC values.

This thesis suggests new cut-off points for WC in Saudi, in the context of metabolic diseases. The new cut-off points for WC range between 90 to 92 cm for women and 94 to 99 cm for men. When comparing these with WC cut-off points defined for other Arab populations using ROC, they appear relatively similar to those in Egypt, Lebanon and Qatar (88 to 91 cm for women and 95.5 to 102 cm for men) (Chedid, Gannagé-Yared et al. 2009; Bener, Yousafzai et al. 2013; El Din, Zaki et al. 2014). These new cut-offs are different than the Caucasian and Asian WC cut-offs. The newly developed WC cut-offs are higher than the cut-offs for Asian men and women (90 and 80 cm, respectively). The newly developed WC cut-off for women are higher than the cut-offs for Caucasian women (88 cm); and WC cut-off for men are lower than the cut-offs for Caucasian men (102 cm). However, these new cut-offs need to be validated using prospective study and accurate imaging techniques such as MRI or CT scan.

With a median BMI at 29 (kg/m^2) in women and 27 (kg/m^2) in men, and an increasing prevalence of obesity, there is concern that the Saudi population is not aware of nutrition guidelines, or not able to implement changes required. As such, the following question was asked:

Are Saudi adults aware of the existing nutrition and health guidelines and does their awareness best predict best the psychosocial constructs to adopt a nutritionally

balanced diet; and is their nutritional knowledge the best predictor of intention to adopt a nutritionally balanced diet?

Very few SA adults appear to have been exposed to health and nutrition advice through the national nutrition and health guidelines (**Chapter 8**). This thesis shows results much lower than Western countries (60%) (Brown, Timotijevic et al. 2011). Individuals with higher awareness about health and nutrition (although in the minority) were more likely to intend to change their behaviour. Awareness regarding nutrition and health guidelines was the strongest predictor of attitude toward behaviour, social norms and knowledge whilst the perceived social pressure to engage in behaviour toward a more nutritionally balanced diet (SN) was the strongest predictor of subjects' intention. These results are in consistent with several studies (Ball, Jeffery et al. 2010; McEachan, Conner et al. 2011; Kothe, Mullan et al. 2012; Brouwer and Mosack 2015; McDermott, Oliver et al. 2015). These studies found a strong association between the previous factors and intention using cross-sectional studies.

There are several barriers that may influence intention (to change/adopt a nutritionally-balanced diet) but knowledge was the only one studied in this thesis (chapter 8). Other barriers can control behaviour such as lack of time or costs (Conner and Sparks 2005). Moreover, the TPB model (along with other social cognition models on behavioural change) cannot fully explain all variances in intention or behaviour. In the case of this thesis, the TPB construct explained only 25% of the variance in intention towards adopting a balanced diet.

Also, this study did not assessed the usual dietary intake of the study population since it would increase their burden. However, information on people behaviour is very importsant because intention is not necessarilly representing the real practice. Therefore, future research should include the usual dietary intake to complete the TPB model and assess the influential impact of intention on real behaviour (dietary intake). Before using the data from the present study in intervention studies, the effect of intention on usual dietary intake should be verified.

9.2 Implications for public health

9.2.1 Salt intake

The Saudi-FFQ in this study had moderate relative validity and fair reliability. Therefore, it can be used to classify an individual's intake into tertiles and to identify the population at risk of high salt intake in SA while acknowledging that FFQ is poor at measuring absolute salt intake.

Population interventions, including health education, are required to reduce sodium intake in SA population. The quantitative and qualitative data provided in this study (chapter 8) could be used to develop and implement strategies for salt intake reduction in SA.

The current thesis observed that one of the main sources of salt intake in the study population was fresh and cooked vegetables (42%), raising a concern regarding the encouragement to increase vegetables intake without including advice regarding the risk of higher salt content of these foods. The source of high sodium in vegetables is mainly from added salt, sauces, or condiments, as vegetables naturally are low in sodium (Paul and Southgate 1991). As revealed in Chapter 8, knowledge and awareness have strong impact on the behavioural intention of consumers toward balanced diet, consumer education could be an important solution in reducing the salt levels in the Saudi diet especially in vegetables.

Salt has been iodised in the SA since 1997 (Omar and Desouky 2015). Reduction of (iodised) salt may affect iodine intake. Hendriksen et al. (2014) observed a reduction on iodine excretion between 2006 (257 µg/d) and 2010 (179 µg/d) in Dutch adults (Hendriksen, van Raaij et al. 2014). These authors concluded that the reduction of iodine excretion could be from reduction of added salt on processed food after implementing a salt-reduction strategy. Therefore, monitoring the use of (iodised) salt in foods and iodine intake is important when evaluating the implementation of new salt reduction regulations.

9.2.2 Body composition

Findings from Chapter 5 and 7 highlight that continued use of BMI as a sole indicator of health risks would mean that 14% to 43% of the whole SA population are misclassified and might not be alerted of health risks. This thesis highlights the superiority of WC over BMI in predicting health risks and metabolic diseases. This study highlights also that

combining WC to BMI does not improve prediction powers of these measures to predict metabolic diseases. However, the recent strategy for prevention and management of obesity suggested adding WC to BMI for managing and preventing obesity (Al-Shehri, Moqbel et al. 2016). Therefore, health authorities in SA such as the Ministry of Health are required to take action regarding the alternative measure for body adiposity.

Chapter 6 also highlights that continued use of skeletal muscle mass index to define low muscle mass status can lead to a large variation in predicting metabolic risks compared to percentage of muscle mass to body weight (%SMM). Therefore, health authorities in SA such as the Ministry of Health, health professionals, and researchers are required to take action to use %SMM as alternative measure for muscle mass status to predict health risks.

9.2.3 Awareness and knowledge

Psychosocial variables that can highly predict intention toward behaviour provide effective levers to promote intention to change. Therefore, as knowledge was strongly associated with intention toward adopting a nutritionally balanced diet, interventions that aim at improving nutritionally balanced diet consumption should include strategies to increase nutrition education with a focus on positive health outcomes of balanced diet consumption.

Awareness of nutrition and health guidelines plays an important role in motivating SA people to intend to take up a more nutritionally balanced diet by influencing the psychosocial variables. Only 45% of the study subjects are knowledgeable about food and nutrition and very few (19%) are aware of any (local/foreign) nutrition and health guidelines in this largely educated sample. The low awareness and knowledge levels could be the result of the education curriculum in SA not including any information regarding health and nutrition promotion, and nutrition-related disease prevention. It also highlights that the stakeholders in SA, especially the Ministry of Health, may be using ineffective channels to convey their health and nutrition messages. These finding urge the stakeholders such as Saudi Food and Drug Authority and policy makers in SA, especially the Ministry of Health and Ministry of Education, to update their awareness strategies and evaluate the channels used to convey the health and wellbeing messages in SA.

9.3 Future research

The results described in this thesis have indicated several areas of possible future research.

9.3.1 Salt intake

A relatively wide range of determinants of salt intake have been investigated in the present study, such as socioeconomic determinants, eating behaviours, sources of salt intake. However, there are other determinants that, in addition to those already investigated, could give a more integrated understanding of salt intake. Other research observed that there are other sources of sodium in different populations such as seasonings and condiments such as mono-sodium glutamate (MSG), soy and fish sauces (Lee 2009; Batcagan-Abueg, Lee et al. 2013). These sources should be investigated more as they could be high sources of sodium in SA diet. The future research question should be raise from these findings as the following:

RQ: Are the vegetables, condiments or dressings main sources of salt intake in SA which need more consideration in future population interventions?

Further efforts should be made to evaluate the reproducibility and reliability of the present FFQ (Saudi-FFQ). The Saudi-FFQ should be conducted several times in the year to assess its reproducibility in estimating salt intake. Also, some food items which high in sodium such as sauces, condiments and seasonings should be included in this questionnaire. The validity and reliability of Saudi-FFQ should be assessed after adding these items.

The food environment may play an important role in salt intake. This kind of determinant has not been investigated in this study. With dramatic changes in socioeconomic status in SA, there is an increase in fast food and take away outlets in cities, making fast food easily available and accessible which could have an impact on food availability. Fast food and hot takeaway meals contain more added salt (Rasmussen, Lassen et al. 2010; Jaworowska, Blackham et al. 2012). A quarter of this study population eats at least 5 times a week from fast food and take away outlets (data not shown). Therefore, it would be interesting to examine the extent to which the food environment in SA is related to salt intake, and if so, to explore environmental change strategies in order to decrease consumption or the content of salt in these products. The future research question should be raise from these assumptions as the following:

RQ: Do fast food and hot takeaway meals contain high content of added salt (sodium) and what is the eating frequency of these meals in SA?

9.3.2 Body composition

The cross-sectional nature of the present survey limits the ability to draw causal inferences from the relationships between body composition and age. Therefore, further prospective long-term studies with imaging techniques are required in SA and the Eastern Mediterranean region to validate our findings. The prospective studies are required to investigate the value of muscle mass indices, waist circumference, and body mass index over time. Prospective studies are required to assess the validity of these measures during weight loss and during progressive diseases. Therefore, the proposed research questions as follow:

RQ: How well do the muscle mass indices, waist circumference, and body mass index perform over time during progress of age?

RQ: How well do the muscle mass indices, waist circumference, and body mass index perform over time during progress of diseases such as T2DM, cancer?

RQ: How well do the muscle mass indices, waist circumference, and body mass index perform over time during weight loss programs?

9.3.3 Awareness and knowledge

As discussed in Chapter 8, the lack of knowledge was considered as a barrier preventing adoption of a nutritionally balanced diet. However, lack of knowledge is not only the barrier in this area of interest. In future research, more barriers influencing the population intention toward nutritionally balanced diet should be investigated and tested in the TPB model.

Behaviour/ practice is the final and important part of the TPB model. However, the usual dietary intake as behaviour in this study was not assessed. Future research should include the usual dietary intake to complete the TPB model. Also, the direct influential effect of knowledge on behaviour should be considered in future research. Therefore, the proposed research questions are as follow:

RQ: Does knowledge influence the behaviour of SA population toward nutritionally balanced diet?

RQ: Is there any barrier influencing the population intention toward nutritionally balanced diet? If yes, is it influencing the population's behaviour directly?

CONCLUSION

This thesis adds a new and unexpected source of salt intake by including vegetables and unprocessed foods. These findings raise a concern regarding the encouragement to increase intake of vegetables without including advice regarding cooking, in light of the risk of higher salt intake in SA. It would be worthwhile to consider education strategies towards the use of alternative ingredients or dressings in salad and cooked vegetables. This thesis also adds evidence about the weakness of BMI and SMI in predicting metabolic diseases and misclassifying the population. Alternatively, this thesis suggests the use of WC as an adiposity measure and %SMM as a muscle mass measure and proposed accurate cut-offs for prevention and management of NCDs. However, these new cut-offs need to be validated using prospective study and accurate imaging techniques. This thesis provides evidence of the importance of increasing the knowledge and awareness of SA population regarding a nutrionally balanced diet. The steep rise in the youthful population in SA will escalate the burden of NCDs in the forthcoming decades unless preventive measures are put in place.

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Appendices:

Appendix1: Ethical Approval

Kingdom of Saudi Arabia
Saudi Food & Drug Authority
(255)
Drug Sector

المملكة العربية السعودية
الهيئة العامة للغذاء والدواء
(٢٥٥)
قطاع الدواء

INSTITUTIONAL REVIEW BOARD
INTERNAL MEMORANDUM

Date : (G) 08 June 2014
(H) 10 Sha'ban 1435

To: Mr. MAJID ALKHALAF
Principle Investigator
PhD Candidate
Human Nutrition Department
School of Medicine , University of Glasgow

From: Prof. SALEH ABDULLAH BAWAZIR
Chairman
Institutional Review Board

Subject: New proposal:
"Planning for the development of nutritional and dietary assessment methods: reliability and validity"

This is in reference to your subject proposal, which has been reviewed by the IRB committee on the 28th of May 2014. Following the review of the IRB on the ethical aspects of the proposal, you are granted permission to conduct your study.

This is to acknowledge that we received and approved the following documents:

- Project proposal.
- Application form for ethical approval (University of Glasgow).
- Procedures manual for diet and nutrition survey.
- Consent form.
- Participant information sheet (English & Arabic version).
- Saudi food frequency questionnaire.
- Multiple pass 24 hours dietary recall forms.
- Demographic, blood pressure and anthropometric questionnaire.
- Instructions for 24-hours urine collection (English & Arabic version).

TERMS OF APPROVAL:

1. **Annual reports:** continued approval of this project is dependent on the submission of an annual report. Please provide the IRB committee with annual report determined by the date of your letter of approval. In addition, the PI will also submit the final report of the study outcome plus immediate reporting of adverse effects to SFDA/IRB committee.

٣٢٩٢ الطريق الدائري الشمالي - حي النفل - الرياض ١٣٣١٢ - ٦٢٨٨ - المملكة العربية السعودية - هاتف: ٢٠٣٨٢٢٢ ١ ٩٦٦+ فاكس: ٢٠٥٧٦٣٣ ١ ٩٦٦+
3292 Northern Ring Rd. - Al Nafal District - Riyadh 13312-6288 - Kingdom of Saudi Arabia - Tel.: +966 1 2038222 - Fax: +966 1 2057633
www.sfda.gov.sa

2. **Amendment to the approved project:** changes to any aspects of the project require the submission of a request for amendment to IRB committee and must not begin without an approval from SFDA /IRB committee. Substantial variations may require a new application.

3. **Monitoring:** Projects may be subject to an audit or any other form of monitoring by SFDA/IRB committee at any time.

4. **Retention and storage of the data:** the PI is responsible for the storage and retention of the original data pertaining to project for a minimum period of five years.

Upon the above permission the PI should contact the IRB committee for any further clarification through E-mail: IRB@sfda.gov.sa or Telephone: 011-2038222 Ext: 2342

We wish you every success in your research endeavors.

Appendix2: Consent Form

University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

DIET AND NUTRITION SURVEY IN RIYADH CITY

المسح الغذائي والتغذوي في مدينة الرياض

CONSENT FORM

نموذج إقرار

Title of Project: DIET AND NUTRITION SURVEY IN RIYADH CITY
Name of Researcher: Majid M. Alkhalaf
PhD Student, Human Nutrition Department, School of Medicine, University of Glasgow

عنوان المشروع المسح الغذائي والتغذوي في مدينة الرياض.
الباحث ماجد مقبل الخلف.
طالب دكتوراه، قسم تغذية الإنسان، كلية الطب، جامعة جلاسكو.

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.
3. I agree to take part in the above study.

1 - أقر بقراءة وفهم جميع ما ورد في ورقة المعلومات المتعلقة بالمشاركة في الدراسة المذكورة أعلاه، كما أتيحت لي الفرصة لطرح الأسئلة حول ذلك.

2 - أعلم أن مشاركتي تطوعية ولي الحق في الانسحاب من الدراسة في أي وقت ومن دون توضيح الأسباب، كما أن مشاركتي ليس لها تأثير على حقي في الرعاية الصحية أو حقوقي القانونية.

3 - أوافق على المشاركة في الدراسة المشار لها أعلاه.

Signature التوقيع	Date التاريخ	Name of subject اسم المشارك
Signature التوقيع	Date التاريخ	Name of Person taking consent (if different from researcher) اسم الشخص الذي أخذ الموافقة (إذا كان غير الباحث)
Signature التوقيع	Date التاريخ	Researcher الباحث

1 for subject; 1 for researcher
نسخة للمشارك ونسخة للباحث

Appendix3: Saudi-FFQ

University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

DIET AND NUTRITION VALIDATION SURVEY IN RIYADH CITY

المسح الغذائي والتغذوي في مدينة الرياض

Date of Interview □□/□□/□□□□

Participant's Code □□□□

Saudi Food Frequency Questionnaire

1. Dairy Products: الحليب ومنتجاته

During the past year, on average, how often have you consumed the following, dairy foods? (Please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
1.1	**Milk: حليب**											
1.1.1	كامل الدسم Whole											
1.1.2	قليل الدسم Low Fat											
1.1.3	منزوع الدسم Skimmed											
1.2	**Laban: لبن**											
1.2.1	كامل الدسم Whole											
1.2.2	قليل الدسم Low Fat											
1.2.3	منزوع الدسم Skimmed											
1.3	**Cream Cheese:** جبنة الكريمة القابلة للدهن(مثل:المراعي،بوك،كرافت)											
1.3.1	كامل الدسم Whole											
1.3.2	قليل الدسم Low Fat											
1.4	**White cheese (Feta, Mozzarella and Spread Cheeses)** الجبنة البيضاء(فيتا، موزاريلا،الجبنة قابلة للدهن)											
1.5	**Cheddar Cheese** جبنة التشيدر											
1.6	**Yogurt:** زبادي/روب											
1.6.1	كامل الدسم Whole											
1.6.2	قليل الدسم Low Fat											
1.6.3	منزوع الدسم Skimmed											
1.7	**Labnah:** لبنه											
1.7.1	كامل الدسم Whole											
1.7.2	قليل الدسم Low Fat											
1.8	**Ice cream:** آيس كريم											
1.9	**Quashta (Cream) /Gaymar** قشطة/قيمر											

Please, make sure you have given an answer for every line before leaving this page

1

2. Fruits: الفواكه

During the past year, on average, how often have you consumed the following fruits? (please check the appropriate box)

(For seasonal fruits marked *, please estimate your average use when the fruit is in season)

(للفواكه الموسمية ذات العلامة *، يرجى تقدير متوسط استهلاكك لها في الموسم)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
2.1	Fresh Fruit Salad سلطة فواكه طازجه											
2.2	Tinned Fruits (all kinds) فواكه معلبه											
2.3	Apple تفاح											
2.4	Bananas موز											
2.5	*Strawberry, raspberries فراولة، توت											
2.6	Oranges and Mandarin برتقال ،يوسفي											
2.7	Grapefruit جريب فروت											
2.8	Plums, Peaches /Nectarines, or Apricots برقوق، بخاري،خوخ أو مشمش											
2.9	Dates: تمر											
2.9.1	Dry dates (Tammer) تمر											
2.9.2	Fresh Dates (Ruttab, refriger.) تمر مبرد											
2.9.3	*Fresh (Ruttab or Fresh) رطب أو بلح											
2.10	Pears, Pineapple, Kiwi, Figs, Cherries كمثرى، أناناس، كيوي، تين، كرز											
2.11	Grapes عنب											
2.12	Olives زيتون											
2.13	Dried Fruits (e.g. Figs, Apricots, Raisins, Peaches) فواكه مجففه(تين،مشمش،زبيب،خوخ)											
2.14	*Watermelon بطيخ											
2.15	*Other melons (e.g. Canteloupe, Galia or Honeydew) شمام/بطيخ اصفر											
2.16	Mango مانجو											
2.17	Pomegranate رمان											

Please, make sure you have given an answer for every line before leaving this page

3. Vegetables: الخضروات

During the past year, on average, how often have you consumed the following vegetables? (please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6 +	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
3.1	Cabbage: ملفوف/كرنب											
3.1.1	طازج Fresh											
3.1.2	مطبوخ Cooked											
3.2	Mixed Vegetable Salad (fresh) سلطة مشكلة											
3.3	Mixed Vegetables (cooked) خضار مشكلة مطبوخة											
3.4	Cauliflower, Broccoli or Brussels sprouts (cooked) زهرة،القرنبيط المطبوخ أو كرنب											
3.5	Tabouleh تبولة											
3.6	Green leafy vegetables (Molokhia & spinach) الورقيات الخضراء (ملوخية، سبانخ), Okra & Green Beans باميا، لوبا فاصوليا خضراء											
3.7	Peas (cooked)/ (bazelah) بازلاء مطبوخة											
3.8	Carrots جزر											
3.9	Tomatoes طماطم											
3.10	Mushrooms فطر(مشروم)											
3.11	Leeks كراث											
3.12	Cucumber خيار											
3.13	Lettuce خس											
3.15	Sweetcorn ذرة											
3.16	Onion بصل											
3.17	Beans (fava, red, white and Soya beans), lentils, Pigeon, Chick & cow peas) (cooked) فول،عدس،فول الصويا،فاصوليا،حمص(بليلة) فاصوليا											
3.18	Baked beans فاصوليا حلوة											
3.19	Boiled potatoes بطاطس مطبوخة (مسلوقة)											
3.20	Fried potatoes (French fries) بطاطس مقلية (اصابع)											
3.21	Potato crisps بطاطس تشيبس (مثل برينقلز أو ليز)											

Please, make sure you have given an answer for every line before leaving this page

4. Meat, Fish and Eggs: لحوم، أسماك وبيض

During the past year, on average, how often have you consumed the following meat, fish, eggs etc.? (please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
4.1	Boiled Egg بيض مسلوق											
4.2	Fried eggs, Scrambled eggs or omelets بيض مقلي، أومليت											
4.3	Chicken or turkey (boiled, grilled or fried) دجاج، رومي(مسلوق،مشوي،مقلي)											
4.4	Lamb or mutton as a mixed dish (e.g. Kabsah, stew, casserole, Spaghetti, lasagne etc. لحم ضأن مضاف لأطباق مشكله كبسة لحم..إيدام/مرق، سباغيتي ولازانيا باللحم											
4.5	Lamb or mutton as a main dish (eg. Steak, roast, in gravy etc.) لحم ضأن طبق أساسي، ستيك، اضلاع مشوي أو في مرق/إيدام											
4.6	Beef as a or mixed dish (e.g. Kabsah, stew, casserole, Spaghetti, lasagne etc. لحم بقري في طبق متنوع من الحوم البقرية (كبسة،بيدام/ مرق، سباغتي، لازانيا)											
4.7	Beef as a main dish (eg. Steak, roast, in gravy etc.) لحم بقري كطبق اساسي ستيك، اضلاع مشوي أو في إيدام/مرق											
4.8	Camel Meat لحم جمل											
4.9	Burgers (beef burger or Chicken Burger) برجر (لحم بقري او دجاج)											
4.10	Fried fish سمك مقلي											
4.11	Grilled or steamed fish سمك مشوي أو سمك بالبخار											
4.12	Canned tuna, salmon, mackerel, or sardine تونة معلبه سلمون، الإسقري، سردين											
4.13	Prawn or Shrimps جمبري او ربيان											
4.14	Mussels, oysters, scallops or cockles بلح البحر، المحار، اسكلوب، الصدفيات											
4.15	Organ meat (liver,brain,heart) لحوم الاحشاء(كبد، مخ،قلب)											

Please, make sure you have given an answer for every line before leaving this page

5. Mixed Dishes: أطباق مختلطة

During the past year, on average, how often have you consumed the following mixed dishes? (please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
5.1	Vegetable soup شوربة خضار											
5.2	Chicken soup with cream شوربة الدجاج بالكريمه											
5.3	Lentil soup شوربة عدس											
5.4	Oat meal Soup شوربة الشوفان											
5.5	Jareesh (gerish), Marqooq, harees, mataziz, or Qorsan جريش،مرقوق،هريس،مطاطيز،قرصان											
5.6	Saleeq سليق/رز طايقي											
5.7	Marasia (Marassia) مراصيع											
5.8	Aseeda (Asseda) عصيد											
5.9	Rice (Kabsah, Beriani, Bukhari or mandi) without meat أرز (كبسة،برياني،بخاري،مندي)بدون لحم											
5.10	Rice with Vegetables (Maqloobah) without meat أرز بالخضار(مسلوق) بدون لحم											
5.11	Kebbah كبه											
5.12	Mottabaque W/ egg (Muttabagh) مطبق بالبيض											
5.13	Stuffed vegetables (Vine leaves, cabbage, squash) خضراوات محشية ورق عنب،ملفوف،كوسا)											
5.14	Eggplant (aubergine), Zucchini (Marrow) (cooked) (Mussakaah OR Moussaka) باذنجان،كوسة(مصقعه)											
5.15	Lasagne لازانيا											

6. Breads, Cereals and Starches: مخبوزات، حبوب ونشويات

During the past year, on average, how often have you consumed the following Breads, cereals and starches? (Please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
7.1	Breakfast cereals (corn flakes) رقائق الذرة (كورن فلكس)											
7.2	White bread (Samoli, tabonah, tannor, toast, pita) خبز ابيض(صاموني،تنور،توست											
7.3	Brown bread (Samoli, Tabonah, toast, pita) خبز بر (صاموني، توست)											

Please, make sure you have given an answer for every line before leaving this page

7.4	Tamees or Irani bread with sesame تميس او خبز ايراني مع السمسم														
7.5	Pasta spaghetti and Macaroni مكرونة(باستاسباغتي)														
7.6	Dates Biscuits بسكوت بالتمر														
7.7	Other Biscuits and crackers كل أنواع البسكويت														

7. Beverages, Juices and Drinks: العصائر والمشروبات

During the past year, on average, how often have you consumed the following beverages?

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
8.1	Regular Coffee and Instant coffee (e.g. Nescafe) القهوة السوداء والتركية مثل النسكافيه											
8.2	Arabic Coffee قهوة عربية											
8.3	Coffee Whitnesrs e.g. coffee-mate مبيض القهوة (كوفي مبت)											
8.4	Regular fizzy soft drink (e.g. Cola, lemonade, etc.) مشروبات غازية											
8.5	Low calorie (diet) fizzy soft drink (e.g. Cola, lemonade, etc.) مشروبات غازية (بدون سكر)											
8.6	Black Tea شاي اسود											
8.7	Green Tea شاي اخضر											
8.8	Fruit squash or cordial العصائر المضاف لها ماء (تانج أو فيمتو)											
8.9	Hot chocolate/ Cocoa drinks هوت تشوكليت											
8.10	Horlicks/Ovaltine/ Nesquik/ Milo بودرة معززة الطعم تضاف للحليب أو الماء الساخن (نسكويك أو مايلو)											
8.11	Mineral water (not in other drinks) (sehha) مياه الشرب المعبأة أو المياه المعدنية											
8.12	Tap water (not in other drinks) ماء الصنبور أو الحنفية											
8.13	Pure fruit juice (orange, apple,etc.) عصير الفاكهه (برتقال، تفاح أو غيرها)											
8.14	Energy Drinks مشروبات الطاقة											

8. Sweets: الحلويات

During the past year, on average, how often have you consumed the following sweet baked goods? (please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
9.1	Cream caramel كريم كراميل											
9.2	Halawah Tahinah (Tahini) طحينية											

Please, make sure you have given an answer for every line before leaving this page

9.3	Doughnuts دونات											
9.4	Basbousah and Konafah بسبوسة وكنافه											
9.5	Mohallabiah مهلبية											
9.6	Klijah & Lugimat Al-Ghadi (Lugimat) كليجة و لقيمات											
9.7	Cake (All) كيك											
9.8	Arabic sweets Baklawa حلويات عربية (بقلاوة)											
9.9	Chocolate شكولاته											
9.10	Honey عسل											
9.11	Jam مربى											
9.12	Jellies, All Kinds جلى											

9. Seeds and Nuts: المكسرات والبذور

During the past year, on average, how often have you consumed the following seeds? (please check the appropriate box)

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6 +	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
10.1	Almond اللوز											
10.2	Cashew nuts كاجو/سن العجوز											
10.3	Peanut فول سوداني											
10.4	Pistachio فستق											
10.5	Walnut جوز											
10.6	Hazelnuts بندق											
10.7	Pecan nut عين الجمل											
10.8	Chest nut أبو فروه											
10.9	Mixed nuts مكسرات مشكله											
10.10	Seeds (sunflower, melon, sesame seeds) بذور الحبحب، القرع أو دوّار الشمس											
10.11	Peanut butter زبدة الفول السوداني											

10. How often do you eat meals at a fast food/non-fast food restaurant?

في الغالب، ما هو معدل استهلاكك للوجبات الغذائية خارج المنزل سواء من مطاعم الوجبات السريعة أو غيرها؟

Average Frequency									
Per day (times)				Per week			Per month		Office use only
6+	4-5	2-3	once	5-6	2-4	once	1-3	Never, less than once/ month	
☐	☐	☐	☐	☐	☐	☐	☐	☐	

11. Artificial Sweeteners: المحليات الاصطناعية

Do you take Artificial Sweeteners regularly? هل تستخدم المحليات الاصطناعية ؟

☐ No لا ☐ Yes نعم

Please, make sure you have given an answer for every line before leaving this page

If Yes, what kind (including brand name) and how often do you consume.

إذا كانت الإجابة بنعم، ما هو نوع هذا المحلي الاصطناعي (بما في ذلك الاسم/العلامة التجارية) وكم الكمية المستهلكة في الغالب؟

Artificial Sweetener		Average Frequency									
Name &Brand	Dose	Per day (times)				Per week			Per month		Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Never, less than once/ month	

12. Vitamins and Minerals: الفيتامينات والمعادن

Do you take supplements such as vitamins or minerals regularly?

هل تأخذ المكملات الغذائية مثل الفيتامينات أو المعادن بانتظام؟

☐ No لا ☐ Yes نعم

If Yes, what kind (including brand name) and how often do you consume.

إذا كانت الإجابة بنعم، ما هو نوع المكمل الغذائي (بما في ذلك الاسم/العلامة التجارية) وكم الكمية المستهلكة في الغالب؟

Supplement		Average Frequency									
Name &Brand	Dose	Per day (times)				Per week			Per month		Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Never, less than once/ month	

13. Fats, Oils and Sugar: الدهون، الزيوت والسكر

A. Spreads and Oils: (الدهون والزيوت القابلة للدهن، عدا التي تستخدم في الطبخ)

Do you use any butter, margarine or other spread or oil on bread?

هل تستخدم الزبدة، السمن، المارجرين أو الزيوت على الخبز؟

☐ No لا ☐ Yes نعم

If yes, please give full details of the type(s) you use most often?

إذا كانت الإجابة بنعم، يرجى إعطاء التفاصيل الكاملة للأنواع التي تستخدم في معظم الأحيان؟

Office code

..... ☐☐

..... ☐☐

..... ☐☐

..... ☐☐

Please, make sure you have given an answer for every line before leaving this page

If yes, how many teaspoons of butter, margarine or other spread did you use each day on bread?
إذا كان الجواب نعم، كم ملعقة شاي تستخدم يومياً من الزبدة، المرجرين، السمن أو الزيوت الأخرى التي استخدمتها على الخبز؟

B. Sugar: السُكَّر

Do you add sugar on your tea or coffee? هل تقوم بإضافة السكر على الشاي، القهوة، الكورن فليكس أو غيرها الخاصة بك؟

☐ **No** لا ☐ **Yes** نعم

If yes, what type of sugar you are using? إذا كان الجواب نعم، فما هو نوع السكر المستخدم

☐ **White** سُكَّر أبيض ☐ **Brown** سُكَّر بُنِّي

☐ **Others** (غيرها) ..... (include brand names please)
(بما في ذلك الاسم أو العلامة التجارية)

How many teaspoons of table sugar did you use each day in drinks and on cereals or deserts?
إذا كان الجواب نعم، كم من ملعقة شاي من سكر المائدة التي تستخدمها كل يوم في المشروبات، الكورن فليكس وغيرها

(If you did not use any table sugar, please enter 0). (إذا كنت لا تستخدم أي كمية من سكر المائدة، من فضلك ضع (0)).

C. Salt: ملح الطعام

Do you add Salt to food while cooking? هل تقوم بإضافة الملح إلى طعامك أثناء الطبخ؟

☐ **Never** لا ☐ **Rarely** نادراً ☐ **Sometimes** أحياناً

☐ **Usually** عادة ☐ **Always** دائماً

Do you add Salt to any food at the table (while eating)? هل تقوم بإضافة الملح إلى طعامك أثناء الأكل؟

☐ **Never** لا ☐ **Rarely** نادراً ☐ **Sometimes** أحياناً

☐ **Usually** عادة ☐ **Always** دائماً

Do you regularly use a salt substitute (e.g. LoSalt)? هل تستخدم بدائل الملح بانتظام (على سبيل المثال: لوسولت)؟

☐ **No** لا ☐ **Yes** نعم

If yes, which brand? .....

D. Cooking fats and oils: دهون وزيوت الطهي/الطبخ

Do you use any fat or oil for home frying or cooking? هل تستخدم أي دهون أو زيت للقلي أو الطبخ في المنزل؟

☐ **No** لا ☐ **Yes** نعم

Please, make sure you have given an answer for every line before leaving this page

If yes, what type of cooking oil is usually used at home and what is the frequency of consumption?
إذا كانت الإجابة بنعم، ما هو نوع زيت الطهي/الطبخ المستخدم عادة في المنزل وما هو معدل الاستهلاك؟

Code	Food Item	Per day (times)				Per week			Per month or Never		Measure	Code (office use only)
		6+	4-5	2-3	once	5-6	2-4	once	1-3	Less than once		
15.1	**Butter** زبدة											
15.2	**Margarine** زبدة نباتية (مارجارين)											
15.3	**Animal Fat (Tallow or Dripping)** شحم حيواني											
15.4	**Vegetable Oils (Represent. for Sunflower, Canola, Corn, Cottonseed, Palm and Soybean Oils)** زيوت نباتية											
15.5	**Olive oil** زيت زيتون											
15.6	**Ghee (represent. palm and butter)** سمن نباتي أو حيواني											
15.7	**Mayonnaise** مايونيز											

THANK YOU FOR ANSWERING THESE QUESTIONS

شكراً جزيلاً على الإجابة

Please, make sure you have given an answer for every line before leaving this page

Appendix4: 24- hours Urine Collection Record

University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

DIET AND NUTRITION	المسح الغذائي والتغذوي
SURVEY IN RIYADH CITY	في مدينة الرياض

24- hours Urine Collection Record

سجل جمع البول خلال 24 ساعة

الاسم:.. العمر:..

تاريخ بداية الجمع:.................................. الجنس: ذكر/أنثى

وقت بداية الجمع:.................................. وقت الانتهاء من الجمع:..................................

Comments ملاحظات	Volume الكمية	Time الوقت
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM
		___ ___ : ___ ___ ص AM/م PM

Please report on the following : يُرجى الاجابة عن ما يلي:

1. Any lost specimens (how many times and in what time?) — 1- هل فقدت أي عينات من البول (كم مره و في أي وقت؟)

....
....
....

2. Any blood and/or faeces dropped in urine during collection (how many times and what time)?؟ 2- هل وقع أي دم أو براز في البول خلال عملية الجمع (كم مره و في أي وقت؟)

....
....
....

3. Any medication or supplements taken during the urine collection (name & amount):
3- هل تناولت أي دواء أو مكمل غذائي خلال جمع البول؟ (الاسم و الكمية):

....
....
....

The time at which the PABA tablets been taken: 4- ما هي أوقات تناول أقراص فيتامين البابا:

Breakfast الفطور	Lunch الغداء	Dinner العشاء
___ ___ : ___ ___ AM ص/PM م	___ ___ : ___ ___ AM ص/PM م	___ ___ : ___ ___ AM ص/PM م

PLEASE RETURN COMPLETED COLLECTION RECORD WITH THE URINE SPECIMEN

الرجاء إعادة سجل جمع البول بعد تعبئته مع وعاء حفظ البول

Appendix5: Estimation of mis-reporters of Actual Energy Intake (AEI):

In chapter 3, we have implemented arbitrary energy cut-offs (<500 kcal/day or >5,000 kcal/day) were suggested by Walter Willet (Willett 2012) and implemented by several studies (Larson, Neumark-Sztainer et al. 2011; Liu, Wang et al. 2013; Jensen-Otsu and Austin 2015; Zhao, Yan et al. 2016). Any subject have daily energy intake below 500 or above 5,000 kcal was considered with an implausible energy intake and was excluded from the analysis. However, in this appendix, we have added our analysis regarding indirect measurement of Basal Metabolic Rate (BMR) using the Schofield prediction equations based on age, body weight (in kg) and sex (Schofield 1985), as adopted by the FAO (Food and Agricultural Organization), WHO (World Health Organization) (2004) (FAO/WHO/UNU 2004) and the Scientific Advisory Committee on Nutrition (2011) (Nutrition 2011). These equations are shown in **Table 2.4-4**. Estimated BMR was multiplied by a physical activity level (PAL) value of 1.2 to calculate estimated energy requirement per day. This PAL value (1.2) corresponds to the value to be multiplied with the BMR of totally inactive dependent person (bed bound or chair bound) with no strenuous or leisure activity (Goldberg, Black et al. 1991; FAO/WHO/UNU 2004).

To identify the mis-reporting status of Actual Energy Intake (AEI), the ratio of reported AEI to estimated Basal Metabolic Rate (BMR) (AEI:BMR) was calculated for each individual and compared with cutoff values for EI:BMR (Livingstone and Black 2003). Then, the study subjects were categorised as under-reporters (AEI:BMR <0.76), plausible reporters (AEI:BMR = 0.76-1.24), or over-reporters (AEI:BMR >1.24) of AEI. These definitions are partly based on the 95% confidence limits of agreement between AEI and EE measured by the double labeled water method as proposed by Black and Cole (Black and Cole 2000). This approach for identifying the mis-reporting of AEI has been adopted and used in several studies (Black 2000; Mccrory, Hajduk et al. 2002; Livingstone, Robson et al. 2003; Timpson, Emmett et al. 2008; Carlsen, Lillegaard et al. 2010; Murakami, Miyake et al. 2012). However, the investigated outliers and potential under-, plausible and under-reporters were reviewed for coding errors but were not excluded in this chapter.

Table 0-1 Schofield prediction equations for estimating basal metabolic rate (BMR) (kcal/day)

Sex	Age	BMR* (Kcal/day)
Males	18-30	15.057 weight (kg) + 692.2
	31-60	11.472 weight (kg) + 873.1
Females	18-30	14.818 weight (kg) + 486.6
	31-60	8.126 weight (kg) + 845.6

Source: (FAO/WHO/UNU 2004, Page 37, Table 5.2 and Scientific Advisory Committee on Nutrition 2011, Page 105, Table 17)

* BMR: Basal metabolic rate = weight coefficient x weight (kg) + constant

Mis-reporting results of Actual Energy Intake (AEI):

Table 3.3-4 shows the percentages of under-reporters, plausible reporters and over-reporters in the study sample for both Saudi-FFQ and 24-HDR methods. The percentages of under-reporters, plausible reporters and over-reporters from the Saudi-FFQ method were 15%, 35% and 50%, respectively. Furthermore, the percentages of under-reporters, plausible reporters and over-reporters from the 24-HDR method were 55%, 39% and 6% respectively.

1.1.1.1 Gender and Mis-reporting:

Women tend to under-report their intake than men in both 24-HDR and FFQ methods. The magnitude of the difference in under-reporting of dietary intake between women and men using Saudi-FFQ methods was statistically significant (chi-square=8.33, p=0.004). However, the magnitude of the difference in under-reporting of dietary intake between women and men using 24-HDR method was not statistically significant (chi-square=0.004, p=0.947). Furthermore, men tend to over-report their intake than women using both methods. The magnitude of the difference in over-reporting of dietary intake between women and men using Saudi-FFQ method was statistically significant (chi-square=11.1, p=0.001). However, the magnitude of the difference in over-reporting of dietary intake between women and men using 24-HDR method was not statistically significant (chi-square=3.36, p=0.067). **Tabele 6** shows the general characteristic of under- , plausible and over-reporters by gender for Riyadh city adults, Saudi Arabia based on MP-24-Hour Dietary Recall and Saudi-FFQ methods.

1.1.1.2 Adiposity and Mis-reporting

Obese participants (BMI≥30 kg/m^2) tend to under-report their intake than non-obese participants (BMI<30 kg/m^2) using FFQ method. The magnitude of the difference in

under-reporting of dietary intake between obese and non-obese using Saudi-FFQ method was statistically significant (chi-square=6.27, p=0.012). However, participants with Risk2 WC (females, >88cm, males >102cm) tend to not under-report their intake than non-Risk2 WC participants (females, ≤88cm, males ≤102cm) using FFQ method. The magnitude of the difference in under-reporting of dietary intake between Risk2 WC and non-Risk2 WC using Saudi-FFQ method was not statistically significant (chi-square=0.023, p=0.495).

Participants with elevated BMI (≥25 kg/m^2) tend to under-report their intake than participants with Normal BMI (<25 kg/m^2) using FFQ method. The magnitude of the difference in under-reporting of dietary intake between participants with elevated BMI (≥25 kg/m^2) and with normal BMI (<25 kg/m^2) using Saudi-FFQ method was statistically significant (chi-square=16.48, p=0.0001). However, participants with elevated WC (females, >80cm, males >94cm) tend to not under-report their intake than Non-elevated WC (females, ≤80cm, males ≤94cm) using FFQ method. The magnitude of the difference in under-reporting of dietary intake between participants with elevated WC (females, >80cm, males >94cm) and participants with non-elevated WC (females, ≤80cm, males ≤94cm) using Saudi-FFQ method was not statistically significant (chi-square=3.73, p=0.054).

1.1.1.3 Age and Mis-reporting

Young participants aged 19-29 years tend to under-report their energy intake than other participants using FFQ method. The magnitude of the difference in under-reporting of energy intake between young participants aged 19-29 years and the participants aged 30-60 years using Saudi-FFQ method was statistically significant (chi-square= 4.34, p=0.037).

Table 0-2: Medians (IQR) of intake and urinary excretions of energy, macro- and micronutrients obtained from the Saudi-FFQ (n=601), repeated MP-24-Hour Dietary Recalls (24-HDRs) (n=213) and 24-hour urinary excretions (n=23) among Riyadh city adults, Saudi Arabia.

Nutrients	Saudi-FFQ (n=601)		Repeated MP-24-Hour Dietary Recall (n=2013)		24-Hour Urinary excretion (n=23)	
	Median	*IQR*	Median	*IQR*	Median	*IQR*
Energy (Kcal)	2346	(1766-3208)	1419	(1024-1809)	-	-
Fat (g)	93	(65-134)	50	(33-69)	-	-
Protein (g)	86	(62-116)	51	(33-69)	105	(89-118)
CHO (g)	298	(217-418)	184	(134-249)	-	-
Fibre (g)	23	(15-35)	11	(8-17)	-	-
Retinol (µg)	550	(363-807)	380	(207-660)	-	-
B-Carotene (µg)	2451	(1338-3760)	741	(370-1459)	-	-
Thiamin (mg)	1.3	(0.8-8.4)	0.5	(0.4-0.8)	-	-
Riboflavin (mg)	2.7	(1.9-3.7)	1.2	(0.8-2.3)	-	-
Vitamin C (mg)	103	(54-169)	23	(11-63)	-	-
Sodium (mg)	3457	(2298-4696)	2217	(1380-3261)	3366	(2564-3877)
Salt (g/day)	8.7	(5.8-11.9)	5.6	(3.5-8.2)	9	(7-10)
Potassium (mg)	5345	(3253-8159)	2070	(1241-4233)	1639	(1275-1934)
Calcium (mg)	782	(531-1113)	300	(182-473)	-	-
Phosphorous (mg)	1755	(1246-2331)	951	(637-1379)	-	-
Iron (mg)	35.8	(20.4-55.9)	14.7	(7.8-34.8)	-	-
Water (ml)	1932	(1355-2626)	976	(730-1350)	-	-

Table 0-3: General characteristic of under- , plausible and over-reporters by gender for Riyadh city adults, Saudi Arabia based on MP-24-Hour Dietary Recall (n=213) and Saudi-FFQ (601) methods

Gender [a]	Under-reporters (AEI:TEE<0.76)		Plausible-reporters (EI:TEE 0.76-1.24)		Over-reporters (EI:TEE >1.24)	
	FFQ (n=601)	24-HDR (n=213)	FFQ (n=601)	24-HDR (n=213)	FFQ (n=601)	24-HDR (n=213)
Men (n(%))	26/265 (10)	51/104 (49)	86/265 (32)	44/104 (42)	153/265 (58)	9/104 (9)
Women (n(%))	61/336 (18)	65/109 (60)	127/336 (38)	40/109 (37)	148/336 (44)	4/109 (4)
All (n(%))	87/601 (15)	116/213 (55)	213/601(35)	84/213 (39)	301/601 (50)	13/213 (6)

[a] These definitions are partly based on the 95% confidence limits of agreement between AEI and EE measured by the double labeled water method as proposed by Black and Cole (Black and Cole 2000). TEE: Total Energy Expenditure (Basal metabolic rate * 1.2); AEI: Actual Energy Intake.

Table 0-4: General characteristic of under- , plausible and over-reporters by age group for Riyadh city adults, Saudi Arabia based on MP-24-Hour Dietary Recall (n=213) and Saudi-FFQ (601) methods

Gender [a]	Under-reporters (AEI:TEE<0.76)		Plausible-reporters (EI:TEE 0.76-1.24)		Over-reporters (EI:TEE >1.24)	
	FFQ (n=601)	24-HDR (n=213)	FFQ (n=601)	24-HDR (n=213)	FFQ (n=601)	24-HDR (n=213)
19-29 (n(%))	54/311 (17)	53/98 (54)	103/311 (33)	39/98 (40)	154/311 (50)	6/98 (6)
30-39 (n(%))	16/152 (11)	36/60 (60)	54/152 (35)	21/60 (35)	82/152 (54)	3/60 (5)
40-49 (n(%))	10/80 (13)	13/31 (42)	30/80 (37)	15/31 (48)	40/80 (50)	3/31 (10)
50-60 (n(%))	7/58 (12)	14/24 (58)	26/58 (45)	9/24 (38)	25/58 (43)	1/24 (4)
All (n(%))	87/601 (15)	116/213 (55)	213/601(35)	84/213 (39)	301/601 (50)	13/213 (6)

[a] These definitions are partly based on the 95% confidence limits of agreement between AEI and EE measured by the double labeled water method as proposed by Black and Cole (Black and Cole 2000). TEE: Total Energy Expenditure (Basal metabolic rate * 1.2); AEI: Actual Energy Intake.

Appendix6: Questionnaire of knowledge and perceptions of Saudi adults towards food and health

University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

SURVEY ON ADULTS' PERCEPTIONS ON FOOD & HEALTH IN SAUDI ARABIA

البحث المسحي حول تصورات وآراء البالغين في المملكة العربية السعودية حول الغذاء والصحة

Date of Interview
تاريخ المقابلة
☐☐/☐☐/☐☐☐☐

Participant's Code
رمز المشارك
☐☐☐☐ ☐

Perceptions of Saudi Arabian Adults towards Food and Health
استبيان لتقييم تصورات وآراء البالغين في المملكة العربية السعودية نحو الغذاء والصحة

Introduction:

You have been invited to participate in a research study. Before you decide whether or not to take part in the study, it is important for you to understand why the research is being done, and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask the researcher(s) if there is anything that is not clear or if you would like more information, and take time to decide whether or not you wish to take part. What is the purpose of the study? Saudi Arabia (SA) suffers from a high burden of health issues such as cardiovascular diseases, hypertension and type 2 diabetes mellitus. Many research studies have found that eating behaviours are determinant of health status, and these behaviours are largely modifiable. However, changing these behaviours is a complex challenge and there is a lack of information in Saudi Arabia regarding the underlying belief structures that influence these behaviours. Therefore, this study wants to explore peoples' views on food and how it relates to their health status. In particular, this study aims to explore the influencing factors on changes in food choices and food behaviours.

Taking part in this study is entirely voluntary. If you do decide to take part, you will be asked to keep this information sheet and to sign a consent form. You will receive a copy of your signed consent form. If you do decide to take part, you are free to withdraw from the study at any time without providing an explanation. Any information collected from you would then be destroyed. All information collected about you during the course of the research will be kept strictly confidential. You will be identified by an ID number, and any information about you will have your name and address removed so that you cannot be recognised by it. You will also have the opportunity to provide us with a contact number should you be willing to take part in a short phone interview on the same subject in the future. If you would like to discuss anything further, please contact Mr. Majid Alkhalaf via the following contact details:

Mobile (KSA): 0505199739
Mobile (UK): 00447864741438
Email: m.alkhalaf.1@research.gla.ac.uk & mmkhalaf@sfda.gov.sa

1

University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

المقدمة:

أنت مدعو للمشاركة في دراسة بحثية لتقييم تصورات وآراء البالغين حول الغذاء والصحة والعوامل التي تؤثر على التغيير من نمط الحياة لديهم في المملكة العربية السعودية. قبل أن تقرر، من المهم بالنسبة لك أن تعرف لماذا يُجري هذا البحث وماذا سوف سيترتب على مشاركتك في هذه الدراسة. يرجى أخذ الوقت الكافي لقراءة المعلومات التالية بعناية ومناقشتها مع الباحثين إذا كنت ترغب في ذلك. الرجاء السؤال إذا كان كنت ترغب في مزيد من المعلومات.

ما هو الغرض من الدراسة؟ وجدت العديد من الدراسات البحثية أن سلوكيات الإستهلاك الغذائي والعادات الغذائية هي العامل المحددة للحالة الصحية للفرد والمجتمع. ومع ذلك، فإن تغيير هذه السلوكيات يعد معقد وتحدي للتحكم بالأمراض غير المزمنة. هناك نقص في المعلومات في المملكة العربية السعودية التي الاعتقادات والعوامل السائدة والتي بدورها تؤدي إلى هذه السلوكيات. لذلك، فإن هذه الدراسة تسعى لاستكشاف وجهات نظر المجتمع على الغذاء ومدى ارتباطه بحالتهم الصحية. على وجه الخصوص، فإننا نريد استكشاف العوامل التي تؤثر على التغيرات في الاختيارات الغذائية والسلوكيات الغذائية. ومن المأمول أن النتائج المستخلصة من هذا البحث ستؤدي إلى تحسين أساليب ودقة التدخلات والسياسات الغذائية والتغذوية في المملكة العربية السعودية.

تعتبر المشاركة في هذه الدراسة عمل تطوعي، إذا قررت المشاركة، سوف يطلب منك أن تُبقي ورقة المعلومات هذه والتوقيع على استمارة الموافقة (نسختين)، حيث ستعطى نسخة من استمارة الموافقة التي وقعت عليها. إذا قررت المشاركة فأنت حر في الانسحاب من الدراسة في أي وقت، دون تقديم أي مبرر لذلك. كما سيتم التخلص من جميع المعلومات المرتبطة بك التي تم جمعها حال إنسحابك من الدراسة. ستبقى جميع المعلومات التي تم جمعها عنك أثناء البحث في سرية تامة. سيتم التعرف عليك من قبل رقمك التسلسلي في البحث **(Code)**، وسيتم ازالة أية معلومات تحتوي على اسمك وعنوانك بحيث لا يمكن التعرف عليك عن طريقها.

سيكون لديك أيضا فرصة لتزويدنا بأرقام الإتصال الخاصة بك إذا كنت ترغب المشاركة في مقابلة هاتفية قصيرة حول نفس الموضوع في المستقبل. إذا كنت ترغب في مناقشة أي شيء آخر، يرجى الاتصال بالأستاذ ماجد الخلف عبر عناوين التواصل التالية:

الجوال (السعودية): 0505199739

البريد الإلكتروني: m.alkhalaf.1@research.gla.ac.uk و mmkhalaf@sfda.gov.sa

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Section 1: Demographic Measurements: المعلومات الديموغرافية

Please tell us a bit about yourself من فضلك قل لنا قليلا عن نفسك

1. **Age** (العمر): ..... (years/سنة)

2. **Gender:** الجنس

☐ Male ذكر	☐ Female أنثى

3. **What is your nationality?** ما هي جنسيتك؟

☐ Saudi Arabian سعودي	☐ Not Saudi Arabian غير سعودي

4. **Which region you are from?** في أي منطقة تعيش؟

☐ Central region المنطقة الوسطى	☐ Western region المنطقة الغربية
☐ Eastern region المنطقة الشرقية	☐ Southern region المنطقة الجنوبية
☐ North region المنطقة الشمالية	

5. **Which city or village you are living in, please specify?** في أي مدينة أو قرية تعيش؟ الرجاء التحديد؟

.....

6. **Marital Status:** الحالة الإجتماعية

☐ Never Married أعزب	☐ Divorced مطلق
☐ Married متزوج	☐ Widowed أرمل

7. **Family members:** عدد أفراد العائلة

How many family members live with you in the same household? كم عدد أفراد العائلة والذين يسكنون معك في نفس المنزل؟	.....

8. **Do you have children (18 years old and less)?** هل عندك أبناء؟

☐ Yes نعم	☐ No لا	**How many?** ..... كم عددهم؟

9. **How many children (18 and under) live in your household, please specify?**
كم عدد الأطفال (18 سنة وأقل) يعيشون معك في المنزل، يرجى التحديد؟
.....

10. **How many adults (19 and over) live in your household, please specify?**
ك في المنزل، يرجى التحديد؟كم عدد االبالغين (19 سنة وأكثر) يعيشون مع

.....

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11. Do you care for an elderly relative? هل لديك كبير سن قريب لك تقوم برعايته؟

☐ Yes نعم ☐ No لا

12. What kind of accommodation do you live in? ما هو نوع السكن الذي تعيش فيه؟

☐ Own room in flat/house share سكن مشترك
☐ In student accommodation سكن طلاب
☐ In own rented home بيت مستأجر
☐ In own purchased home (mortgaged or owned outright) بيت ملك
☐ B&B/hostel فندق
☐ Sofa surfing سكن مؤقت مع قريب أو صديق
☐ Other: (please specify) غير ذلك، يرجى التحديد؟ .....

13. Who do you live with? مع من تعيش؟

☐ Husband/wife زوج/زوجة
☐ Parents الوالدين
☐ With friends/flatmates/housemates صديق/زميل
☐ Alone وحدي
☐ Other: (please specify) غير ذلك، يرجى التحديد؟ .....

14. What kind of kitchen equipment do you have access to?

☐ Kettle غلاية
☐ Toaster محمصة خبز كهربائية
☐ Equipment: cutlery, crockery and kitchen utensils انية الفخارية وأدوات المطبخ المعدات: أدوات المائدة والأو
☐ Fridge ثلاجة
☐ Freezer الفريزر: ثلاجة التجميد
☐ Microwave oven فرن الميكروويف
☐ Hob غاز/مرجل الطبخ
☐ Oven فرن
☐ No kitchen access لا تستطيع الوصول للمطبخ

15. Are you the main grocery shopper in your household? الرئيسي من هل أنت المتسوق البقالة في المنزل؟

☐ Yes نعم ☐ No لا

16. Please indicate your occupational status? ما هو العمل الذي تزاوله؟

☐ Employee موظف
☐ Student طالب
☐ Household ربة منزل
☐ Unemployed أبحث عن عمل
☐ Retired متقاعد

17. Please indicate your monthly income? يرجى اختيار دخلك الشهري؟

☐ No income لا يوجد دخل
☐ Less than 3500 SR per month من 3500 ريال شهريا أقل
☐ Between 3500 SR To 8500 SR per month بين 3500-8500 ريال شهريا
☐ More than 8500 SR per month أكثر من 8500 ريال شهريا

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18. How many years of schooling (education) have you completed?
كم عدد سنوات الدراسة والتعليم التي أتممتها (المستوى التعليمي)؟

☐ Illiterate أمي	☐ College or Diploma الكلية أو دبلوم
☐ Read and Write أقرأ و أكتب فقط	☐ Bachelor بكالوريوس
☐ elementary الابتدائية	☐ Master ماجستير
☐ Intermediate المتوسطة	☐ PhD or higher دكتوراه أو أعلى
☐ Secondary الثانوية	

19. Education background: الخلفية التعليمية

Did your studies focus on any of the following?

☐ Food Sciences علوم الأغذية ☐ Nutrition Sciences علوم التغذية ☐ Dietetics تغذية سريرية
☐ Health Sciences (ie: medicine, nursing, midwifery, pharmacy)
العلوم الصحية: الطب، والتمريض، والصيدلة
☐ None of them لا أحد منهم

20. Medical insurance: التأمين الصحي

Are you covered by private medical insurance? ☐ Yes نعم ☐ No لا
هل تمتلك تأميناً صحياً؟

21. Are you pregnant? مل؟هل أنت حا

☐ Yes نعم ☐ No لا **In which month?** ☐
في أي شهر؟

22. Are <u>currently</u> breast feeding? هل ترضعين طفلك رضاعة طبيعية، حالياً؟

☐ Yes نعم ☐ No لا

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Section 2: Your opinions on food and food choices
آرائكم حول الغذاء والخيارات الغذائية

Please select the option that most closely reflects the extent to which you agree or disagree with the following statements:

الرجاء تحديد الخيار الذي يعكس بشكل دقيق إلى أي مدى توافق أو لا توافق على العبارات التالية:

1. **What I eat now plays an important part in reducing my risk of developing chronic diseases in later life** (eg: cancer, heart disease, diabetes or stroke)
ما أستهلكة الآن من مواد غذائية يلعب دورا هاما في الحد من تعرضي لخطر الإصابة بأمراض مزمنة في المراحل اللاحقة من الحياة (على سبيل المثال: السرطان وأمراض القلب والسكري والسكتة الدماغية)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

2. **The way I eat can change my well-being in the short term**
طريقة أكلي الآن ممكن أن تغير مستوى صحتي على المدى القصير

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

3. **The way I eat can change my appearance**
طريقة أكلي الآن يمكن أن تغير مظهري الخارجي

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

4. **Changing the way I eat will have an impact on my immediate well-being**
تغيير طريقة أكلي من الممكن أن يكون لها تأثير على مستوى صحتي بشكل فوري

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

5. **Changing the way I eat will reduce my risk of developing chronic diseases in later life**
لمراحل اللاحقة من الحياةتغيير طريقة أكلي سوف تقلل من خطر إصابتي بالأمراض المزمنة في ا

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

6. **Good health is just a matter of luck**
الصحة الجيدة هي مجرد مسألة حظ

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

7. **It's important to me to just enjoy my food, regardless of whether it's good for me**
التسـية لـي أم لامـن المهـم بالتسية لـي أن اسـتمتع بطعـامي، بغـض النظـر عمـا إذا كانـت جيـدة ب

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

8. **It's important to me to eat a broad range of food rich in nutrients and in the correct amounts**
التسـية لـي أن أسـتهلك مجموعـة واسـعة مـن الأطعمـة الغنيـة بالعناصـر الغذائيـة وبكميـات صـحيحةمن المهم ب

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

9. **The kind of food I eat does not matter, it's just fuel and fill my empty stomach**
لا أهتم بنوعية الطعام التي آكلها، مجرد طاقة وسد للجوع

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

10. **Being aware of what you eat is only important if you want to lose weight**
ليس من المهم لدي معرفة نوعية الطعام إلا إذا أردت انقاص وزني فقط

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

11. **I'm not sure if I eat a balanced diet with the right nutrients so I take supplements as an insurance**
أنـا لسـت متأكـدا ممـا إذا كنـت أتنـاول غـذاء متـوازن يحتـوي علـى المـواد المغذيـة الصـحيحة لـذلك أنـا أتنـاول المكمـلات الغذائيـة بمثابـة تـأمين عـن النقـص

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

12. **Taking supplements reduces my risk of having a heart attack or stroke**
تنـاول المكمـلات الغذائيـة تقلـل خطـر الاصـابة بالنوبـة القلبيـة أو السـكتة الدماغيـة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

13. **As long as I take supplements I don't need to worry about what I eat and its effect on my health**
الغذائيـة قـلا داعـي للقلـق حـول مـا أكلـه وتـأثيره علـى صـحتي طالمـا أنـني أتنـاول المكمـلات

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

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14. I spend as little as possible on food
علي الطعام أنا أصرف أقل ما قدر الإمكان

Strongly disagree غير موافق بشدة	Disagree غير موافق	Neutral محايد	Agree موافق	Strongly agree موافق بشدة	N/A لا أدري
☐	☐	☐	☐	☐	☐

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Section 3: What influences your opinions on food and food choices?
ذيـــة وخيـــاراتكم الغذائيـــة؟مـا هـي العوامـل الـتي تؤثـر علـى ارائكـم حـول الأغ

Please select the option that most closely reflects the extent to which you agree or disagree with the following statements

الرجاء تحديد الخيار الذي يعكس بشكل دقيق إلى أي مدى توافق أو لا توافق على العبارات التالية:

1. **I am interested in reading articles about food and health**
أنـا مهتـم فـي قـراءة المقـالات حـول الغـذاء والصـحة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

2. **Watching TV shows about food and health influences the food choices I make**
مشـاهدتي للـبرامج التلفزيونيـة عـن الغـذاء والصـحة تؤثـر علـى خيـاراتي الغذائيـة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

3. **I need to change the way I eat because my partner/husband/wife is concerned about my health**
أنـا بحاجـة إلـى تغيـير طريقـة أكلـي لأن زوجي/زوجـتي تشـعر بـالقلق إزاء صـحتي

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

4. **I take more interest in food and health now that I have children**
اصـبحت الآن أكـثر اهتمامـا فـي الغـذاء والصـحة لأنـه أصـبح لـدي أطفـال

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

5. **I take more interest in food and health since someone close to me got ill**
قريـب مـني أصـيبت الآن أكـثر اهتمامـا فـي الغـذاء والصـحة بسـبب مـرض شـخص

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

6. **I always check nutritional information labels before I buy any food**
دائما اتحقق من المعلومات الغذائية والبطاقة الغذائية على المنتجات قبل شرائها

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

7. **Information about food and health from official sources influences my food choices**
(eg: Department of Health, doctor, public health adverts)
بـــة تؤثـــر علـــى الخيـــارات الغذائيـــة لـــدي (علـــى ســـبيل المعلومـــات عـــن الغـــذاء والصـــحة مـــن المصـــادر الرســـم (المثـــال: وزارة الصـــحة، الطبيـــب، الاعلانـــات الصـــحية العامـــة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

8. **Information about food and health in the media influences my food choices**
(eg: magazines, newspapers, online, TV)
المعلومات عن الغذاء والصحة في وسائل الإعلام تؤثر على الخيارات الغذائية لدي (على سبيل المثال: المجلات والصحف شبكات التواصل الاجتماعي، والتلفاز)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

9. **When eating out, my choice of food is influenced by nutritional information provided**
(eg; on menus in restaurants and cafes)
عند تناول الطعام خارج المنزل، يتأثر اختياري للأغذية بالمعلومات الغذائية المقدمة (على سبيل المثال، قائمة الطعام في المطاعم والمقاهي)

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

10. **When in the supermarket, I will always buy special offers regardless of the nutritional content of the food**
عندما أكون في السوبرماركت أو البقالة، دائما اقوم بشراء المواد الغذائية ذات العروض الخاصة بغض النظر عن المحتوى الغذائي في هذه المواد

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

11. **I mainly buy from the value brand/essentials ranges**
أنا دائما أقوم بشراء المواد الغذائية ذات العلامة التجارية المخفضة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

12. **I was brought up to always finish the food on my plate and still do**
لقد تربيت على إنهاء الطعام الذي أمامي في الإناء وما زالت أفعل ذلك

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	مـــوافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

13. I'd never use a food bank because of what other people would think of me
لا أقوم أبدا باستخدام بنك الطعام (الطعام المقدم من الجمعيات الخيرية) بسبب نظرة الناس لي

Strongly disagree غير موافق بشدة	Disagree غير موافق	Neutral محايد	Agree موافق	Strongly agree موافق بشدة	N/A لا أدرى
☐	☐	☐	☐	☐	☐

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Saudi Food & Drug Authority

Section 4: Changing your food choices تغيير خياراتك الغذائية

Please select the option that most closely reflects the extent to which you agree or disagree with the following statements:

الرجاء تحديد الخيار الذي يعكس بشكل دقيق إلى أي مدى توافق أو لا توافق على العبارات التالية:

1. **I'd like to pay more attention to food and health but my lifestyle doesn't allow for it**
يودي أن أبذل مزيدا من الاهتمام حول الغذاء والصحة ولكن نمط حياتي لا يسمح لي

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

2. **There are no nutritionally balanced options available for lunch when I'm at work**
لا يوجد هناك مواد غذائية ذات قيمة تغذوية متوازنة أثناء جودي في وقت العمل الرسمي

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

3. **I don't have time to eat a nutritionally balanced diet, I just "grab and go"**
ليس لدي وقت لاتباع نظام غذائي متوازن، فقط "أشتري غذاء جاهزوأذهب"

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

4. **Nutritionally balanced foods are so much more expensive**
الأطعمة ذات القيمة التغذوية المتوازنة غالية جدا

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

5. **I like my food too much to much to worry about food and health**
أنا أحب الطعام جدا فليس هناك داعي للقلق حول الطعام والصحة

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

6. **Nutritionally balanced food is boring and tasteless**
الغذاء المتوازن ممل ومذاقه غير جيد

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

7. **There are no nutritionally balanced options available when I eat out**
لا يوجد هناك أطعمة متوازنة تغذويا عندما أتناول الطعام خارج المنزل

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

8. **I go through phases of eating a nutritionally balanced diet and then I give in to temptation**
قطعت شوطا كبير في اتباع الأغذية ذات القيمة التغذوية المتوازنة ولكني في الاخير استسلمت للاغراءات

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

9. **I can only eat a nutritionally balanced diet when I want to lose weight**
يمكنني أن اتبع نظام غذائي متوازن عندما أريد انقاص وزني

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

10. **I can't say no to my children when they want to eat snacks between meals**
لا أستطيع أن أقول لا لأطفالي عندما يريدون أن يأكلوا وجبات خفيفة بين الوجبات

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

11. **I usually finish what my child/children leave on their plate(s)**
عادة أنهي الأكل المتبقي في صحون أبنائي

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

12. **If my partner/friends/children are having dessert, I usually have one too, even if I'm full**
إذا زوجي/زوجتي / الأصدقاء /أطفالي تناولوا الحلوى أمامي، عادة ما أشاركهم ذلك، حتى ولو كنت شبعان

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

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Saudi Food & Drug Authority

Section 5: How much do you know about what is a nutritionally balanced diet?
ماذا تعرف عن الغذاء المتوازن؟

Please say whether you think the following statements are true or false and fill in the blanks
يرجى إعطاء رأيك حول العبارات التالية سواء صحيحة أو خاطئة وذلك بإختيار أحد المربعات التي أمامها

1. **Starchy foods such as bread, cereals, rice, pasta and potatoes should be the main component of a nutritionally balanced diet**
الأطعمة النشوية مثل الخبز والحبوب والأرز والمعكرونة والبطاطا يجب أن تكون هي المكون الرئيس للغذاء المتوازن

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

2. **What percentage of the food we eat should be made up of starchy foods?**
(eg: bread, cereals, rice, pasta, potatoes)
ما هي النسبة المئوية من الطعام الذي تاكله يجب ان تتكون من الأطعمة النشوية؟
(على سبيل المثال: الخبز والحبوب والأرز والمعكرونة والبطاطا)

.....(%)

3. **It is more important to eat a wide variety of vegetables than fruits**
من المهم ان تاكل تشكيلة واسعة من الخضار اكثرمن الفواكه

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

4. **How many portions of fruit and vegetables should we eat each day?**
كم عدد حصص الفاكهة والخضراوات التي يجب أن نتناولها كل يوم؟
.....(عدد/number)

5. **How many grams should one portion of fruit or vegetables weigh?**
وكم غرام تحتوي كل حصة من الفاكهة أو الخضروات؟
.....(جرام/grams)

6. **Eating white fish is just as important for health as eating oily fish such as salmon**
تناول السمك الأبيض مهم للصحة كأهمية تناول الأسماك الزيتية مثل السلمون

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

7. **How many portions of fish should we eat each week?**
كم عدد الحصص من الأسماك يجب أن نتناولها كل أسبوع؟
.....(عدد/number)

8. **How many of these should be oily fish?**
كم من هذه الأسماك ينبغي أن تكون أسماك زيتية؟
.....(عدد/number)

9. **We should try to eliminate as much fat as possible from our diet**
يجب علينا أن نزيل الدهون والشحوم من نظامنا الغذائي قدر الإمكان

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

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Saudi Food & Drug Authority

10. A diet with lots of high sugar foods is ok as long as it is low in calories
الطعام المحتوي على كميات عالية من السكر غير مضرة طالما أنها منخفضة في السعرات الحرارية

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

11. What is the maximum recommended intake of sugar for adults, in grams/day
ما هو الحد الأقصى الموصى به من تناول السكر للبالغين، في اليوم (غرام / يوم)
.....(grams/day)

12. What is the maximum recommended intake of salt for adults, in grams/day
ما هو الحد الأقصى الموصى به من تناول الملح للبالغين، في اليوم (غرام / يوم)
.....(grams/day)

13. Most of the salt in our diet comes from what is added to food at the table
معظم الملح في طعامنا يأتي من الملح المضاف أثناء الأكل

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

14. Fizzy drinks contribute to daily fluid intake just as much as water
المشروبات الغازية كبديل للماء، تساهم في تغطية ما يحتاجه الجسم من السوائل يوميا

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

15. Tea and coffee contribute to daily fluid intake just as much as water
الشاي والقهوة كبديل للماء، تساهم في تغطية ما يحتاجه الجسم من السوائل يوميا

☐ True ☐ False ☐ Not sure

16. Maintaining a healthy weight is important to reduce the risk of developing hypertension, diabetes and some types of cancer
المحافظة على الوزن الصحي مهمة جدا للحد من خطر الإصابة ببعض الامراض غير المعدية كالسرطان و ارتفاع ضغط الدم والسكري

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

17. Reduce or avoid the high salt food products is important to reduce the risk of developing hypertension, strokes and other heart diseases
التقليل أو تجنب تناول المنتجات الغذائية ذات المحتوى العالي من الملح والصوديوم مهمة جداً للحد من خطر الإصابة بالجلطات الدماغية، أمراض القلب والذبحة الصدرية

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

18. Mono-sodium glutamate (agina moto) is considered as one of healthy salt alternatives?
تعتبر مادة أحادي جلوتامات الصوديوم أو الماجي الأبيض (أجيناموتو) بديل مناسب (صحي) لملح الطعام

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

19. Sea salt is considered as one of healthy salt alternatives?
يعتبر الملح البحري بديل مناسب (صحي) لملح الطعام

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

20. Spices and condiments are considered as one of healthy salt alternatives?
تعتبر التوابل وبعض المنكهات مثل الليمون بديل مناسب (صحي) لملح الطعام

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

21. Vitamin/mineral supplements are an important part of a healthy diet
المدعمات الغذائية من الفيتامينات والمعادن هي جزء مهم من النظام الغذائي الصحي

☐ True صحيح ☐ False غير صحيح ☐ Not sure لا أعلم

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الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

Section 6: About your intention to change your diet?

نيتك لتغيير النظام الغذائي الخاص بك؟

Please select the option that most closely reflects the extent to which you agree or disagree with the following statements

الرجاء تحديد الخيار الذي يعكس بشكل دقيق إلى أي مدى توافق أو لا توافق على العبارات التالية:

1. **I am happy that I currently eat a nutritionally balanced diet and have no plan to change it**

أنا سعيد لأنني حاليا أتبع نظام غذائي متوازن وليس لدي خطة لتغييره

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

2. **I know my diet isn't as balanced as it should be. I don't see this as a problem and I'm not planning to change it**

أنا أعلم أنني حاليا لا أتبع نظام غذائي متوازن، لكنني لا أرى في ذلك مشكلة، وأنا لا أخطط للتغيير

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

3. **I intend to make changes to my diet to eat more nutritionally balanced diet**

أعتزم إجراء تغييرات على نظامي الغذائي إلى نظام غذائي أكثر توازنا

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

4. **If you intend to make significant changes to your diet in the next 3 months please give details of what these changes are and why you are planning to make them**

إذا كنت تنوي إجراء تغييرات كبيرة في نظامك الغذائي الخاص خلال 3 أشهر القادمة، الرجاء إعطاء تفاصيل عن ماهية هذه التغييرات وما هي خطتك؟

.....
.....
.....
.....
.....
.....

5. **I have already made changes to my diet to eat more nutritionally balanced diet**

لقد قمت بالفعل بتغيير نظامي الغذائي إلى غذاء أكثر توازنا

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	N/A
غير موافق بشدة	غير موافق	محايد	موافق	موافق بشدة	لا أدري
☐	☐	☐	☐	☐	☐

6. **If you have already made significant changes to your diet in the last 3 months please give details of what these changes were and why you made them**

إذا كنت قد قمت بالفعل بتغيير نظامك الغذائي إلى غذاء أكثر توازنا خلال 3 أشهر الماضية، يرجى إعطاء تفاصيل عن ماهية هذه التغييرات وماذا فعلت خلالها؟

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Section 7: About your current health حول حالتك الصحية حاليا

Please tell us about your current state of health قل لنا عن حالتك الصحية الحالية

1. **How is your current health in general?** كيف حالتك الصحية بشكل عام
   My current health is good in general

Strongly disagree غير موافق بشدة	Disagree غير موافق	Neutral محايد	Agree موافق	Strongly agree موافق بشدة	N/A لا أدري
☐	☐	☐	☐	☐	☐

2. **Do you have any medical conditions or illnesses lasting or expected to last for 12 months or more?**
   هل لديك أي ظروف صحية أو أمراض دائمة من المتوقع أن تستمر لمدة 12 شهر أو أكثر؟

☐ Yes نعم ☐ No لا

3. **If yes, have you been told by your doctor or health professional that you have any of the following?**
   هل تم تشخيصك من قبل الطبيب بأنك مصاب بأحد الحالات التالية؟

- ☐ High Blood Pressure ارتفاع ضغط الدم
- ☐ Type 1 Diabetes (النوع الأول) مرض السكري
- ☐ Type 2 Diabetes (النوع الثاني) مرض السكري
- ☐ High Cholesterol ارتفاع الكولسترول
- ☐ Anemia (due to iron deficiency) الأنيميا (بسبب انخفاض الحديد)
- ☐ Osteomalacia (due to vitamin D deficiency) هشاشة (لين) العظام (بسبب نقص فيتامين د)
- ☐ Others Please specify: ..... أمراض أخرى، الرجاء التحديد
- ☐ Heart Disease أمراض القلب
- ☐ High Triglyceride زيادة في الدهون الثلاثية
- ☐ Cancer السرطان
- ☐ Kidney Disease أمراض الكلى
- ☐ Liver Disease أمراض الكبد
- ☐ Stomach Ulcer قرحة المعدة

4. **Does anyone close to you have any medical conditions or illnesses lasting or expected to last for 12 months or more?**
   هل أحد من المقربين لديك (والدين/إخوة/زوج/زوجة/ابن/ابنة..) لديه ظروف صحية أو أمراض دائمة، أو من المتوقع أن تستمر هذه الأمراض لمدة 12 شهرا أو أكثر؟

☐ Yes نعم ☐ No لا

5. **Please provide brief details of their medical condition or illness**
   يرجى تقديم تفصيل موجز عن حالتهم الطبية أو المرضية

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6. Do you regularly take any vitamin, mineral or other nutritional supplements?
هل تأخذ بشكل منتظم أي فيتامينات، معادن أو مكملات غذائية أخرى؟

☐ Yes نعم ☐ No لا

7. Please specify which ones you take? الرجاء تحديد هذه الفيتامينات والمعادن والمكملات الغذائية؟

.....
.....
.....
.....
.....
.....

8. Please give brief details of why you take them لماذا تأخذ هذة المكملات، رجى تقديم تفصيل موجز؟

.....
.....
.....
.....
.....
.....

9. Smoking:
Are you هل أنت؟

☐ Current smoker مدخن حاليا ☐ Former Smoker مدخن سابق ☐ Not smoking لست مدخنا

10. How physically active are you? كيف نشاطك البدني؟

☐ Fairly inactive (walking only) غير نشطة إلى حد ما (أمشي فقط)

☐ Moderately active (occasionally take exercise that raises heart rate, less than 3 times per week)
نشطة بشكل متوسط (أحيانا أعمل رياضة ترفع معدل ضربات القلب، أقل من 3 مرات في الأسبوع)

☐ Very active (regularly take exercise that raises heart rate 3 time a week or more)
نشطة جدا (بشكل منتظم أعمل رياضة ترفع معدل ضربات القلب، أكثر من 3 مرات في الأسبوع)

11. Which of the following best describes your usual diet?
من الأوصاف التالية، ما أقرب وصف لنظامك الغذائي المعتاد؟

☐ No special diet لا يوجد نظام غذائي خاص
☐ Vegetarian نباتي
☐ Weight reduction diet حمية لخفض الوزن
☐ Diabetic diet حمية السكري
☐ Low salt diet حمية قليلة الملح
☐ Low Fat / Cholesterol diet (to lower blood fat)
حمية قليلة الدهون/قليلة الكولسترول (لمحاولة خفض نسبة الدهون في الدم)
☐ Other special diet, please specify:
نوع اخر من الحمية، يرجى التحديد
.....

12. Have heard about or read the following guidelines?
هل سمعت بـ أو اطلعت على الأدلة الإرشادية التالية؟

(1) Dietary Guidelines for Saudis: "Healthy Food Palm" الدليل الغذائي السعودي "النخلة الغذائي الصحية"	☐ Yes نعم	☐ No لا
(2) Diet and Physical Activity strategy (DPAS) "دليل العمل الوطني السعودي للغذاء الصحي"	☐ Yes نعم	☐ No لا
(3) Other guidelines such as Eat Well Plate or Food Guide Pyramid etc. أدلة إرشادية أخرى مثل "الصحن الصحي البريطاني" أو الهرم الغذائي الأمريكي" أو غيرها	☐ Yes نعم	☐ No لا

13. If yes, Are you following anyone of them and what is your opinion about it?
إذا كانت الإجابة بنعم، هل تتبع أحد هذة الأدلة في نظامك الغذائي وماهو رأيك حولها؟
يرجى تقديم تفصيل موجز؟

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University of Glasgow | Section of Human Nutrition

الهيئة العامة للغذاء والدواء
Saudi Food & Drug Authority

Section 8: Anthropometric Measurements القياسات الجسمية

Do you know your body measurements? هل تعرف قياساتك الجسمية؟

☐ Yes نعم ☐ No لا

If yes, please indicate in the following boxes:
إذا كانت الإجابة بنعم، الرجاء التحديد

1. **Height:** الطول ☐☐ cm سنتيمتر
2. **Weight:** الوزن ☐☐ kg كيلوجرام
3. **Waist circumference:** محيط الخصر ☐☐ cm سنتيمتر
4. **Hip circumference:** محيط الورك ☐☐ cm سنتيمتر

14. Contact details for further interview معلومات اتصال للتواصل مستقبلا

If you are happy for us to contact you for a short phone interview as a follow up to this survey, please provide your contact details in the box below (all data will remain anonymous):
إذا كنت ترغب أن نتواصل معك لإجراء مقابلة هاتفية قصيرة كمتابعة لهذه الدراسة، يرجى تقديم تفاصيل الاتصال الخاصة أدناه (ستبقى جميع بياناتك سرية للغاية):

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The End of Questionnaire نهاية الاستبيان

شكراً جزيلاً لكم