Physical activity and sedentary behaviour in humans and pet dogs

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Summary

Physical inactivity is a major contributor to non-communicable diseases and many adults and children are insufficiently active to maintain good health. The proportion of children who meet the United Kingdom recommendations for physical activity (at least 60 minutes of moderate-vigorous intensity physical activity each day) has been reported to be as low as 3% for boys and 2% for girls. Systematic reviews on interventions to promote physical activity in childhood have shown that although physical activity is modifiable to some degree most interventions have had only modest and short-term impacts on physical activity. Therefore, novel approaches to physical activity promotion in childhood are required. Dog ownership is a significant societal factor that may be used to encourage and sustain health behaviour change at individual and population levels. A number of observational studies have reported that dog ownership and/or dog walking are associated with increased levels of physical activity. However, evidence is lacking as to whether and how interventions with families and their dogs can be used to promote physical activity. Therefore, the major aim of this thesis was to assess the feasibility, acceptability and potential efficacy of a theory-driven, family-based, dog walking intervention for 9–11 year old children and their families.

However, prior to this it was essential to develop ActiGraph cut-points for measuring physical activity intensity in dogs. The ability to measure the intensity of dog physical activity accurately was important as it allows for the effectiveness of dog walking interventions to be tested, therefore another aim of this thesis was to calibrate and cross-validate ActiGraph cut points that can be used to describe physical activity in dogs by intensity. Similarly, no studies have been published previously that assess which factors are related to dog physical activity when measured using ActiGraph accelerometry. It was therefore desirable to explore whether body condition score, breed, age, and neutered status are associated with ActiGraph measured dog physical activity. Furthermore, no published studies have described the spontaneous changes in dog physical activity during substantial weight loss; therefore, another aim of this thesis was to explore changes in physical activity in dogs during a 6 month calorie controlled weight loss programme.

Using Receiver Operating Curve analyses Chapter 2 showed that the ActiGraph GT3X can accurately measure the amount of time a dog spends sedentary, in light-moderate intensity physical activity and in vigorous intensity physical activity. The sensitivity and specificity

of the cut-points developed when using both the integrated axes and vertical axis accelerometry data were high. Agreement between the accelerometer data and direct observation in the cross-validation subset was also ‘very good’ (as measured by Cohen’s Kappa). This indicates that the ActiGraph GT3X accelerometer is accurate when measuring the intensity of physical activity in dogs, facilitating the use of the ActiGraph GT3X to describe the frequency, intensity and duration of dog physical activity in Chapters 3-6 of this thesis.

Chapter 3 shows that, in a sample of dogs of varying breed and body condition scores, obese dogs spend significantly less time in ActiGraph measured vigorous intensity physical activity than ideal weight dogs (6 ± 3minutes/day versus 20 ± 14 minutes/day). Chapter 4 focussed on the factors related with physical activity in the two most commonly registered dog breeds in the United Kingdom, Labrador Retrievers and Cocker Spaniels. Five potential correlates (age, sex, breed, neuter status, body condition score) were tested with associations with ActiGraph measured physical activity. Age and breed were associated with total volume of physical activity, light-moderate intensity physical activity and sedentary behaviour in the final models and age was also associated with vigorous intensity physical activity. Unlike Chapter 3 body condition score was not related with any physical activity variables. Chapter 5 explored the changes in physical activity and sedentary time during weight loss in dogs enrolled in a 6 month calorie controlled weight loss programme. Despite an average weight loss of 15% body weight from baseline there was no marked increase in any ActiGraph measured physical activity variable.

Chapter 6 describes the results of the Children Parents and Pets Exercising Together (CPET) Study. CPET was the first exploratory randomised controlled trial to develop and evaluate an intervention aimed at dog-based physical activity promotion in children, their parents and pet dogs. The results show that the CPET intervention was both feasible and acceptable to study participants. Eighty-nine percent of families enrolled in CPET were retained at follow up. Ninety-five percent of intervention sessions were delivered and ActiGraph measured physical activity data were collected for 100% of children, 96% of parents and 96% of dogs at baseline, and 100% of children, 96% of parents and 96% of dogs available at follow up. Despite the apparent feasibility and acceptability of CPET there was no significant change in the primary outcome measure (child physical activity) or the majority of the secondary measures.

This thesis shows that the ActiGraph GT3X accelerometer is capable of accurately measuring the intensity of dog physical activity. It also shows that obesity may be related to lower levels of objectively measured vigorous intensity physical activity and the physical activity levels in dogs decline with age and vary by breed. However, it appears that physical activity levels do not increase spontaneously as dogs lose substantial amounts of body weight. Using pet dogs as the agent of lifestyle change in physical activity interventions in children and their parents is both feasible and acceptable; however, the lack of any apparent increase in child physical activity suggests that the intervention may need to be modified in a future, more definitive trial.

In summary, the findings of this thesis have important implications for the measurement of physical activity intensity in dogs, the understanding of factors associated with dog physical activity and for the development of dog-walking interventions in children and their parents.

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Declarations

I declare that all of the work submitted herewith has been carried out by myself. Collaborative work is acknowledged where present.

Ryan Morrison 2015

Contents

List of Figures

List of Tables

Acronyms

ANOVA	Analysis of variance
ASPCA	American Society for the Prevention of Cruelty to Animals
AUC	Area under the curve
BCS	Body condition score
BMC	Bone mineral content
BMI	Body Mass Index
CARS	Child Activity Rating Scale
CLASS	Children's Leisure Activities Study Survey
CONSORT	Consolidated Standards of Reporting Trials
CPAF	Children's Physical Activity Form
CPET	Children Parents and Pets Exercising Together
cpm	counts per minute
CVD	Cardiovascular disease
DEPCAT	Deprivation category
DLW	Doubly labelled water
DofH	Department of Health
DPAF	Dog Physical Activity Form
DXA	Dual energy x-ray absorptiometry

GLOBOCAN Global Burden of Cancer Study

GPAQ Global Physical Activity Questionnaire

ICC Intraclass correlation coefficients

IPAQ International Physical Activity Questionnaire

IQR Interquartile range

MET Metabolic equivalent

MVPA Moderate-vigorous intensity physical activity

PA Physical activity

PAEE Physical activity induced energy expenditure

PARA Physical activity research assistant

PDSA Peoples Dispensary for Sick Animals

PedsQL Pediatric Quality of Life Inventory

RCT Randomised controlled trial

REE Resting energy expenditure

RMR Resting metabolic rate

ROC Receiver Operating Characteristic

SD Standard deviation

TEE Total energy expenditure

TEF Thermic effect of food

WHO World Health Organization

Publications and Presentations

Peer reviewed papers

Chapter 2 and 3

- R. Morrison, V. Penpraze, A. Beber, J.J. Reilly, and P.S. Yam (2013). *Associations between obesity and physical activity in dogs: a preliminary investigation*. Journal of Small Animal Practice 54, 570-574.

Chapter 4

- R. Morrison, V. Penpraze, R. Greening, T. Underwood, J.J. Reilly, and P.S. Yam (2014). *Correlates of objectively measured physical activity in dogs*. Veterinary Journal 199, 263-267.

Chapter 5

- R. Morrison, J.J. Reilly, V. Penpraze, E. Pendlebury, and P.S. Yam (2014). *A 6-month observational study of changes in objectively-measured physical activity during weight loss in dogs*. Journal of Small Animal Practice 55, 566-570.

Chapter 6

- P.S. Yam, R. Morrison, V. Penpraze, C. Westgarth, D.S. Ward, N. Mutrie, P. Hutchison, D. Young, and J.J. Reilly (2012). *Children, parents, and pets exercising together (CPET) randomised controlled trial: study rationale, design, and methods*. BMC Public Health 12, 208.

- R. Morrison, J.J. Reilly, V. Penpraze, C. Westgarth, D.S. Ward, N. Mutrie, P. Hutchison, D. Young, L. McNicol, M. Calvert, and P.S. Yam (2013). *Children, parents and pets exercising together (CPET): exploratory randomised controlled trial*. BMC Public Health 13, 1096.

Presentations

2011

- R. Morrison, V. Penpraze, A. Beber, J.J. Reilly, and P.S. Yam (2011). *A Pair-matched Comparison of Objectively Measured Sedentary and Physical Activity Levels of Obese/Overweight Dogs with Normal Weight Dogs*. 2nd International Congress on Ambulatory Monitoring of Physical Activity and Movement, Glasgow UK, May 2011.

2012

- R. Morrison, V. Penpraze, A. Beber, J.J. Reilly, and P.S. Yam (2012). *A Comparison of Objectively Measured Sedentary and Physical Activity Levels of Obese and Overweight Dogs with Ideal Weight Dogs*. Vet 150 Conference, Glasgow UK, October 2012.

2013

- R. Morrison, V. Penpraze, J.J. Reilly, E. Pendlebury, and P.S. Yam (2013). *Physical activity in pet dogs undergoing a calorie controlled weight loss programme*. British Small Animal Veterinary Association 56th Annual Congress, Birmingham UK, April 2013.

- R. Morrison, J.J. Reilly, V. Penpraze, C. Westgarth, D.S. Ward, N. Mutrie, P. Hutchison, D. Young, and P.S. Yam (2013). *Children, parents and pets exercising together (CPET): an exploratory randomised controlled trial*. International Society of Behavioral Nutrition and Physical Activity, Ghent Belgium, May 2013.

1 Introduction and Literature Review

1.1 Contents of the Literature Review

In order to give the reader a sense of what physical activity (PA) and sedentary behaviour actually mean the literature review begins with a brief description of the definitions of both PA and sedentary behaviour in humans and dogs. The methods of measuring PA in both species, as well as their relative strengths and weaknesses, and practical issues are then discussed at length. This is intended to give the reader an overview of what methods are available and why the ActiGraph family of accelerometers were chosen to measure PA in this thesis. It is important that when reading this thesis the reader has some understanding of the importance of adequate PA, therefore the main health benefits of meeting UK government recommendations for PA, the recommendations themselves, and the number of people estimated to meet these guidelines are discussed. In addition, the limited published literature on the health benefits of PA for dogs are also discussed. Finally, the literature review ends with a discussion of the published literature on the association between dog ownership and PA and why this is a potentially fruitful strategy for the promotion of PA in children and adults

1.2 Defining physical activity and sedentary behaviour

Historically the definitions of both PA and sedentary behaviour have caused some confusion. The terms "physical activity" and "exercise", for example, are often used to describe the same thing but since exercise is actually a component, or "subcategory" of PA (Caspersen *et al*., 1985), the two terms should not be used synonymously. Similarly, the term sedentary behaviour has had two contrasting and contradictory definitions. It has been defined in the academic literature as both a low energy expenditure while sitting or in a reclined position, or as not meeting PA guidelines (Sedentary Behaviour Research Network, 2012). It is perhaps not surprising then that confusion may arise when comparing the outcome of separate studies which use contrasting definitions of the term (Sedentary Behaviour Research Network, 2012).

In humans PA has been broadly defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen *et al.*, 1985, World Health Organization, 2013a). It is a complex behaviour comprising a wide range of activities including sport, recreational, and everyday activities (Figure 1.1). Sports, such as swimming or rugby, are planned and structured activities whereas non sporting activities compromise occupational, household and leisure time activities (Caspersen *et al.*, 1985, Caspersen, 1989). For the purpose of this thesis the definition offered by Caspersen *et al.* (1985) will be used to define PA, encompassing all activities whether sporting or non-sporting.

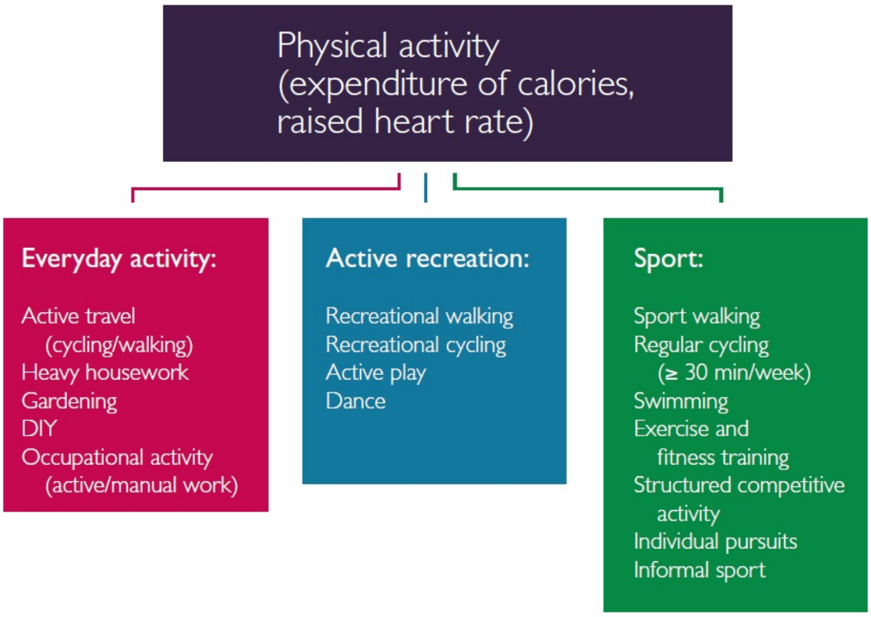

Figure 1.1 The range of activities that physical activity is comprised of. (Department of Health, 2011).

The three components of total energy expenditure (TEE) in humans can be thought of as resting energy expenditure (REE), the thermic effect of food (TEF) and physical activity induced energy expenditure (PAEE) (Butte *et al.*, 2012, Hall *et al.*, 2012). Although the contribution of PAEE to TEE is relatively small (Speakman and Selman, 2003) there is a popular belief that PA contributes to TEE independent of the actual energy cost of the activity itself (Hall *et al.*, 2012). One suggested mechanism for this is an after effect of PA on REE which may last for up to 48 hours (Speakman and Selman, 2003), although the excess energy expenditure may only account for around 6-15% of the energy expended during the activity itself (LaForgia *et al.*, 2006). The effect of PAEE on other components of TEE remains unclear; therefore it may be that the contribution of PA to TEE may be predominantly mediated by the energy cost of the activity itself. However, PAEE is the most variable component of TEE (Butte *et al.*, 2012) and therefore has the greatest potential to be altered of all the components of TEE.

PA can be further subcategorised by intensity (Caspersen *et al.*, 1985) and can be operationally defined in terms of metabolic equivalent (MET) values (Ainsworth *et al*., 2011). A MET is defined as the ratio of the work metabolic rate to resting metabolic rate (RMR), which is approximately 3.5 $mL.kg^{-1}.min^{-1}$ (Ainsworth *et al.*, 2011). Light intensity PA, which includes activities such as walking slowly or light housework, can be quantified as 1.6-2.9 METs. Moderate intensity activities such as brisk walking or light bicycling result in energy expenditure equivalent to 3-5.9 METs, and vigorous intensity activities such as jogging and swimming result in energy expenditure equivalent to ≥ 6 METs (Ainsworth *et al.*, 2011). However, there has been, and remains, debate about whether using 3.5 $mL.kg^{-1}.min^{-1}$ to define 1 MET is appropriate at the individual level. There is evidence that RMR is lower than 3.5 $mL.kg^{-1}.min^{-1}$ in certain sub-groups of the population for example, such as the overweight and females (Kozey *et al*., 2010a, Ainsworth *et al.*, 2011) and is greater than 3.5 $mL.kg^{-1}.min^{-1}$ in children (Harrell *et al*., 2005). Using 3.5 $mL.kg^{-1}.min^{-1}$ as the denominator for 1 MET may therefore lead to over or under estimation of energy expenditure depending on the characteristics of the study sample.

The term “physical activity” has not been commonly used in the dog literature and as such there is no published, widely accepted definition of PA in dogs, as there is in humans. Historically the term “exercise” has been used to describe all the activities that dogs might do voluntarily or at the behest of their owner (Laflamme, 2006, Courcier *et al*., 2010, German, 2010). For reasons of clarity, the accepted definition of PA in humans, “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen, 1989), will be used to define PA in dogs in this thesis. This will include energy expended during all forms of PA, whether this is when being physically active in the home in the absence of the owner, when playing with owners or other dogs, or when being walked. Yam *et al.* (2011) originally suggested that PA in dogs could be categorised by intensity in the same way as in humans; light intensity PA; moderate intensity PA; and vigorous intensity PA. However, they found that when measured objectively using accelerometry there was no significant difference between light intensity and moderate intensity PA (Yam *et al.*, 2011). Thus, the authors’ suggested that light and moderate intensity PA should be combined, leaving two distinct categories of PA in dogs, light-moderate intensity PA and vigorous intensity PA (Yam *et al*., 2011).

While the negative health impact of leading a sedentary lifestyle is well recognised (Pate *et al*., 2008) inconsistencies in the terminology and how sedentary behaviour is defined in humans causes confusion, especially when interpreting the different studies assessing the impact of sedentary behaviours (Sedentary Behaviour Research Network, 2012). The term 'sedentary' has recently been used in the literature to describe behaviours with low energy expenditure (e.g. RMR, ≤ 1.5 METs) and a sitting or reclining posture (Pate *et al.*, 2008, Tremblay *et al.*, 2010). However, many other studies have used the term to describe subjects who do not participate in moderate-vigorous intensity physical activity (MVPA) (Church *et al.*, 2009, Melanson *et al.*, 2009, Mullen *et al.*, 2011, Sims *et al.*, 2012). Using this definition would therefore classify study participants as sedentary even though they take part in light intensity PA. The Sedentary Behaviour Research Network (2012) recently suggested that sedentary behaviour should be defined as "any waking behaviour characterized by an energy expenditure ≤ 1.5 METs while in a sitting or reclining posture".

In dogs the term "sedentary" has been used to describe dogs confined to a cage (Ritzer *et al.*, 1980, Billman *et al.*, 2006), dogs that remain at home (Meek, 1999) or dogs that are not assigned to an exercise protocol (Galassetti *et al.*, 1999). Clearly, dogs in any of these situations will have the opportunity to participate in at least some light intensity PA and therefore a clearer definition of sedentary is required. Yam *et al.* (2011) proposed that sedentary should be used to describe behaviour in dogs where "there is no movement of the trunk, e.g. when lying still or sleeping" (Yam *et al.*, 2011). It is this definition that will be used to describe sedentary behaviour in dogs in this thesis.

1.3 Methods for assessing physical activity and sedentary behaviour

Measuring PA and sedentary behaviour is important for a variety of reasons. It allows researchers to monitor temporal trends in PA (Knuth and Hallal, 2009), to measure the effect of PA interventions (Conn *et al.*, 2011, Metcalf *et al.*, 2012) and to specify which dimensions of PA are most important for health outcomes (Maher *et al.*, 2013). However, assessing PA and sedentary behaviour accurately in free living subjects can be challenging in a research context. All of the methods available to measure PA and sedentary behaviour have strengths and weaknesses which are discussed below.

The most common methods for assessing PA fall under one of three categories: criterion methods; subjective methods; and objective methods. An overview of the strengths and limitations of each of the wide variety of methods available will be discussed in the following sections.

1.3.1 Criterion methods

1.3.1.1 Doubly labelled water

Doubly labelled water (DLW) is a method for measuring TEE and is applicable to studies assessing PA in the field and laboratory. Study participants are dosed with the stable isotope tracers ^{2}H (deuterium) and ^{18}O on the basis that the hydrogen in ingested water is eliminated from the body as water only, whereas the oxygen is lost as water and carbon dioxide (Lifson *et al*., 1955, Schoeller and van Santen, 1982). The resulting difference in elimination of the isotopes provides a measure of CO_2 production and therefore TEE (Vanhees *et al*., 2005, Bluck, 2008).

The technique has been validated against whole room calorimetry in humans (Klein *et al*., 1984, Schoeller *et al*., 1986) and indirect calorimetry in dogs (Speakman *et al*., 2001b). It has been used in a number of applications, ranging from the assessment of energy expenditure in infants (Butte, 2005), children (Torun, 2005) and adults (Shetty, 2005), to estimating the beneficial effects of PA (Evans *et al*., 2005). Furthermore, because DLW is a criterion method for measuring TEE it has been widely used as a gold standard against which other techniques for assessing PA have been validated (Wareham *et al*., 2003, Westerterp and Plasqui, 2004).

Using the DLW technique in PA research provides an accurate assessment of TEE (Klein *et al.*, 1984, Schoeller *et al.*, 1986) and is suitable for all populations (Warren *et al*., 2010). It is also unlikely to influence habitual PA levels in free living conditions (Vanhees *et al.*, 2005). However, there are a number of disadvantages to using DLW to measure TEE. The cost of the isotopes administered to study participants is expensive (Vanhees *et al.*, 2005, Bluck, 2008) as is the cost of analysing isotope concentrations (Butler *et al*., 2004). In studies where the choice of measurement method depends on budget, the high cost of DLW may prohibit its use. Another disadvantage of the DLW method is that it does not provide information about the intensity, frequency or duration of PA. Although TEE may be an important contributing factor to energy balance (Hall *et al.*, 2012) and therefore an area of interest in PA research (Reilly *et al.*, 2004) recent evidence suggests that other factors such as MVPA and patterning of sedentary behaviour may be related to health outcomes (Tremblay *et al*., 2011, Glazer *et al*., 2013). Therefore, using DLW in studies where trends or current levels of MVPA or sedentary behaviour are of importance would be unsuitable.

1.3.1.2 Indirect Calorimetry

A number of systems of indirect calorimetry have been developed all based on the principle of measuring O_2 consumption and/or CO_2 production and converting this to energy expenditure (Levine, 2005). Open and closed circuit systems have been validated for measuring energy expenditure in both humans (Levine, 2005, da Rocha *et al.*, 2006) and dogs (O'Toole *et al.*, 2001).

Indirect calorimetry provides an accurate and reliable measure of energy expenditure (Levine, 2005) and, unlike DLW, can be used to measure all components of energy expenditure including TEE, BMR, REE, TEF and PAEE (da Rocha *et al.*, 2006). Due to the nature of the equipment needed to measure energy expenditure using indirect calorimetry applications of the technique are often restricted to laboratory settings. However, recent developments of portable metabolic systems have facilitated the use of indirect calorimetry in field settings (McLaughlin *et al*., 2001, Vogler *et al*., 2010), although the accuracy of portable devices can be lower compared to stationary ones (Duffield *et al*., 2004).

A major disadvantage of indirect calorimetry is the burden placed on study participants, who are often asked to wear a mouthpiece, mask or transparent hood for short term measurements (Douglas, 1911, Littlewood *et al*., 2002, da Rocha *et al.*, 2006), or asked to remain in a chamber for longer measurement periods (Even *et al*., 1994, Kumahara *et al*., 2004). Another disadvantage is cost, indirect calorimetry systems can be expensive to purchase, operate and maintain (Levine, 2005). These disadvantages mean that indirect calorimetry is rarely used to measure energy expenditure in study participants long-term. Therefore it is most commonly used in PA research as a criterion, or “gold” standard to validate other methods of measuring PA (Ceesay *et al*., 1989, Bassett *et al*., 2000, Puyau *et al*., 2002, Kumahara *et al.*, 2004). Because of the burden placed on participants when using indirect calorimetry, the DLW method may be preferred as this does not interfere with daily life.

1.3.1.3 Direct observation

The third criterion method for assessing PA is direct observation. It is most commonly used to classify PA in children (McKenzie, 2002) but has also been used to classify the PA behaviour of dogs (Yam *et al.*, 2011). Trained and experienced researchers observe study participants using any one of many observational systems and record their behaviour, classifying PA into distinct categories using codes (Vanhees *et al.*, 2005). At least nine different systems of direct observation have been developed and are widely used in PA research involving children (McKenzie, 2002). Some of the most common systems include the Child Activity Rating Scale (CARS) (Puhl *et al*., 1990), validated against indirect calorimetry, and the Children's Physical Activity Form (CPAF) (O'Hara *et al*., 1989), validated against heart rate monitoring. Due to the subjective nature of direct observation a common concern is the inter-observer, or inter-rater reliability, however the coefficients of agreement between observers is generally high, ranging from 84% to 99% (McKenzie, 2002).

As well as being able to classify PA behaviours into distinct categories, using direct observation allows researchers to obtain more contextual information such as the influences or determinants of PA (Vanhees *et al.*, 2005). Therefore both quantitative and qualitative aspects of PA can be recorded in great detail. However, there are disadvantages of using the technique. Observers are required to meticulously observe and record the PA behaviours of study participants; it is therefore very labour intensive, time consuming and expensive. Finally, there is also the possibility that the presence of a researcher may positively or negatively impact on the habitual PA of study participants. Direct observation is now most commonly used as a criterion validation when assessing the validity of other methods of measuring PA (Reilly *et al*., 2003, Van Cauwenberghe *et al*., 2011a).

1.3.1.4 Summary

Each of the criterion methods described have considerable advantages when measuring PA. Indirect calorimetry and DLW are able to measure energy expenditure accurately, while direct observation provides detailed quantitative and qualitative information about PA behaviours. However, studies where PA is measured are often constrained by small budgets and the expensive nature of all three methods generally prohibits their use in PA assessment. They are therefore commonly used as criterion, or gold standards against which other, less expensive, methods of PA assessment are validated.

1.3.2 Subjective methods

Subjective methods are widely used when measuring PA and are often the least expensive method available to researchers. The most commonly used subjective methods are self-report or interviewer-assisted questionnaires, proxy-report questionnaires and PA diaries or logs. Each of these methods require a study participant to recall their own PA behaviours, or on the behalf of others (usually a child or pet). Clearly energy expenditure or PA are not measured directly and each method must be validated against a criterion method (DLW, indirect calorimetry or direct observation) or objective method (accelerometers, pedometers or heart rate monitoring).

An extensive and wide variety of PA questionnaires have been used to assess PA in research settings (Pereira *et al*., 1997). Some of the earliest questionnaires developed include the Baecke Physical Activity Questionnaire (Baecke *et al*., 1982); the Godin Shephard Leisure Time Questionnaire (Godin and Shephard, 1985); the Paffenbarger Physical Activity Questionnaire (Paffenbarger *et al*., 1993); and the Seven-Day Physical Activity Recall (Sallis *et al*., 1993). More recent, and widely used, questionnaires are the International Physical Activity Questionnaire (IPAQ) (Craig *et al*., 2003) and the Global Physical Activity Questionnaire (GPAQ) (Bull *et al*., 2009). Questionnaires have even been designed specifically to assess PA in children (Chinapaw *et al*., 2010) and dogs (Slater *et al*., 1992, Sallander *et al*., 2001).

The criterion validity of PA questionnaires remains equivocal. For example, Godin and Shephard (1985) concluded that the Godin Shephard Leisure Time Questionnaire was a valid method for measuring leisure time PA. However, when tested against indirect calorimetry in a sample of 78 adults the correlation coefficient was only 0.32 (Jacobs *et al*., 1993). Furthermore, a recent review of the short form of the IPAQ questionnaire found that its validity was generally poor when tested against criterion or objective methods (Lee *et al*., 2011). The reliability of PA questionnaires is often tested using test/retest intraclass correlation coefficients (ICC) (Shephard, 2003). Using this method the reliability varies widely depending on which dimension of PA is evaluated. For instance the ICC for strenuous activity as recorded by the Godin Shephard Leisure Time Questionnaire is 0.94, whereas for moderate intensity activity the ICC is only 0.46 (Godin and Shephard, 1985).

A systematic review of questionnaires available for assessing PA in children concluded that none of the questionnaires examined had acceptable levels of reliability and validity (Chinapaw *et al.*, 2010). One of the most promising questionnaires designed for 10-12 year old children, the target age-group of Chapter 6 in this thesis, is the Children's Leisure Activities Study Survey (CLASS) (Telford *et al*., 2004). When assessed for reliability CLASS was found to have an ICC of 0.75 and 0.37 for MVPA frequency and duration, respectively, when reported by children themselves (Telford *et al.*, 2004). When proxy-reports of the parents of the children taking part were analysed the ICC were 0.67 and 0.58

for MVPA frequency and duration, respectively (Telford *et al.*, 2004). When validated against an accelerometer the CLASS questionnaire was found to have generally poor correlation with the accelerometer output, the only significant correlation was for proxy-reported vigorous intensity PA (r = 0.24) (Telford *et al.*, 2004).

When assessing PA in dogs, owner reported surveys are the most common method used (e.g. Courcier *et al*., 2010). This is despite a lack of reliability and validation studies of dog PA questionnaires. Slater *et al.* (1992) assessed the repeatability of a combined diet and exercise questionnaire in a sample of 101 dog owners. The questionnaire examined the frequency, intensity, duration and type (on lead or off lead) of exercise and test-retest repeatability (measured by kappa) ranged from 0.29 for the duration of on-lead walks to 0.55 for the frequency of off-lead walks. Sallander *et al.* (2001) assessed the repeatability of a similar combined diet and exercise questionnaire and found that the test-retest repeatability (kappa) was 0.70 for the number of hours walking per day and 0.94 for the number of hours jogging per day. Neither of these questionnaires were validated against a criterion method of measuring PA and neither assessed the frequency or duration of the standard parameters of PA used in human PA research (e.g. light, moderate and vigorous intensity PA).

Despite their limited reliability and validity PA questionnaires and diaries have been widely used to assess PA. The main advantage that subjective measures have over other methods of measuring PA is cost; of all the common methods of measuring PA subjective methods are the least expensive. Another advantage is that questionnaires can examine the domain in which PA took place, i.e. whether participants took part in PA in the home, the workplace, a gym, or even outdoors. However, the advantages described do not outweigh the disadvantages of using this method. For example, all questionnaires require a participant to recall the frequency, duration and intensity of physical activities. The process of storing and retrieving memories is a complex task (Willis *et al*., 1991, Durante and Ainsworth, 1996) and can lead to under or overestimation of PA (Pereira *et al.*, 1997, Sirard and Pate, 2001).There is also a strong possibility that asking a study participant to complete a PA diary could influence the amount of PA levels during the assessment period (LaPorte *et al*., 1985), meaning that diaries would not be able to record habitual PA levels. Subjective methods are most commonly used in situations where their relatively inexpensive nature makes them a suitable choice, i.e. in studies with large sample sizes.

1.3.3 Objective methods

1.3.3.1 Heart rate monitoring

One of the basic principles of sport and exercise science is that heart rate increases linearly in response to increasing energy expenditure during exercise involving large muscle groups (Karvonen and Vuorimaa, 1988). This is the basis for using minute-by-minute heart rate monitoring to measure PA, therefore allowing the identification of the frequency intensity and duration of PA. This technique has been widely used to estimate energy expenditure in children (Rowlands *et al*., 1997) and adults (Prince *et al*., 2008) but not dogs.

Study participants are typically asked to wear a chest strap which connects wirelessly to a wrist worn watch which generally have the capacity to store multiple days' worth of data. Alternatively, electrode based monitors may be used which require study participants to have multiple electrodes attached to the torso, but issues regarding irritation of the skin can be a barrier to long-term wear with such systems (Andre and Wolf, 2007).

Usually, heart rate is measured in dogs as part of a veterinary cardiac examination (Fuentes *et al*., 2010) but has also been used to monitor stress and welfare (Vincent and Leahy, 1997, Hydbring-Sandberg *et al*., 2004, Palestrini *et al*., 2005) and the physiological response to PA (Ordway *et al*., 1982, Essner *et al*., 2013). To date though, there are no published studies validating the use of heart rate monitoring to estimate energy expenditure or PA in dogs. It has even been suggested that it is unlikely that heart rate monitoring would be able estimate energy expenditure accurately in dogs due to increased heart rate with excitement during low intensity PA and movement error during high intensity PA (Hill, 2006).

A number of studies in humans have used absolute heart rate values to determine the intensity of PA (Gilliam *et al*., 1981, Armstrong *et al*., 1990, Janz *et al*., 1992). Usually, some threshold is used to determine activities of a certain intensity, in children a heart rate of $\geq$ 140 beats per minute has been suggested as suitable for defining MVPA (Simons-Morton *et al*., 1988). However, it has been shown that there is considerable inter-individual variability in the relationship between heart rate and energy expenditure during a variety of activities (Li *et al*., 1993). This suggests that selecting an absolute threshold to define the intensity of PA is not suitable when assessing PA in a heterogeneous group of study participants. Furthermore, at rest and during light intensity PA the relationship between heart rate and energy expenditure is not linear and therefore heart rate monitoring is often used to assess PA of moderate to vigorous intensity only (Warren *et al.*, 2010).

In order to overcome these limitations more accurate solutions have been developed (Sirard and Pate, 2001). The most common of these is the flex-HR method (Spurr *et al*., 1988). This method involves calibrating heart rate in each individual study participant with energy expenditure as measured by indirect calorimetry. Both heart rate and energy expenditure are measured at rest and during a range of activities thereby determining the threshold between rest and PAEE (the flex-HR), and overcoming the inter-individual variability in heart rates. The method has been validated in free living conditions against DLW in children (Emons *et al*., 1992) and adults (Livingstone *et al*., 1990).

Even though there are advantages of using the flex-HR method over absolute heart rates, it does carry some limitations. As described previously heart rate has to be calibrated against energy expenditure for each study participant, therefore increasing the burden on both the participants and researchers and incurring the added expense of operating an indirect calorimetry system. The flex-HR method assumes that the within participant relationship between heart rate and energy expenditure remains constant. However, it has been shown that during a range of activities there can be as much as 20% intra-individual variation in the relationship between heart rate and energy expenditure when performed on separate occasions (Li *et al.*, 1993). The linear relationship between heart rate and energy expenditure can also be confounded by a range of other factors such as medication to control high blood pressure and the effects of asthma (Butte *et al.*, 2012), or by improved cardiovascular fitness (Dugas *et al*., 2005). Therefore, more accurate objective methods are generally used when assessing PA.

1.3.3.2 Pedometers

Pedometers are small, lightweight and inexpensive motion sensors which measure and record the number of steps taken by a study participant. They are typically worn on a belt or waistband in humans or on a collar in dogs, from waking until sleep. There are three primary mechanisms used in pedometers; a spring suspended lever arm; a magnetic reed proximity switch; and a piezoelectric crystal (Schneider *et al.*, 2004). The fundamental aspect of each mechanism is that they convert vertical displacement to step counts. The step count is recorded and stored in the devices internal data storage, and can be displayed digitally along with other parameters such as estimates of energy expenditure and distance travelled.

The accuracy of pedometers when measuring step count has been studied extensively in humans and to a lesser extent in dogs. In a validation study of 10 different pedometer models involving a sample of 10 adults, the authors found that six out of 10 models were accurate to within ± 1% of step counts recorded during direct observation of walking at speeds between 4.8 and 6.4 km/h (Crouter *et al*., 2003). Another study in adults found that three out of 10 electric pedometers were accurate to within ± 3% of actual step counts during a 400m walking test (Schneider *et al*., 2003). In children pedometers have been found to be inaccurate when measuring step counts during walking at slow speed but their accuracy increases with increasing speed (McNamara *et al*., 2010). Beets *et al.* (2005) found that all four pedometer models examined agreed well with actual step counts (ICC ≥ 0.93) at speeds between 4.8 and 5.6 km/h during treadmill walking in 5-11 year old children.

One study has assessed the validity of using pedometers to measure step count in dogs. Chan *et al*. (2005) found that a pedometer overestimated the actual number of steps taken during walking by 16% when dogs of all size were considered. This increased to 20% and 16% for large and medium dogs respectively, and when small dogs were analysed separately the pedometer underestimated the actual step count by 7%.

Despite their accuracy when measuring step count in humans, pedometers are much less accurate when estimating energy expenditure. For example, Crouter *et al.* (2003) found that nine out of 10 models studied significantly overestimated net kilocalorie expenditure (measured by indirect calorimetry) in adults during walking at various speeds on a treadmill. Therefore, it has been suggested that analysis of data output from pedometers should be performed on total daily step count as this will prevent the addition of error from using estimates of other parameters of PA (Corder *et al*., 2007a).

There has been some concern among PA researchers that the digital output from pedometers may encourage study participants to alter their usual PA behaviours. Clemes and Parker (2009) showed that, when asked to record their step counts in a diary, step count increased significantly in adults, suggesting that pedometers with the ability to record data for long periods and with covers that can be sealed to prevent participants being influenced by their step count should be used. However, Ozdoba *et al.* (2004) found that step count was not significantly different using unsealed pedometers compared to sealed pedometers in children. The authors did note though, that some children accidentally reset the step count on their pedometer. This also suggests that devices with covers that can be sealed are the most suitable when measuring PA. Another limitation of using pedometers is that they only measure absolute step count and are therefore unable to provide any information regarding sedentary behaviour or of the intensity, frequency or duration of PA. They are therefore mostly used in PA interventions designed to increase total or daily step count (Brown *et al*., 2006, Pillay *et al*., 2012).

1.3.3.3 Accelerometers

When a human, or dog, moves during bouts of PA the body is accelerated by the force produced by skeletal muscles. As PA is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen *et al.*, 1985) measuring the acceleration produced by muscles can therefore theoretically provide an estimate of energy expenditure. These raw accelerations are measured by using small, lightweight, portable, and non-invasive motion sensors called accelerometers.

There are typically two primary mechanisms used in modern research grade accelerometers. One consists of a piezoelectric element with a sensor which is deformed in response to acceleration (John and Freedson, 2012). The conformational change in the sensor results in the production of an electric charge proportional to acceleration, which is measured by the accelerometer. The other mechanism, known as a capacitive accelerometer, consists of two fixed plates acting as electrodes with a moveable central plate, which together form a differential capacitor (John and Freedson, 2012). The variation in capacitance causes voltage changes which are proportional to the acceleration. Both mechanisms typically use a filtering and amplification process to then convert the voltage signals into raw counts. The raw counts are then summed over a specific time period (or epoch), usually 15 seconds to 1 minute, and output as activity counts.

In addition to the type of mechanism used accelerometers differ in the number of axes in which acceleration is measured. The most common accelerometers are either uniaxial, e.g. the ActiGraph GT1M (ActiGraph, USA) or triaxial, e.g. the ActiGraph GT3X+ (ActiGraph, USA). Uniaxial accelerometers measure acceleration in one longitudinal body axis, usually the vertical plane, whereas triaxial accelerometers measure acceleration in three axes, the vertical, mediolateral, and anterior-posterior planes. The devices are typically worn on a belt and positioned at the hip, although some devices have been developed that can be worn at the lower back or even on an ankle or wrist.

Accelerometers have become the method of choice in PA research in recent years due to their advantages over other methods of measuring PA. Modern devices have the capacity to store many days' worth of data, > seven days, provide an objective indicator of body movement, and place little burden on study participants. As well as providing information on the total amount, or volume, of PA they are able to quantify the duration and frequency of bouts of varying intensity. Unlike when using heart rate monitors and pedometers the pattern of sedentary behaviour can also be investigated. For these reasons they have been used in numerous settings where not only the total volume of PA is of importance, but also the intensity of PA and pattern of sedentary behaviour. They have been widely used to monitor PA in large cohort studies (Riddoch *et al*., 2007, Troiano *et al*., 2008, Basterfield *et al*., 2011), to measure change in PA in randomised controlled trials (RCT's) (Reilly *et al*., 2006, Hughes *et al*., 2008), and more recently to describe patterns of sedentary behaviour (Klitsie *et al*., 2013). Associations between PA and health outcomes such as obesity and cardiovascular risk factors have been shown by measuring PA using accelerometry (Andersen *et al*., 2006, Ness *et al*., 2007), which has been partly attributed to the accuracy of accelerometers over other methods of measuring PA (Reilly *et al*., 2008).

Conclusions from a number of reviews suggest that accelerometers provide an objective, accurate and reliable means of quantifying habitual PA and sedentary behaviour in humans (Sirard and Pate, 2001, Corder *et al*., 2008, Reilly *et al*., 2008, Warren *et al*., 2010, Butte *et al*., 2012, Matthews *et al*., 2012). A wide variety of accelerometer models have been validated against criterion methods in children and adults (Matthew, 2005, De Vries *et al*., 2009). Correlation between activity counts generated by accelerometers and PA measured by direct observation in children are generally moderate to high (Kelly *et al*., 2004, Sirard *et al*., 2005). Strong correlations have also been shown between activity counts and indirect calorimetry in both children and adults (Brage *et al*., 2003, Puyau *et al*., 2004, Schmitz *et al*., 2005b, Pfeiffer *et al*., 2006). However, when accelerometer derived activity counts are compared to energy expenditure measured by DLW, correlation coefficients vary widely and can be as low as 0.18 in children (Plasqui *et al*., 2013). Some of this disagreement can be attributed to the type of accelerometer studied; nevertheless, some models may be unsuitable for estimating energy expenditure.

As well as being widely used in human PA research, accelerometers have also been validated for measuring PA in dogs (Yamada and Tokuriki, 2000, Hansen *et al*., 2007, Yam *et al*., 2011, Preston *et al*., 2012). Yamada and Tokuriki (2000) found that an accelerometer was able to differentiate between activities involving whole-body movement and activities involving change of posture (lying, sitting and standing) in a sample of 10 beagle dogs. However, the dogs were caged and the activities examined are therefore unlikely to reflect the habitual PA of dogs. Hansen *et al.* (2007) assessed the validity of using the Actical accelerometer to measure PA in a sample of 4 cross breed dogs. Accelerometers were attached to eight different locations and validity assessed against direct observation while dogs were allowed to roam freely within a caged area. When the accelerometer output was compared to total distance travelled and time spent moving the authors found that the correlation coefficients ranged from 0.71 to 0.93 and were similar for all eight locations.

Yam *et al.* (2011) assessed the validity, practical utility and reliability of the ActiGraph GT3X for measuring PA in dogs. In their validation study a sample of 30 dogs of varying age and breed were observed during four separate intensities of movement intended to replicate habitual PA. The intensities were: sedentary, defined as no movement of the trunk; light intensity PA indoors, defined as slow translocation of the trunk, confined within a room or kennel; light to moderate intensity PA outdoors, defined as slow to moderate translocation of the trunk with the dog on a lead; and vigorous intensity PA, defined as rapid translocation of the trunk while running outdoors and off a lead. They found that the accelerometer output was significantly different for all intensities except light intensity indoors and light-moderate intensity outdoors, suggesting that these two categories should be combined. In the practical utility and reliability study accelerometers were attached to a separate sample of 20 dogs for seven consecutive days. Complete data sets were obtained from all 20 dogs and the reliability of the accelerometer output was high, ranging from 86% for two days of monitoring up to 93% for all seven days. Preston *et al.* (2012) assessed the validity of using the ActiGraph GT3X for detecting change in PA on a treadmill in a sample of six dogs of varying age and breed. The accelerometer output from four separate locations, with two attachment configurations at each location, was assessed while dogs were at rest and while walking and trotting on a treadmill. The accelerometer output increased from rest to walking at 3 km/h and 5 km/h at 0% slope from all placement/attachment locations, but only increased from walking at 5 km/h to trotting at 7 km/h when the accelerometer was placed in a pouch attached to a harness.

Both the Yam *et al*. (2011) and Preston *et al*. (2012) studies concluded that the ActiGraph GT3X is a valid method for measuring PA in dogs.

Although accelerometers are used extensively in PA research they are not able to quantify all types of PA. For example, energy expenditure during activities such as carrying loads and walking uphill is increased compared to walking on a flat surface or when not carrying a load. However, acceleration measured by accelerometers does not usually change during these activities and energy expenditure is therefore underestimated (Warren *et al.*, 2010, Preston *et al.*, 2012). Hip mounted accelerometers are also unable to measure PA during activities such as cycling (Corder *et al.*, 2007a). Another issue is the lack of an industry standard for converting raw acceleration to activity counts. Manufacturers typically use an algorithm when converting acceleration to counts. However, proprietary restrictions usually prevent them from releasing algorithms to the public, making comparison of accelerometer output between studies that use different models difficult. Despite these weaknesses accelerometers remain the method of choice when quantifying PA in free living subjects (Strath *et al*., 2013).

1.3.4 Practical considerations when using accelerometers

The use of an accelerometer to measure PA requires an understanding of: the type of accelerometer to choose; what sampling interval is appropriate; the appropriate placement of the accelerometer on the body; what cut points are most suitable for the target population; and how many days and hours per day of monitoring are required to constitute a valid data set.

1.3.4.1 Choice of accelerometer

Before deciding which thresholds to use to define MVPA and sedentary behaviour, or any of the other practical considerations of using accelerometers, PA researchers must decide which accelerometer to use. At least 19 different models of accelerometer from a variety of manufacturers have been used in PA research; these are listed in Table 1.1. The available models vary in the mechanism used to measure acceleration, their size and weight, the number of axes in which acceleration is measured, and the specific populations in which they have been validated for use. Choosing an accelerometer can therefore be difficult, although it is important to make a decision based on the objectives of the study, and to take into account the available resources to purchase the accelerometers. It is also important that decisions are evidence based and the accelerometer chosen is suitable for measuring PA in the target population.

Accelerometer	Manufacturer	Number of axes	Size (mm)	Weight (g)
3dNX	BioTel Ltd., Bristol, UK	Triaxial	125 x 58 x 8	93
ActiGraph 7164	No longer available	Uniaxial	51 x 41 x 15	43
ActiGraph GT1M	ActiGraph, Pensacola, FL, USA (no longer available)	Uniaxial	38 x 37x 18	27
ActiGraph GT3X	ActiGraph, Pensacola, FL, USA (no longer available)	Triaxial	38 × 37 × 18	27
ActiGraph GT3X+	ActiGraph, Pensacola, FL, USA	Triaxial	46 x 33 x 15	19
Actiheart	Cambridge Neurotechnology Ltd, Cambridge, UK	Uniaxial	7 × 33 connected to sensor by wire	8
Actical	Philips-Respironics, Andover, MA, USA	Omni-directional	29 x 37 x 11	16
Actitrac	Individual Monitoring Systems, Baltimore, MD, USA	Biaxial	37 x 55 x 12	23
ActiWatch	Philips-Respironics, Andover, MA, USA	Omni-directional	37 x 35 x 12	25
ActivPAL	PAL Technologies Ltd, Glasgow, UK	Uniaxial	35 x 53 x 7	15
BioTrainer Pro	Individual Monitoring Systems, Baltimore, MD, USA (no longer available)	Biaxial	76 x 51 x 19	51
Caltrac	Muscle Dynamics Fitness Network, Torrance, CA, USA (no longer available)	Uniaxial	70 x 70 x 20	78
Dynastream AMP-331	Dynastream Innovations Inc. Cochrane, Alberta, Canada (no longer available)	Triaxial	71 x 21 x 38	50
GENEA	Unilever Discover, Sharnbrook, Bedfordshire, UK	Triaxial	36 x 30 x 12	16
Lifecorder	Suzuken Co. Ltd., Nagoya, Japan	Uniaxial	62 x 46 x 26	42
Mini-logger Series 2000	Mini-Mitter, Bend, OR, USA (no longer available)	Omni-directional	44 x 33 x 10	125g
RT3	Stayhealthy, Inc. Monrovia, CA, USA	Triaxial	68 x 48 x 18	63
Tritrac	Reining Ltd., Madison, WI, USA	Triaxial	120 x 65 x 22	168
Tracmor	Philips New Wellness Solutions, Eindhoven, the Netherlands	Triaxial	32 x 32 x 5	13

Table 1.1 Accelerometers commonly used in physical activity research

Of all the accelerometers which are available to measure PA the ActiGraph is the most popular and widely studied (Cain *et al*., 2013). One of ActiGraph's earliest models, the uniaxial GT1M, has been widely used in studies involving both children and adults (Rowlands and Eston, 2007, Sasaki *et al*., 2011, Cain *et al.*, 2013). The GT1M replaced the AM7164 which has been widely validated against criterion methods for use in children and adults (Freedson *et al*., 1998, Puyau *et al.*, 2002). Several studies have shown that activity counts produced by the GT1M are similar to the AM7164, therefore activity counts can be compared between monitors (Corder *et al*., 2007b, Kozey *et al*., 2010b). Although the GT1M or AM7164 have not been validated for use in dogs, the triaxial GT3X, released in 2009, has (Yam *et al.*, 2011). The authors found that output from both the vertical axis, and the integrated measure of all three axes correlated well with directly observed movement. The GT3X has also been validated for use in children (Jimmy *et al*., 2013) and it has recently been shown that the vertical output from the GT3X is comparable to the vertical output from the GT1M (Sasaki *et al.*, 2011, Kaminsky and Ozemek, 2012, Robusto and Trost, 2012). Since the release of the original GT3X, ActiGraph have released an updated version, the ActiGraph GT3X+. The main benefit of the GT3X+ over the older GT3X is that the GT3X+ is waterproof up to depths of 1m for as long as 30 minutes. The waterproof feature means that the device can be left attached during periods of torrential rain, or when bathing. This is especially useful when used in dogs as the device does not have to be removed and reattached.

Due to the available evidence, resources available, and diverse range of study populations in this thesis the ActiGraph range of accelerometers were chosen to measure PA. Both the GT3X and GT3X+ were used to measure PA in dogs. The GT3X (vertical axis only) was used to measure PA in children, and the GT1M was used to measure PA in adults.

1.3.4.2 Choice of epoch

Accelerometers typically measure acceleration constantly, summing the activity count for a predetermined time period. At the end of each time period, also known as an epoch, the summed data is stored in the devices internal memory. Early accelerometer models often had limited storage capacity; therefore in order to capture PA over long periods (i.e. seven days) it was necessary to use what are now regarded as relatively long sampling intervals, usually 1 minute. Most of the research on epoch length has been carried out in children based on the theory that children participate in frequent, shorter bursts of MVPA compared to adults. Activity counts based on 1 minute epochs could therefore significantly underestimate the sporadic nature of children's PA patterns. Short, frequent bursts of MVPA which may only last a few seconds are averaged over the 1 minute period, possibly diluting these bouts of MVPA. The internal storage capacity of modern accelerometers is greater than early devices and this enables researchers to measure PA over much shorter time sampling periods.

Recent evidence in children and adults suggests that the choice of epoch length may have some influence on reported amounts of PA. Edwardson and Gorley (2010) studied the effect of a range of epoch lengths from 5 seconds to 60 seconds in sample of 7-11 year old children. They found a decrease in the amount of time spent in MVPA as the duration of epoch decreased. Reilly *et al.* (2008) applied epoch lengths ranging from 15 seconds to 1 minute to existing data in 5 and 6 year old children, finding that the 15 second epoch significantly increased the amount of MVPA per day compared with the 60 second epoch, but no effect of epoch length on sedentary time was found. Similarly, Gabriel *et al.* (2010) found that a shorter epoch time (10 seconds) significantly increased the amount of MVPA in adults compared to a longer epoch of 60 seconds. Therefore, in all studies in this thesis accelerometers were set to record activity counts in 15 second epochs.

1.3.4.3 Choice of cut-points to express PA and sedentary behaviour

When measuring PA recorded by an accelerometer as the amount of time spent sedentary, or in light intensity, moderate intensity or vigorous intensity PA the raw activity counts are usually interpreted using specific thresholds, or cut-points, for each intensity. The cut-points are usually derived from calibration studies, a number of which have been carried out in humans. There is wide variation among cut-points for both sedentary behaviour and MVPA, even when only using the ActiGraph accelerometer. Reilly *et al.* (2008) examined the effect of applying the most commonly used cut-points on the amount of MVPA and sedentary behaviour measured in children using the ActiGraph. In that study, statistically and biologically significant differences in the amount of both sedentary behaviour and MVPA were found depending on the cut-point applied. Given the variation in published cut-points for the ActiGraph accelerometer the rationale for choosing cut-points should be based on what are considered the most appropriate thresholds for defining sedentary behaviour and MVPA in the target population.

At the time of designing the protocol for Chapter 6 in this thesis the most appropriate ActiGraph cut-points for defining sedentary behaviour and MVPA in children were those of Puyau *et al.* (2002). In that study 26 children between 6 and 16 years old wore ActiGraph 7164 accelerometers and energy expenditure was measured while performing a number of activities of varying intensity intended to mimic the normal activities of children. Regression analysis was then performed to calibrate the ActiGraph output with energy expenditure at each intensity level. The cut-points of Puyau *et al.* (2002) have been widely used to define MVPA and sedentary behaviour in PA studies involving children (Kelly *et al*., 2006, Hughes *et al.*, 2008, Mendoza *et al*., 2011, Robertson *et al*., 2011). However, a recent study comparing the most commonly used ActiGraph cut-points for defining PA intensities in children (Trost *et al*., 2011) found that the most favourable cut-points were those of Evenson *et al.* (2008). The authors suggested that these cut-points should be the preferred choice when reporting PA in children. However, more studies of this nature which are designed to assess the comparative validity of available cut-points, are required before abandoning existing methods, i.e. the use of Puyau cut-points. Furthermore, the only study in this thesis in which PA is measured in children is an RCT assessing change in PA over time, therefore, the Puyau cut-points remain an appropriate choice for defining sedentary behaviour and MVPA.

At least 15 different regression equations have been used to calibrate ActiGraph activity counts to PA intensities in adults (Crouter *et al*., 2006). Two comparison studies of ActiGraph cut-points have concluded that no single set of ActiGraph cut-points can predict all activities (Strath *et al*., 2003, Crouter *et al.*, 2006). Therefore there is no widely accepted standard for choosing which cut-points to use to predict PA intensity in adults. Despite this, the most popular cut-points used in PA research in adults using the ActiGraph are those of Freedson *et al.* (1998). The Freedson cut-points were developed by calibrating the ActiGraph output with energy expenditure during walking and running on a treadmill in 50 young adults. Like the cut-points of Puyau, the Freedson cut-points have been widely used to define the intensity of PA in several studies (Cooper *et al*., 2000, Hagstromer *et al*., 2007), although they may underestimate activities other than walking or running (Matthew, 2005). Although the Freedson cut-points may underestimate some activities this limitation is unlikely to impact the results of Chapter 6 in this thesis as its aim is to assess change in PA in adults over time.

Two studies have validated the use of the ActiGraph accelerometer for measuring PA in dogs, although neither study developed cut-points that could be used to define the intensity of PA. Therefore one aim of this thesis was to calibrate and cross-validate ActiGraph cut-points for defining PA intensity in dogs.

1.3.4.4 Accelerometer placement

Accelerometers can be placed in a number of positions on the body; devices have been placed on the waist, wrist, back and ankle (Matthews *et al.*, 2012). Bouten *et al.* (1997) explored how the placement of accelerometers influenced the relationship between body acceleration and energy expenditure. They suggested that placing an accelerometer on the trunk (either on the lower back or hip) was more appropriate than limb placements such as the wrist or ankle due to the greater influence of gravity on the limb placements compared to the trunk. Nilsson *et al.* (2002) assessed the effect of accelerometer placement at the hip or lower back on PA in children. They found no significant difference in total accelerometer counts per minute (cpm) and correlation between the accelerometer output from the hip and back was 0.81. The hip placement resulted in higher predicted minutes of moderate PA, but no significant difference was found for vigorous intensity PA or MVPA. Yngve *et al.* (2003) found no difference between mean accelerometer cpm in adults who wore an accelerometer at the lower back (392 ± 139 cpm) and hip (402 ± 143 cpm) for seven consecutive days. There were also no difference in time spent in moderate or vigorous intensity PA, indicating that estimates of free living PA are not influenced by placement at the lower back vs the hip.

Choosing between the lower back and hip for the most appropriate placement of an accelerometer in humans may come down to practical reasons, rather than which site offers the most accurate estimate of PA. Placing an accelerometer at the lower back makes it difficult for a study participant to visually check that the accelerometer remains in the correct position, whereas placing at the hip ensures that the device is easily kept in one place during the assessment period. It is also appropriate to use the same attachment site as those in validation studies of the accelerometer being used; in validation studies of the ActiGraph, hip placement has been used in both children and adults (Freedson *et al.*, 1998, Puyau *et al.*, 2002).

Accelerometers have also been placed at a variety of sites when measuring PA in dogs. They have been attached to the withers using an elastic belt or vest, or attached to the dogs' collar (Bodey and Michell, 1996, Yamada and Tokuriki, 2000, Hansen *et al.*, 2007, Dow *et al.*, 2009, Preston *et al.*, 2012). When validating the use of the ActiGraph, Yam *et al.* (2011), used the dogs collar as the attachment site for the accelerometer. Only Preston *et al.* (2012) have assessed the influence of ActiGraph placement on accelerometer output. They examined whether placement on the dogs collar or along the dorsal midline attached to a harness had any effect on accelerometer output during walking and trotting on a treadmill. Only the accelerometer placed on the dorsal midline resulted in statistically significant increases in accelerometer count as walking speed increased form 5 km/h to 7 km/h. However, the activities assessed by the authors were carried out on a treadmill, and included a small sample size (n = 6), so its relevance to placement of the ActiGraph in free living conditions remains uncertain. The study by Yam *et al.* (2011) is the only study to assess the validity of using the ActiGraph to measure PA in dogs under free living conditions, indicating that placement of the ActiGraph on the dogs' collar may be most appropriate in studies assessing habitual PA. Collar placement may also be the most practical site for attachment. Most dogs wear a collar, and attaching an accelerometer to this site may reduce the burden placed on dogs (and their owners) compared to attaching devices via vests or a harness, which some dogs may not be used to.

1.3.4.5 How many days of monitoring are required?

In accelerometry research there is no standard practice for the minimum number of days of monitoring required. In an ideal situation a monitoring period should be of sufficient length so that the daily average reflects a study participant's habitual PA. A number of studies have assessed how many days are needed to achieve an acceptable level of reliability. Janz *et al.* (1995) assessed the between day reliability of accelerometry output in 7-15 year old children. They found that the ICC for four days of monitoring was 0.75 to 0.78, but this increased to 0.81 to 0.84 for six days of monitoring. Treuth *et al.* (2003) found that the ICC for activity counts in 8-9 year old girls over four days of monitoring was 0.37. When they applied the Spearman-Brown prophecy formula (Spearman, 1904), a method used to calculate the effect on reliability of lengthening or shortening a monitoring period, a minimum of seven days was required to achieve an ICC of 0.8. In a sample of 12-14 year old girls Murray *et al.* (2004) found that the ICC for a single day of monitoring was 0.42, when the Spearman-Brown prophecy formula was applied a minimum of five days was required to achieve an ICC of 0.8.

Trost *et al.* (2000) assessed the minimum number of days required for acceptable reliability in different subsets of children (those aged 6-8 years old, 9-11 years old, 12-14 years old and 15-17 years old). To achieve an ICC of 0.8, four to five days of monitoring was required in both 6-8 year olds and 9-11 year olds. In the older children this increased to a minimum of eight to nine days, although for all children a minimum of seven days produced reliability coefficients ranging from 0.76 to 0.86. Penpraze *et al.* (2006)

determined the reliability coefficients of a variety of monitoring periods ranging from a single day to seven consecutive days in 5-6 year old children. They found a reliability coefficient of 0.8 for three days of monitoring, suggesting this was sufficient to represent habitual PA. Mattocks *et al.* (2008) examined the number of days required to achieve reliability coefficients of 0.7, 0.8 and 0.9 in 11 year old children. An ICC of 0.7 was achieved with as little as three days of monitoring, whereas a minimum of five and 11 days were required for the reliability coefficient to reach 0.8 and 0.9 respectively.

The apparent disagreement in the minimum number of days required to estimate habitual PA in children is mirrored in studies involving adults. Gretebeck and Montoye (1992) evaluated the number of days required to achieve reliable estimates of PA in adults aged 24-67 years. They assessed the minimum number of days required to estimate a seven day period with less than 5% error and found that at least five days were needed to minimise within individual variance in PA. Levin *et al.* (1999) calculated that a single day ICC in a sample of 77 adults who wore an accelerometer for 48 consecutive hours every 26 days for one year was 0.41. When the Spearman-Brown prophecy formula was applied they calculated that a monitoring period of at least six days was required to achieve an ICC of 0.8. Matthews *et al.* (2002) assessed PA for 21 consecutive days in 92 adults ranging from 18 to 79 years old. To achieve an ICC of 0.8, three to four days of monitoring were required and a minimum of seven days were required to achieve an ICC of 0.9. Jerome *et al.* (2009) assessed the reliability of accelerometer measurements in a large sample of overweight and obese adults. They found that using a monitoring period of four days optimised the balance between reliability and participant burden.

It is perhaps unsurprising that there is much less evidence concerning the minimum number of days required to estimate PA in dogs given the paucity of studies assessing PA in dogs generally. Dow *et al.* (2009) evaluated the optimal sampling interval in a wide variety of dog breeds and suggested that a monitoring period of at least seven days may be most appropriate in dogs as this would guarantee the inclusion of weekend days which in their study were more variable compared to weekdays. Yam *et al.* (2011) assessed reliability in dogs of varying age and breed. They found that reliability coefficients of accelerometry output ranged from 0.9 for as little as three days of monitoring to 0.93 for seven consecutive days of monitoring, and in contrast to Dow *et al.* (2009), that accelerometry output was not significantly different on weekdays compared to weekends.

In light of the inconsistencies in minimum monitoring periods required to estimate habitual PA in children, adults and dogs, a reasonable approach would be to ask that all participants wear an accelerometer for seven consecutive days. However, there are likely to be some instances of poor compliance with such an approach, considering that acceptable reliability coefficients have been determined for surprisingly few days in each population, data from participants who do not wear the accelerometer for the full monitoring period can still be included in analysis providing the accelerometer has been worn for at least three days.

1.3.4.6 What constitutes a valid accelerometry day?

Another important factor to consider when using an accelerometer to measure PA is deciding the minimum number of hours that will constitute a valid day. In order to capture complete PA patterns it would be necessary to have accelerometers attached for 24 hours each day. This obviously places a significant burden on study participants and increases the risk of poor compliance with the study protocol. In an effort to find a compromise between accuracy of PA measurement and compliance, studies commonly employ a reduced sampling period, asking that accelerometers be worn during waking time only. However, there is a chance that some participants may only wear an accelerometer for part of this waking period, so researchers must decide on a minimum number of hours per day to employ in their study. Studies have used a range of criteria to define a valid day although 10 hours per day as a minimum has become popular, especially in adults, despite a lack of empirical evidence. However, there are some published studies that have tackled this issue.

Penpraze *et al.* (2006) calculated the reliability of accelerometer counts from as little as three hours wear time per day up to 13 hours per day in a sample of 5-6 year old children. The reliability coefficients remained stable from 3 hours per day up to 10 hours per day, but not for more than 10 hours per day, suggesting that minimum daily wear time had less influence on reliability than the minimum number of days. In a similar fashion, Mattocks *et al.* (2008) found that reliability coefficients remained constant between seven and 10 hours per day in 11 year old children. In a more recent study, Rich *et al.* (2013) calculated reliability coefficients for one hour of accelerometer wear up to 14 hours per day in 7 year old children. The reliability coefficient for a minimum of six hours per day was 0.9 as long as the accelerometer was worn for a minimum of four days. Reducing the number of days wear to three only reduced the reliability coefficient to 0.87 for wear time of at least six hours per day. Reliability increased as the number of hours and days increased up to 10 hours per day for 10 days.

At the time of designing the study protocol for Chapter 6 in this thesis a minimum of 10 hours per day of accelerometer wear time was considered appropriate in adults (Troiano *et al.*, 2008). Since then, Herrmann *et al.* (2013) have shown that the number of minutes spent in light and moderate intensity, but not vigorous intensity PA, are significantly different between 10, 11 12, 13 and 14 hours per day of accelerometer wear time in adults. When compared with 14 hours per day of wear time, using 10 hours per day resulted in almost 30% less time spent in light and moderate intensity PA. Although including days with less than 14 hours of data may underestimate PA based on this data, a minimum of 10 hours per day has long been considered a valid day and is the most widely used reference point in adult studies (Trost *et al*., 2005). Using 14 hours per day as a minimum may also increase the amount of data that have to be removed from analysis if a considerable amount of participants do not adhere to the protocol, which may be an issue especially in small studies.

There are no published studies assessing the minimum number of hours per day of accelerometer wear time required to represent habitual PA in dogs. The usual protocol has been to ask owners to ensure that accelerometers are attached to the dogs collar at all times, except during torrential rain or when swimming or bathing, facilitating the measurement of activity in dogs over 24 hours. However, some dogs do not wear a collar at night. Including night time wear is unlikely to have a significant effect on the amount of time spent in PA but will significantly decrease the mean accelerometer cpm due to the amount of inactivity during sleep. The next best approach would be to ask that owners made sure that the accelerometer was attached during waking hours only. However, this would require that owners were awake either before or at the same time as their dog, and went to sleep at the same time or after their dog. This may not be practical for all owners and is likely to introduce extra burden on them. The most suitable approach, and that which is used in this thesis, is to ask that the accelerometer is attached at all times, except for those dogs who will not wear a collar at night, but to use day time wear only in the analysis. Selecting the data representing the time period between 6am and 11pm is sufficient to represent habitual PA in dogs, and reduces the burden placed on owners of detaching and reattaching the accelerometer each day.

1.4 The role of physical activity in health

The idea that PA is beneficial for health is not a new one. It was Hippocrates (460-370 B.C.) who wrote “eating alone will not keep a man well; he must also take exercise”

(Hippocrates, 1953). Modern day research on PA and health owes much to the early work of epidemiologists Jeremy Morris and Ralph Paffenbarger. Morris *et al.* (1953) tested the hypothesis that deaths from coronary heart disease were less common in men with physically active jobs compared to those in less active jobs. They found that sedentary drivers of London buses were more likely to die of coronary heart disease than bus conductors who climbed around 600 stairs per day. In the Harvard Alumni Health Study, a large cohort study assessing the effect of PA on health, Paffenbarger *et al.* (1986) reported that deaths due to cardiovascular disease (CVD) reduced with increasing weekly energy expenditure up to 3500 kcal per week. Since the early studies of Morris and Paffenbarger there has been a significant increase in the number of studies focussing on PA and health, driven by the knowledge that physical inactivity is a leading cause of preventable death (World Health Organization, 2013b). This section is not intended to be a comprehensive account of the academic literature relating to PA and health, but rather a summary of the link between PA and health and its importance. For further reading on the topic the reader is referred to the U.S. Department of Health and Human Services Physical Activity Guidelines Advisory Committee Report (2008), Warburton *et al.* (2010) which is an excellent review on the benefits of PA on health in adults, and Start active, stay active: a report on physical activity from the four home countries' Chief Medical Officers (2011) which outlines the volume, duration, and frequency of PA required to achieve health benefits across all age groups.

1.4.1 Overweight and obesity in humans and dogs

It is estimated that by 2030 1.35 billion adults globally will be overweight and 573 million will be classed as obese (Kelly *et al*., 2008). Furthermore, current estimates suggest that 31% of Scottish children aged 2-16 are either overweight or obese (Bromley *et al*., 2012). Obesity and overweight are commonly measured using the Body Mass Index (BMI), which is calculated by dividing a person’s body weight in kg by the square of their height in metres. Adults are considered to be overweight when BMI is between 25 kg/m^2 and 29.9 kg/m^2, and an adult who has a BMI of greater than 30 kg/m^2 is considered obese. In children, BMI needs to be adjusted for age and gender based on UK 1990 growth reference charts. Children who are above the 85^{th} percentile based on the 1990 data are considered overweight, whereas those above the 95^{th} percentile are considered obese. Both overweight and obesity result from a prolonged imbalance between energy intake and energy expenditure.

The relationship between PA and overweight and obesity has been extensively studied in both adults and children. A recent review found that of 31 observational studies in children, the majority reported weak to moderate associations between PA and overweight/obesity (Janssen and LeBlanc, 2010). However, when the studies assessing PA objectively were assessed separately from those that assessed PA using self- or parental-report, associations were stronger. For example, in a sample of 5,500 12 year old children Ness *et al.* (2007) reported a significant negative association between PA and fat mass, and that less active children were more likely to be obese. In a study of the change in body mass over 10 years in 2,564 men and 2,695 women in Finland it was found that those who were inactive throughout the study, or those who became less active during the study gained weight (Haapanen *et al*., 1997). The most active groups either lost or maintained weight. In another study of the change in body mass over 10 years, Williamson *et al.* (1993) reported that inactive men and women were three to four times more likely to gain weight than physically active participants. It has even been suggested that the association between PA and overweight/obesity may be bidirectional, i.e. that physical inactivity may lead to weight gain, and overweight/obesity may lead to physical inactivity (Ekelund *et al*., 2008, Bauman *et al*., 2012).

Although the association between PA and overweight/obesity is well established the available evidence suggests that increased PA alone cannot lead to substantial weight loss. In a 12 month RCT of the effect of PA on body weight in adults, participants in the intervention group were asked to engage in 300 minutes of moderate intensity PA per week (McTiernan *et al*., 2007). Women in the intervention group lost 1.4kg on average compared to an increase of 0.7kg in the control group. For men, the average weight loss was 1.8kg in the intervention group compared to an increase of 0.1kg in the control group. Donnelly *et al.* (2003) carried out a 16 month RCT and reported that men in the exercise group lost, on average, 5.2kg compared to 0.5kg in the control group. Women in the exercise group gained 1.6kg on average; but this was less than those in the control group (2.9kg). Although the male participants in the study by Donnelly *et al.* lost a significant amount of body weight the amount of PA they were asked to engage in was relatively high (225 minutes of moderate intensity PA per week) and was carried out under controlled settings in a laboratory. Whether such decreases in body weight are achievable when PA is unsupervised is debatable. Studies which have asked adult participants to engage in 150 minutes or less of PA per week have generally reported no significant change in body weight (Dengel *et al*., 1998, Murphy *et al*., 2002, Campbell *et al*., 2007a). A review of the health benefits of PA in children concluded that the pooled effect size of interventions designed to change % body fat was -0.40, and the effect sizes for studies that found significant improvements in either % body fat, BMI, or body weight were small (<0.50) (Janssen and LeBlanc, 2010).

However, systematic reviews of the effect of PA on the prevention of weight gain, weight loss, and the prevention of weight regain in humans, have consistently concluded that more PA is beneficial (Fogelholm and Kukkonen-Harjula, 2000, Donnelly *et al*., 2009, Janssen and LeBlanc, 2010, O'Donovan *et al*., 2010). It is likely that the dose of PA required will vary from person to person (Saris *et al*., 2003) and that combined diet and PA interventions will work best for weight loss providing that energy restriction is not severe (Donnelly *et al.*, 2009).

Although studies assessing the impact of PA on weight loss in dogs are lacking, PA is recommended for the treatment of obesity (German, 2010) and published weight loss interventions in dogs typically include a PA component (German *et al*., 2007, Wakshlag *et al*., 2012). However, consultations at veterinary practice will typically concentrate on diet rather than PA. Wakshlag *et al.* (2012) reported that physically active dogs (those walking > 7250 steps per day) were able to consume around 20% more calories per day than inactive dogs, while still exhibiting the same rate of weight loss as the inactive dogs during a combined PA and calorie controlled weight loss programme. It is likely that the relationship between PA and obesity in dogs will be better understood in the coming years, as interest in this field grows, and methodological advancements for measuring PA are made. In the 1980’s it was already estimated that 25-45% of domestic dogs attending veterinary clinics were obese (Hand *et al*., 1989). More recent evidence reports similar proportions of overweight and obese dogs, with studies showing that 15-60% of dogs are overweight or obese (McGreevy *et al*., 2005, Colliard *et al*., 2006, Lund *et al*., 2006, Holmes *et al*., 2007, Courcier *et al.*, 2010). Thus establishing whether there is a link between low levels of PA and overweight/obesity in dogs is important.

1.4.2 Cardiovascular disease in humans and dogs

It is estimated that in the year 2015, 20 million people will die as a result of CVD (Deaton *et al*., 2011). A number of epidemiologic studies have shown that low PA is a risk factor for CVD and CVD mortality (Paffenbarger *et al.*, 1986, Rodriguez *et al*., 1994, Lee *et al*., 2003, Barengo *et al*., 2004). A review of prospective cohort studies incorporating a total of 726,474 participants found that the incidence of CVD is reduced by 33% in physically active adults (Warburton *et al.*, 2010). When the association between PA and stroke is assessed independently of other CVD the risk reduction has been estimated to be at least 25-30% in the most physically active adults (Katzmarzyk and Janssen, 2004, Warburton *et al.*, 2010). There is evidence that even small amounts of PA are inversely associated with CVD mortality, Wisloff *et al.* (2006) reported that a single weekly bout of vigorous intensity PA reduced the risk of death from CVD in both men and women.

There are a number of associations between PA and CVD risk factors in children. It has been shown that, in adolescents, blood pressure is lower in those with higher maximal oxygen uptake (VO_{2max}) (Andersen, 1994, Nielsen and Andersen, 2003). In an RCT involving 67 9-11 year old children Hansen *et al.* (1991) showed that an 8 month aerobic training program can significantly reduce systolic and diastolic blood pressure in both normotensive and hypertensive children. In the hypertensive group systolic blood pressure fell by 4.9 mm Hg and diastolic by 3.8 mm Hg. Andersen *et al*. (2011) reviewed the effects of PA on blood pressure in all published intervention studies and found that effect sizes were in excess of 0.8 in all. There is also some evidence that blood lipid profiles can be improved with PA. A Cochrane review of RCT's that aimed to improve blood lipids concluded that, although interventions have had no effect on total cholesterol or low density lipoprotein cholesterol (LDL-C), small increases in high density lipoprotein cholesterol (HDL-C) and reductions in triglycerides can be achieved (Dobbins *et al*., 2009). Furthermore, results of the European Youth Heart study showed a strong inverse relationship between fitness and metabolic risk score, a composite score of fasting insulin, glucose, triglycerides, total cholesterol and HDL-C, blood pressure and body fat (Andersen *et al.*, 2006)

Although it has been suggested that regular PA offers cardiovascular benefits in dogs (German, 2010), observational and experimental studies showing an association between PA and CVD risk and/or mortality are lacking. Despite this, it has been shown that PA can improve coronary artery function in dogs (Wang *et al*., 1993, Sessa *et al*., 1994). Pape *et al.* (1986) reported that untrained greyhounds had significantly higher systemic vascular resistances than trained greyhounds. Furthermore, Montoya *et al.* (2006) found a strong relationship between body condition score (BCS; a method for distinguishing between weight status in dogs) and systolic and diastolic blood pressure. If increased PA can have a positive influence on weight status in dogs then it is therefore possible that it may also reduce blood pressure, although there are no published studies confirming this.

1.4.3 Type 2 Diabetes in humans

Type 2 diabetes is a condition which can have significant long-term health impacts on those diagnosed with the disease. It is estimated that by the year 2030 7% of the global population of adults (387 million) will have type 2 diabetes (Shaw *et al*., 2010). It has been reported that type 2 diabetes cost the UK £21.8 billion pounds for the year 2010/2011 (Hex *et al*., 2012). PA is recommended as an important tool for the prevention and management of type 2 diabetes, and has been shown to significantly improve blood glucose levels (Colberg *et al*., 2010). Chudyk *et al.* (2011) conducted a review of published articles assessing the effects of aerobic or resistance exercise on cardiovascular risk markers in patients with type 2 diabetes and found that aerobic exercise significantly improved HbA(1c), a measure of average blood glucose levels, by -0.6%. Avery *et al.* (2012) reviewed published behavioural interventions designed to increase PA in adults with type 2 diabetes and found that increased PA led to clinically significant improvements in HbA(1c) (weighted mean difference between control and intervention groups -0.32%) and BMI (weighted mean difference between control and intervention groups -1.05 kg/m^2).

Although commonly called adult-onset diabetes, an increase in the prevalence of type 2 diabetes in children and youth has been reported (Chen *et al*., 2012), and it has been reported that early onset of type 2 diabetes is associated with increased risk of mortality (D'Adamo and Caprio, 2011). There are no published RCT's that address whether PA prevents type 2 diabetes in children, however the TODAY Study Group (2012) carried out an RCT comparing the effects of three different treatments on glycaemic control in children and youth aged 10-17 with type 2 diabetes. They reported that the treatment failure rate in the group receiving metformin alone was higher than the group receiving metformin and a lifestyle intervention (combined dietary restriction and 200 - 300 mins of MVPA per week), but that this difference was not significant. Furthermore, a number of studies have shown an association between PA and insulin resistance/insulin sensitivity in children. Ferguson *et al.* (1999) reported that 160-200 minutes per week of exercise training for four months resulted in improved glucose tolerance in 7-11 year old obese children, and that any benefits disappeared when children ceased the training regimen. In addition Danielsen *et al.* (2011) reported that screen time, and therefore, sedentary time was significantly associated with insulin resistance in 7-13 year old boys and girls.

1.4.4 Cancer in humans

Cancer is a major cause of death worldwide. Globally, it is estimated that 32.6 million people were living with cancer in 2012 and around 8.2 million people died of cancer in the same year (GLOBOCAN, 2012). There are more than 200 types of cancer but the ones most commonly associated with PA are colon cancer, breast cancer, endometrial cancer, lung cancer, and prostate cancer (Friedenreich *et al*., 2010). It is a group of diseases that affect adults, children and dogs; but as yet there is no evidence that adequate PA prevents cancer in dogs.

There is considerable evidence that PA has a beneficial effect on the risk of colon cancer in adults. Reviews on the association between PA and colon cancer have consistently reported that the most physically active men and women are 20-25% less likely to develop colon cancer than the least active members of the adult population (Samad *et al*., 2005, Harriss *et al*., 2009, Wolin *et al*., 2009). Similarly, there is around a 25% risk reduction for developing breast cancer when comparing the most active women with the least active (Monninkhof *et al*., 2007), with risk reduction greatest in those over the age of 50 (Friedenreich and Cust, 2008). A review of 20 cohort and case-control studies assessing the association between PA and endometrial cancer risk found that 8 out of 10 high quality studies included in the review reported a risk reduction of greater than 20% for the most active participants (Voskuil *et al*., 2007). There is also some evidence that PA has possible beneficial effects on the risk of developing lung cancer, it has been reported that a significant inverse relationship between PA and lung cancer risk exists (Tardon *et al*., 2005), although when risk is assessed by smoking status the risk reduction is weaker among non-smokers (Leitzmann *et al*., 2009). There appears to be a small reduction in risk of developing prostate cancer in the most physically active men (Liu *et al*., 2011), although it remains unclear what type of PA and during which time periods in life are most beneficial.

Increased PA is also associated with better quality of life in cancer survivors. Four RCT’s have assessed the effect of PA on insulin and insulin-like growth factors, a significant confounder on breast cancer risk, in survivors of the disease (Fairey *et al*., 2003, Schmitz *et al*., 2005a, Irwin *et al*., 2009, Janelsins *et al*., 2011). All four studies reported that serum concentrations of insulin-like growth factor-I either decreased insignificantly or remained constant in women randomised to PA interventions, compared to controls. Although when these data were reviewed in a recent meta-analysis of RCT’s assessing the role of PA in cancer survivors, PA was associated with significant reductions in insulin-like growth factor-I (Fong *et al*., 2012). Fong *et al*. (2012) also reported that when data from RCT's assessing the effect of PA on body weight in cancer survivors was pooled, body weight was significantly reduced in those randomised to a PA intervention compared to controls, although this difference was small and not biologically significant (intervention-control difference of -1.1kg). There is also some evidence that PA is associated with reduced fatigue and depression in adult cancer survivors (Cramp and Daniel, 2008, Kaltsatou *et al*., 2011).

It has been reported frequently that child survivors of cancer are less physically active than their healthy peers (Reilly *et al*., 1998, Tillmann *et al*., 2002, Winter *et al*., 2009). This is thought to have a further negative impact on the already harmful side effects of cancer treatment, including treatment related fatigue and muscle atrophy. Oldervoll *et al.* (2003) reported that 20 weeks of 40-60 minutes of MVPA reduced fatigue in child survivors of Hodgkins disease who also suffered from chronic fatigue at baseline. In a 16 week PA intervention adolescent cancer survivors randomised to an exercise group significantly increased total PA by around 25 MET hours per week by the mid-point of the intervention (eight weeks). However, the difference was not significant and decreased to 18 MET hours by the end of the intervention (16 weeks) (Keats and Culos-Reed, 2008). By the end of the intervention those in the exercise group had also significantly increased their flexibility and decreased general fatigue as measured by PedsQL. San Juan *et al.* (2007) reported that a 16 week combined aerobic and resistance training programme (90-120 minutes three times per week) resulted in significant improvements in physical fitness, muscle strength and functional mobility in 4-7 year old survivors of acute lymphoblastic leukaemia. Further research of the effects of PA in paediatric cancer survivors is ongoing, although it appears that there is increasing evidence that regular PA can improve health status and quality of life in children with cancer, and possibly counteract some of the adverse effects of treatment (San Juan *et al*., 2011).

1.4.5 Bone health and PA in humans and dogs

As humans age, bone strength decreases and bones become more fragile, leading to an increase in the likelihood of fractures (Rachner *et al*., 2011). It is estimated that by the year 2050 there will be an almost four-fold increase in the incidence of hip fractures as a result of osteoporosis, compared to 1990 estimates (Cooper *et al*., 1992). Strategies that help prevent the development of osteoporosis are clearly important, and there is strong evidence of an association between PA and bone health in humans (Warburton *et al*., 2010).

Robitaille *et al.* (2008) reported in a survey of 8073 women aged 20 years or over that the incidence of osteoporosis was greater in those engaging in no PA compared to those who did perform PA, and the greatest risk reduction was found in women who engaged in a high amount of PA (more than 30 MET hours per week). A number of systematic reviews have shown that both aerobic and resistance based exercise have benefits on bone health, particularly in post-menopausal women (Kelley, 1998, Kelley *et al*., 2000, Bonaiuti *et al*., 2002). Furthermore, it has been shown that strength and balance training can reduce fall risk score by up to 57% in elderly women compared to non exercising controls (Liu-Ambrose *et al*., 2004), which therefore reduces the risk of fracture as a result of falling. Gregg *et al.* (2000) reviewed the evidence of the association between PA and fracture risk and found that physically active adults can reduce the risk of hip fracture anywhere from 20-40% compared to the least physically active. Similarly, Moayyeri (2008) reported that MVPA was associated with a reduction in risk of hip fracture of 45% for men, and 38% for women. The exact type, duration and intensity of PA required to reduce risk of osteoporosis and fractures is unclear, although moderate amounts may be sufficient (Feskanich *et al*., 2002, Robitaille *et al*., 2008).

Although osteoporosis is a disease typical of old age, PA for the prevention of osteoporosis is not only important in adulthood, as evidence suggests that PA in childhood does not only lead to bone mass accrual but has benefits in reducing the risk of developing the disease in adulthood. Evidence from observational studies shows that physically active children have higher bone mineral content (BMC) and bone mass accrual than less active children (Gunter *et al*., 2012). Furthermore, Fuchs *et al.* (2001) assessed the effect of high impact jumping exercises on bone mass in 89 5-10 year old children and found that, in those randomised to the exercise group BMC was 4.5% and 3.1% greater in the femoral neck and lumbar spine bones, respectively, after 7 months of PA compared to controls. Sardinha *et al.* (2008) assessed the relationship between the intensity and duration of PA, measured by accelerometry, on bone strength in 9 year old boys and girls. They found that girls and boys who engaged in around 25 minutes or more of vigorous intensity PA per day had improved femoral neck strength compared to those who performed the least amount of vigorous PA (<12 minutes per day for boys, and <eight minutes per day for girls). Scerpella *et al.* (2011) assessed whether benefits in BMC and bone density gained during childhood are sustained in female ex gymnasts four or more years after training cessation.

They reported that from 4-9 years post training cessation, BMC and bone density was higher at the distal radius in ex gymnasts who had ceased training compared to non gymnast controls, even though there was no difference in PA levels between the two groups during this time period. This suggests that benefits in bone health gained from increased PA in childhood have a lasting effect, even if PA is reduced in subsequent years.

Although there is no evidence to suggest that increased PA is likely to improve bone health in dogs there is strong evidence of an association between PA and bone health in humans (Warburton *et al.*, 2010). This is mediated by weight bearing exercise that increases the mechanical load on bone, promoting an increase in bone mineral density (Kelley *et al.*, 2000). Similar weight bearing exercise in dogs may also increase bone mineral density and therefore lead to improvements in bone health. Future research is needed to determine whether this is the case.

1.4.6 Mental health and physical activity in humans and dogs

Poor mental health is a significant contributor to the global burden of disease. Depression, a prevalent mental disorder, is estimated to affect 340 million people globally (Kruijshaar *et al*., 2005), and approximately 10-20% of children are affected by some mental health disorder (Kieling *et al*., 2011). There is evidence to suggest that regular PA is associated with mental well-being and reduced symptoms of some mental health disorders in children and adults.

In a recent review that assessed the association between PA and mental health in children and adolescents it was reported that evidence from RCT's suggest that PA interventions are beneficial in reducing the symptoms of depression but intervention designs have been generally of low quality (Biddle and Asare, 2011). Another recent review found that the pooled effect size for reducing depression in PA interventions was -0.41 ($p<0.01$) (Ahn and Fedewa, 2011), indicating that increased levels of PA reduces symptoms of depression in children. The same review concluded that increased PA also significantly reduced anxiety ($d=-0.35$, $p<0.05$) and increased self-esteem ($d=0.29$, $p<0.01$) in children taking part in RCT's. Few of the studies included in the review reported frequency, type and duration of the PA intervention and so it is difficult to say how much and what type of PA is required for beneficial effects on mental health. However, it may be that vigorous intensity PA has the greatest effect (Ahn and Fedewa, 2011).

Much more research on the association between PA and mental health has been carried out on adults. Twenty-eight prospective cohort studies assessing the association between PA and risk of depression were reviewed in the US Physical Activity Guidelines Advisory Committee Report (2008). In these studies physically active people were 25-40% less likely to show signs of depression than those who were inactive. It has also been reported that PA is useful in treating the symptoms of depression in adults. A recent Cochrane review on the effect of PA in treating depression reported that PA interventions had a moderate clinical effect on depression symptoms compared to control (Cooney *et al*., 2013). There is also some evidence that the odds of developing an anxiety disorder are significantly decreased in young adults who regularly engage in PA compared to inactive peers (Strohle *et al*., 2007), and a small number of studies have reported that PA can reduce the symptoms of anxiety in adults (Physical Activity Guidelines Advisory Committee, 2008).

Although there are no published studies showing that increased PA is associated with improved mental health in dogs it has been suggested that inadequate PA may be a contributor to anxiety disorders such as separation anxiety in dogs (Sherman and Mills, 2008). The American Society for the Prevention of Cruelty to Animals (ASPCA) recognises that regular PA is important for the well-being of dogs, and that the type and amount will depend on breed and age (ASPCA, 2014).

1.5 Physical activity recommendations and current levels in humans and dogs

The amount of PA that humans are recommended to do is age-dependent. In 2010 the first UK wide guidelines were published (Department of Health, 2011). These guidelines recommend that children and young people, those aged between 5 and 18 years old, should engage in at least 60 minutes and up to several hours of MVPA per day. The guidelines also state that children should engage in vigorous intensity activities on at least three days per week and that sedentary time should be minimised where possible. The World Health Organisation (WHO) also recommend that children should engage in at least 60 minutes of MVPA per day while also suggesting that engaging in PA for greater than 60 minutes per day will likely provide additional health benefits (World Health Organization, 2010). It is likely that meeting these recommendations will result in improvements in cardiovascular health, bone health, cardiovascular and muscular fitness and will help maintain healthy weight in children.

The recommended amount of PA for adults aged 19-64 is less than that for children. The new UK wide guidelines recommend that adults engage in 150 minutes of moderate intensity PA per week, and that bouts of activity should be at least 10 minutes in duration (Department of Health, 2011). Alternatively adults can get comparable health benefits by engaging in 75 minutes of vigorous intensity PA per week. Similar to the guidelines for children, the guidelines for adults also state that sedentary time should be minimised. Adults who engage in this amount of activity are likely to reduce their risk of diseases such as coronary heart disease, stroke, and type 2 diabetes, while maintaining a healthy weight and the ability to perform everyday tasks. They will also likely reduce symptoms of anxiety and depression and improve their self-esteem. Engaging in PA for longer, e.g. 300 minutes of moderate intensity activity per week, may result in additional health benefits over the recommended minimum of 150 minutes per week (World Health Organization, 2010).

The amount and type of PA required to gain health benefits is likely to depend on both age and breed in dogs, but there are no published studies that describe the specific PA needs of dogs. The Kennel Club, which is the largest organisation in the UK concerned with dog training, welfare, and health, advise that although puppies require PA this is likely to be less than fully grown dogs (The Kennel Club, 2013a). This may be as little as 15 minutes, twice per day, depending on the age of the puppy. The most common breed of dog in the UK is the Labrador Retriever (The Kennel Club, 2011). A fully grown Labrador is a large dog which may require more than two hours of PA per day (The Kennel Club, 2013b), whereas a Cocker Spaniel, which is a medium sized dog and the second most common dog in the UK may only require up to one hour per day of PA (The Kennel Club, 2013c). Despite the lack of studies measuring PA objectively in dogs it is likely regular PA will help maintain a healthy body weight, will improve cardiovascular risk profile and enhance the owner-pet bond (German, 2010).

1.5.1 Do humans and dogs meet these guidelines?

The level of PA in children and adults in the UK is measured regularly, by both subjective and objective methods, and reported levels of PA vary widely depending on the surveillance method used. A 2008 study comparing the amount of PA measured by the Health Survey for England Physical Activity Questionnaire with PA measured by accelerometry in a cohort of 130 6-7 year old children found that, the mean time spent in MVPA was 146 minutes per day using the questionnaire but only 24 minutes per day using the accelerometer (Basterfield *et al*., 2008). The most recent Scottish Health Survey, which uses questionnaires to measure PA, showed that 73% of Scottish children (76% of boys and 70% of girls) met the PA guidelines of at least 60 minutes of MVPA per day (Bromley *et al.*, 2012). However, the Health Survey for England 2012 found that only 21% of boys and 16% of girls aged 5-15 met the recommended levels of PA when measured using a questionnaire (Craig and Mindell, 2013). When PA is measured using accelerometry the proportion of participants meeting PA guidelines depends on the accelerometer cut-point used to define MVPA. When using the threshold of 2000 accelerometer cpm Steele *et al.* (2009) found that in a sample of 1862 10 year olds in England, 69% of children (82% of boys and 59% of girls) met the guidelines. Using the same threshold Owen *et al.* (2009) found that 76% of boys and 53% of girls in a sample of 2071 10 year olds accumulated at least 60 minutes of MVPA per day. When the threshold for MVPA is set higher, at 3600 accelerometer cpm, the proportion of children meeting current guidelines is significantly reduced. Riddoch *et al.* (2007) found that only 5% of boys and less than 1% of girls were sufficiently active in a sample of 5595 12 year olds. Therefore, due to the inconsistencies in measurement methods across studies it is difficult to say exactly how many children meet the UK guidelines for PA, but it is clear that a significant proportion of children in the UK do not engage in the recommended amount of PA.

There are also a substantial proportion of UK adults who do not meet current PA guidelines of 150 minutes of moderate intensity PA per week. The 2012 Scottish Health Survey found that 62% of adults (67% of men and 58% of women) were sufficiently active (Bromley *et al.*, 2012). The self-reported levels of PA published in the Health Survey for England 2012 are similar, with 67% of men and 55% of women meeting the guidelines (Craig and Mindell, 2013). Surveillance studies of PA levels among UK adults using objective measures such as accelerometry are scarce. However, the Health Survey for England also includes estimates of PA measured by accelerometry and suggests that when measured objectively only 6% of men and 4% of women achieved the recommended levels (Craig and Mindell, 2013). In the United States it has been estimated that only 3.5% of adults aged 20-59 (3.8% of men and 3.2% of women) accumulate at least 150 minutes of moderate intensity PA per week in bouts of 10 minutes or longer, which count towards the WHO guidelines (Troiano *et al.*, 2008). These data are similar to those published in the Health Survey for England and suggest that the vast majority of adults are not sufficiently active when PA is measured objectively.

To date there are no published studies that quantify the amount and type of PA in dogs using objective methods; those studies which have been published have relied on subjective measures and it is therefore difficult to estimate how many dogs are sufficiently active. The situation is further compounded by the fact that dog owners are unable to recall how active dogs are in their absence, some dogs may be allowed to exercise in a garden while the owner is not at home and may do some PA in that time. For the majority of dogs though PA is likely to be determined by their owner and how often they are walked and whether this is on or off lead. Estimates from studies using subjective measures such as questionnaires or telephone interviews suggest that dogs are walked anywhere between one hour per week to more than one hour per day (Bauman *et al*., 2001, Sallander *et al*., 2010). Considering that a substantial proportion of the UK population do not meet PA recommendations when measured objectively it is likely that dogs whose PA levels are largely determined by their owner are also typically inactive. Furthermore, total PA in humans is likely to be made up of individual components such as walking for recreation, walking to work, or participation in sport. Dog walking may therefore only be a small part of PA for some owners and even some dog's belonging to owners who do meet the guidelines may not be sufficiently active.

1.6 Dog ownership and physical activity

Generally, the most physically active members of the population gain the greatest health benefits, whereas those at the lower end of the PA spectrum have increased risk of developing a wide range of diseases (Physical Activity Guidelines Advisory Committee, 2008, O'Donovan *et al.*, 2010). Despite this, objectively measured PA levels are low in both children and adults (Basterfield *et al.*, 2008, Craig and Mindell, 2013). Systematic reviews of interventions designed to promote PA have concluded that intervention effects have been poor to modest (Conn *et al.*, 2011, van Sluijs *et al*., 2011). There is therefore an urgent need for novel approaches to PA promotion. Researchers have long suspected that pet ownership is good for human health (Friedmann *et al*., 1980). However, improved health outcomes are more general than specific and the mechanisms for improved health are unclear (McNicholas *et al*., 2005). In recent years, a number of observational studies have shown an association between dog ownership and PA levels suggesting that using pet dogs as the agent of lifestyle change in PA interventions may be a useful strategy to promote increased PA in humans. These studies are described in the following section.

1.6.1 Observational studies comparing physical activity levels of dog owners versus non-owners

The first study to report that dog owners were more physically active than non-owners was published in 1996 (Dembicki and Anderson, 1996). The authors reported that, when measured subjectively, elderly dog owners walked 38 minutes per day on average compared to 21 minutes per day in non-owners. In Australian adults aged 25-64 years, it has been reported that dog owners walked 120 minutes per week on average compared to 102 minutes per week in non-owners, although this difference was not significant (Bauman *et al.*, 2001). However, when dog owners who did not engage in regular sustained walking (1 or more hours per week) were removed from the analysis dog owners were significantly more active than non-owners. Comparable findings were reported by Schofield *et al.* (2005), dog ownership was not associated with total PA, but dog owners who regularly walked the dog were more likely to walk for leisure than non-owners. Cutt *et al.* (2008b) reported that Australian adult dog owners walked 150 minutes per week on average compared to 111 minutes for non-owners. Brown and Rhodes (2006) found that Canadian adults who were dog owners reported significantly more walking (300 minutes per week) than non-owners (168 minutes per week) and when dog walking minutes were subtracted from total walking minutes, dog owners walked less and were less active than non-owners. Ball *et al.* (2007) reported that 73% of adult female participants who owned a dog engaged in leisure time PA compared to 61% of non-owners. Yabroff *et al.* (2008) investigated the association between dog ownership and PA in Californian adults and found that dog owners walked 21 more minutes per week for leisure than non-owners ($P < 0.01$), and approximately 10 minutes more per week in total ($P < 0.01$). In a study of the relationship between dog ownership and PA in Japanese adults, Oka and Shibata (2009) found that dog owners engaged in 12.4 MET hours per week compared to 10.5 MET hours per week in non-dog owners (but who owned another type of pet) and 9.8 MET hours per week in those who owned no pets at all.

A number of studies have also reported that dog owners are more likely to meet PA guidelines than non-owners. Giles-Corti and Donovan (2003) assessed the correlates of walking in Australian adults and found that the odds of walking more than 180 minutes per week were 58% higher in dog owners compared to non-owners. In a survey of walking behaviours in US adults aged 45-54 years old, Moudon *et al.* (2007) found that the odds of walking more than 150 minutes per week were 99% higher in dog owners compared to non-owners. Coleman *et al.* (2008) reported that dog walking was associated with more adults meeting U.S. national guidelines for MVPA than non-owners (53% versus 46%), when PA was measured objectively using an accelerometer. More recently, Reeves *et al.* (2011) have shown that dog walking in adults was associated with an odds ratio of 1.34 for engaging in 150 minutes per week of MVPA compared to non-owners, and reported that the odds of doing any leisure time PA were 69% higher in dog walkers compared to non-owners.

Much less of this type of research has been carried out in children and young people. However, there are some published studies that suggest there is a relationship between dog ownership and PA in these groups. One Australian study examined dog walking in children and found that despite the fact that 41% of children who owned a dog did not walk with it at all, dog ownership was associated with 29 minutes more PA per week in young girls (5-6 years old), but no association was found between dog ownership and PA in other children (Salmon *et al*., 2010). A recent UK study suggests that children in dog owning families take significantly more steps per day (difference of 357 steps per day) than those in families without a dog (Owen *et al*., 2010). Similarly, Sirard *et al.* (2011) reported that American adolescents who own a dog participate in more MVPA (approximately three minutes per day) than those who do not own a dog. More recently Christian *et al.* (2013a) reported that children in dog owning families walked for 29 minutes more per week than children who did not own a dog and engaged in 142 minutes more of total PA per week. Children who owned a dog were also 49% more likely to engage in at least 60 minutes of MVPA per day. The results from the studies by Salmon *et al.*, Owen *et al.* and Sirard *et al.* represent only a modest association between dog ownership and PA, but must be considered within the appropriate context. First, in the study by Salmon *et al.* (2010) it is possible that a lack of association between dog walking and PA in boys may be due to the way they interact with their dog. As the authors note they may engage more in activities such as playing fetch rather than actual dog walking. Second, the studies by Owen *et al.* (2010) and Sirard *et al.* (2011) did not examine actual dog walking behaviour. It is reasonable to assume that the responsibility of walking the dog may rest with parents; in that case it is likely that any PA children currently participate in with their dog will contribute less to total PA than that for their parents. Even so, considering that even a modest increase in PA can result in significant health benefits (Lee *et al*., 1999) the potential benefits of dog ownership in children should not be overlooked.

1.6.2 Prevalence of dog walking

Despite the evidence that dog ownership may be related to PA a number of studies have shown that a considerable proportion of dog owners do not walk with their dog. Among Australian adults it has been reported that the proportion of dog owners who walked their dog at all ranged from 41% to 78% (Bauman *et al.*, 2001, Schofield *et al.*, 2005, Cutt *et al.*, 2008a, Cutt *et al.*, 2008b, Salmon *et al.*, 2010). In the US the reported prevalence of dog walking ranges from 28% to 80% (Suminski *et al.*, 2005, Ham and Epping, 2006, Coleman *et al.*, 2008, Hoerster *et al.*, 2011). Harris *et al.* (2009) found that the prevalence of dog walking among elderly adults from the UK was 22%. Salmon *et al.* (2010) reported that 41% of children in dog owning families never walked their dog, and 32% of children never or rarely walked their dog as a family.

Among those owners who do walk their dog there is some evidence that they are more physically active than those who own a dog but do not walk it. Thorpe *et al.* (2006b) showed that among elderly dog owners, those who walked their dog regularly were more likely to engage in recommended levels of PA than owners who did not walk regularly, but no more likely than non-owners who participate in regular bouts of walking. Coleman *et al.* (2008) reported that only 33% of dog owners who did not walk their dog engaged in 150 minutes per week of MVPA, compared to 53% of regular dog walkers. Cutt *et al.* (2008a) found that more Australian adults who walked their dog met public health guidelines for PA (150 minutes of PA per week) than dog owners who do not walk their dog (72% and 40%, respectively). Another Australian study found that regular dog walkers engaged in approximately two hours more PA per week than owners who walk their dog less regularly (Christian *et al.*, 2010).

1.6.3 Longitudinal evidence of the benefits of dog walking

A limitation with all of the studies previously described is their cross-sectional nature and thus inability to determine causality between dog ownership and/or dog walking and PA in humans. To date there are no longitudinal studies that examine whether dog acquisition results in an increase in walking and PA in children, although a small number exist in adults. Serpell (1991) reported that the number and duration of recreational walks increased after one month of dog acquisition and is maintained until 10 months post acquisition, moreover, dog owners walked for an additional 240 minutes per week than non-owners. However, this study examined only a small sample of participants (47 new dog owners) and did not control for potential confounders and so the results must be interpreted with caution. Thorpe *et al.* (2006a) assessed dog walking behaviour in 394 elderly dog owners compared to 2137 non-owners over a three year period. At the end of the three years, dog owners who walked their dog were twice as likely to engage in recommended levels of walking compared to non-owners. Cutt *et al.* (2008c) examined whether a sample of Australian adults who acquired a dog increased the number of minutes per week of recreational walking at 12 months follow up. Walking behaviour was assessed for 773 participants, 12% of whom had acquired a dog at follow-up. The sample of 92 new dog owners increased their leisure time walking by 48 minutes per week compared to 12 minutes per week for non-owners. After adjusting for change from baseline to follow up this decreased to 22 minutes for dog owners. However, this was not reflected in an increase in total PA and the authors suggest that participants simply 'substituted' other types of activity for dog walking.

To date, two studies have examined whether a dog walking intervention can lead to an increase in PA in humans. Kushner *et al.* (2006) assessed the effect of a PA and weight loss intervention in 92 overweight or obese adults. Those who owned a dog (n=36) lost, on average, 4.7 % of body weight and increased self-reported PA by 3.9 hours per week at 12 months follow up, although this was not significantly different from non-owners (n=56). Rhodes *et al.* (2012) examined the effect of a 12 week PA intervention in 58 inactive adult dog owners. Those randomised to the intervention group increased the amount of pedometer measured steps taken per day by 2332, on average, compared to 508 in the control group. No published studies have assessed the efficacy of a dog walking intervention on PA in children.

1.6.4 Summary

It is clear that promoting the use of dogs to increase the amount of PA in children and adults is a potentially fruitful public health strategy. Considering that dog ownership in the UK is quite high (approximately 25% of families own a dog, there are approximately 800,000 dogs in Scotland alone and 8.5 million dogs in the UK) and that a substantial amount of both children and adults do not regularly walk their dog, it becomes apparent that dogs are an underutilised source of PA promotion. The US Heart Association even recommends dog walking as a strategy for the prevention and treatment of cardiovascular disease in adults (Levine *et al*., 2013). Dog walking may address several concerns as a public health strategy; it is novel and innovative (Summerbell *et al*., 2005, van Sluijs *et al*., 2007); it may improve long-term adherence to PA programmes (Morgan, 2001) due to the long term relationships people generally have with their dogs; and will likely provide a purposeful activity for participants (Ham and Epping, 2006).

Since the literature suggests that dog ownership and/or dog walking is associated with several aspects or measures of PA in both adults and children when the dog is walked regularly, families who do not currently participate in regular dog walking may have most to gain from promoting dog walking as a public health strategy. The growing number of observational and longitudinal studies that indicate an association between dog ownership and/or walking and PA in humans suggests that intervention studies to test both the feasibility of using pet dogs to increase PA in children and adults, and the effect such an intervention has on PA are warranted.

1.7 Background to the thesis

The review of the literature identified several apparent knowledge gaps in the literature. This thesis concentrates on the gaps listed below:

- Although the ActiGraph accelerometer has been validated for use in dogs, no peer reviewed/published studies have determined which accelerometer cut-points should be used to determine the intensity of PA.
- No peer reviewed/published studies have examined the association between PA and obesity in dogs using ActiGraph accelerometry.
- No peer reviewed/published studies have examined which factors such as breed, age, and neutered status are correlated with PA in dogs using ActiGraph accelerometry.
- No peer reviewed/published studies have assessed whether PA levels change during weight loss in dogs using ActiGraph accelerometry.
- There are no published or peer reviewed dog walking PA interventions involving children and their families.

1.7.1 Thesis objectives

The main objectives of this thesis were to:

- Determine ActiGraph cut points that can be used to describe PA in dogs by intensity.

- Explore the association between PA and obesity in a sample of dogs of varying breed.
- Determine which of the following dog characteristics are correlates of PA in two of the most common breeds, Cocker Spaniels and Labrador Retrievers; breed, age, neutered status, and body condition score.
- To establish whether PA levels change in dogs enrolled in a calorie controlled weight loss programme.
- To assess the feasibility, acceptability and potential efficacy of a theory-driven, family-based, dog walking intervention for 9–11 year old children and their families.

2 Calibration and cross-validation of ActiGraph accelerometer cut-points in dogs

2.1 Introduction

There is growing evidence of a link between dog ownership and dog walking and human PA levels (Johnson and Meadows, 2010, Owen *et al.*, 2010, Reeves *et al.*, 2011, Rhodes *et al.*, 2012), indicating the potential for using pet dogs as the agent of change in intervention studies with humans. Being able to measure the intensity of dog PA is important in such interventions as it allows for the effectiveness of the intervention to be tested, i.e. a better understanding of dog PA intensity might provide a better understanding of dog-human interactions, and therefore help understand changes in human PA during interventions such as those carried out in Chapter 6.

Obesity in dogs is becoming an increasingly common concern in veterinary medicine (German, 2006, Courcier *et al.*, 2010) and it is recognized that PA in dogs is likely to have a positive influence on weight status (Laflamme, 2006, German, 2010), yet the overall contribution of PA to obesity remains unclear. In humans many of the biological effects of PA depend on its intensity (Department of Health, 2011). While there is no clear evidence that PA intensity determines the biological effects of PA in dogs; the ability to accurately quantify the intensity of PA in dogs will facilitate an improved understanding of the contribution of PA to canine health. This is not just restricted to obesity but is relevant to other applications in veterinary medicine, including the monitoring of PA intensity post surgery or post chemotherapy.

Until recently PA in dogs has been measured subjectively, often relying on owner recall (Slater *et al.*, 1995, Robertson, 2003, Courcier *et al.*, 2010). This can be a relatively simple and cost-effective method of assessing PA but may over or under estimate PA levels in comparison to more objective methods, and is unlikely to provide accurate information on PA intensity or indeed overall PA (Prince *et al.*, 2008). In recent years accelerometry, widely used in human studies (Corder *et al.*, 2008, Troiano *et al.*, 2008, Basterfield *et al.*, 2011), has emerged as a potential method for objectively assessing both PA volume and intensity in dogs (Hansen *et al.*, 2007). There are two commonly used monitors in canine PA research, the Actical (Philips-Respironics, USA) which is an omnidirectional accelerometer that reports movement in all planes, and the ActiGraph GT3X (ActiGraph, USA) which is a triaxial accelerometer capable of measuring and reporting movement on the vertical axis only, or on the integrated axis (a combination of the anteroposterior, mediolateral and vertical planes). The Actical has been shown to be a suitable monitor for measuring PA in a laboratory based setting and in a small sample of dogs (Hansen *et al.*, 2007). More recently, it has also been found to be a valid method for measuring habitual PA in dogs (Dow *et al.*, 2009) and is able to categorize PA by intensity (Michel and Brown, 2011). Yam *et al.* (2011) reported that the ActiGraph GT3X was a valid (relative to direct observation of movement), practical and reliable tool for measuring habitual PA volume and intensity in dogs. In order to measure the intensity of PA though, there is a need, as in human accelerometry, to 'calibrate' accelerometer output to canine PA intensity (See Chapter 1, Section 1.2.2.3.3), by establishing cut-points for the ActiGraph GT3X that allow for the categorisation of activity level; namely sedentary behaviour; light-moderate intensity PA; and vigorous intensity PA.

The objectives of this chapter therefore, were to determine intensity specific accelerometer cut-points in dogs, and to cross-validate these cut-points against a separate sample of pet dogs by testing the agreement between the cut-points and a gold standard criterion measure of PA.

2.2 Materials and Methods

2.2.1 Participants

Yam *et al.* (2011) described a study in a convenience sample of 33 dogs which validated accelerometer output against directly observed dog movement, showing that as intensity of dog movement increased, accelerometry output increased. However, accelerometer cut-points which would discriminate between intensity of PA were not established. In the present study the data from Yam *et al.* was used to calibrate accelerometry cut-points to measure PA intensity.

Dogs belonging to staff and students of the School of Veterinary Medicine of the University of Glasgow, and friends of staff/students were recruited to the study. Of the 33 dogs, three dogs were excluded; two were unwilling to move at vigorous intensity PA and the other due to aggression. In order to determine the most accurate accelerometer cut-points the sample was split into two groups; 1) a randomly selected development subset of 20 dogs used to calibrate the accelerometry data (calibration study); and 2) a cross-validation subset of the remaining 10 dogs to establish the accuracy of the cut-points developed in the sample of 20 dogs (cross-validation study).

Written informed consent was given by all dog owners and the study was approved by the University of Glasgow Ethics and Welfare Committee.

2.2.2 Accelerometer placement and settings, and Dog Physical Activity Form

ActiGraph GT3X accelerometers, capable of measuring movement in three planes, were attached to the dorsal aspect of the dogs collar (Figure 2.1) and set to record PA in 15 second intervals (one epoch) for both the vertical axis and integrated output. Dogs were then observed during four separate intensities of movement of at least 10 minutes duration. The four intensities, described below, were adapted from the Children's Physical Activity Form (CPAF) (O'Hara *et al*., 1989) to form a Dog Physical Activity Form (Appendix A), henceforth known as DPAF (this type of numeric classification has been used previously for the classification of PA intensity and development of accelerometer cut-points in humans (Reilly *et al.*, 2003, van Cauwenberghe *et al*., 2011b)):

1. *Sedentary*: No movement of the trunk, including during sleep.

2. *Light intensity physical activity indoors*: Slow translocation of the trunk, confined within a room or kennel.

3. *Light to moderate intensity physical activity outdoors*: Slow to moderate translocation of the trunk, outdoors with the dog on a lead.

4. *Vigorous intensity physical activity*: Rapid translocation of the trunk while running outdoors and off a lead.

Figure 2.1 A participating dog with an ActiGraph GT3X accelerometer attached to its collar

Activity level was then recorded on the DPAF every 15 seconds by two investigators until 10 minutes consisting of only one level of activity were recorded and confirmed using filmed records. When each minute included only one level of activity it was designated as a ‘clean’ minute. Accelerometry output was synchronised to filmed records by setting the accelerometer and video camera to the same personal computer (PC) clock so that activity levels could be confirmed retrospectively.

2.2.3 Accelerometry data reduction and interpretation

Raw 15 second epochs from the accelerometer were extracted for 10 minutes at each intensity level, according to the time periods recorded by the investigators on the DPAF form, and then summarised as a count per minute (cpm) for both the vertical and integrated axes. Yam *et al.* (2011) reported that there was no difference in accelerometer output between DPAF categories 2 and 3 and so data from these categories were combined to form a single category, now DPAF category 2 (light-moderate intensity PA) for the purposes of this study. Accordingly, DPAF category 4 was renamed as DPAF category 3.

2.2.4 Statistical Analysis

To determine cut-points for each PA category, Receiver Operating Characteristic (ROC) curve analysis was conducted. Essentially ROC analysis determines the cut-point at which sensitivity and specificity are maximized and computes the area under the curve (AUC) for each curve. The average accelerometer cpm (both vertical and integrated axes) for each clean minute of activity recorded on the DPAF for all 20 dogs was modelled as the independent variable. The dependent variable was calculated by coding DPAF categories as either 0 or 1 depending on the boundary being generated; i.e. for sedentary behaviour this corresponded to all activities in DPAF category 1 being coded as 1 and all non-sedentary activities (DPAF categories 2-3) being coded as 0; for vigorous intensity this corresponded to all activities in DPAF category 3 being coded as 1 and all non-vigorous activities (DPAF categories 1-2) being coded as 0. The sedentary and vigorous cut-points provided the boundaries for the light-moderate intensity category.

To test for overall agreement between accelerometer output (both vertical and integrated axes) and direct observation (DPAF records) in the cross-validation subset of dogs, 3 x 3 contingency tables and weighted Kappa (κ) scores were computed. κ is a measure of inter-rater agreement after agreement due to chance is taken out of the equation (Feuerman and Miller, 2008), with strength of score rated as; 'poor' (< 0.20); 'fair' (0.21 – 0.40); 'moderate' (0.41 – 0.60); 'good' (0.61 – 0.8); and 'very good' (0.81 – 1.00) (Altman, 1991). Table 2.1 shows the weighting matrix used when calculating κ.

All statistical analyses were carried out using Minitab 16.1.1 (Minitab Inc, USA) and MedCalc 12.6.1 (MedCalc Software, Belgium).

		Direct observation		
		Sedentary	**Light-Moderate**	**Vigorous**
Accelerometry	**Sedentary**	1	0.5	0
	Light-Moderate	0.5	1	0.5
	Vigorous	0	0.5	1

Table 2.1 Weights used for weighted kappa statistic to evaluate agreement between direct observation and accelerometry

2.3 Results

2.3.1 Participant characteristics

The subset of 20 dogs used to develop the PA cut-points comprised of 10 males (one male, nine male neutered) and 10 females (one female, nine female neutered) and the mean age was 5.4 (SD 3.6) years. The cross validation subset of 10 dogs comprised of five male (five male neutered) and five female (one female, four female neutered) and the mean age was 6.6 (SD 4.0) years. The age, breed and sex of each dog are shown in Table 2.2.

Dog	Breed	Sex	Age
Calibration Study			
1	Border Collie	MN	1 year
2	Border Terrier	FN	10 years
3	Cocker Spaniel	MN	2.5 years
4	Crossbreed	MN	2.5 years
5	Crossbreed	MN	2.5 years
6	Crossbreed	MN	3 years
7	Crossbreed	FN	3 years
8	Crossbreed	MN	8.5 years
9	Crossbreed	FN	11 years
10	Crossbreed	FN	12 years
11	German Shepherd	FN	8.5 years
12	Golden Retriever	F	9 months
13	Golden Retriever	FN	3 years
14	Jack Russell Terrier	M	6 years
15	Jack Russell Terrier	MN	8 years
16	Labrador	MN	1.5 years
17	Labrador	FN	2 years
18	Labrador	FN	8 years
19	Shar Pei	FN	8.5 years
20	Trailhound	MN	6.5 years
Cross validation study			
1	American Golden Retriever	FN	4 years
2	Border Collie	MN	9 years
3	Border Collie	MN	13 years
4	Cocker Spaniel	F	9 months
5	Crossbreed	MN	3.5 years
6	Crossbreed	MN	9 years
7	Jackadoodle	FN	2 years
8	Labrador	MN	7 years
9	Labrador	FN	7 years
10	Labrador	FN	11 years

M Male, MN Male neutered, F Female, FM Female neutered

Table 2.2 Dogs recruited to the calibration (n = 20) and cross validation studies (n = 10)

2.3.2 Calibration study

The ROC curves are shown in Fig. 2.2 and results of the ROC analyses are displayed in Table 2.3. Using the vertical axis data, the ROC analyses found optimal sensitivity and specificity at a cut-point of <562 cpm for sedentary behaviour and >2912 cpm for vigorous intensity PA. The accuracy of the vertical axis accelerometry output in distinguishing between sedentary behaviour and non-sedentary activities, and vigorous PA and non-vigorous activities was high. For the vertical axis sedentary cut point, sensitivity was 94.0%, specificity was 95.5% and the AUC for the ROC curve was 0.99. For the vigorous intensity cut point sensitivity was 93.5%, specificity was 95.5% and the AUC was 0.98. Using the integrated axis data optimal sensitivity and specificity were found at cut-offs of <1351 cpm and >5696 cpm for sedentary behaviour and vigorous PA respectively. Again the accuracy of the integrated output in distinguishing between PA intensities was high. For the integrated axis sedentary cut point, sensitivity was 95.0%, specificity was 98.3% and AUC was 0.99. For the vigorous intensity cut point sensitivity was 92.5%, specificity was 95.7% and the AUC was 0.97.

Accelerometer output	Intensity Category	Sensitivity (%)	Specificity (%)	Area under ROC curve (95% CI)	Cut-points (cpm*)
Uniaxial (vertical axis)	Sedentary	94	95.5	0.987 (0.977-0.994)	0-562
	Light-Moderate	-	-	-	563-2911
	Vigorous	93.5	95.5	0.976 (0.963-0.986)	>2912
Triaxial (integrated output)	Sedentary	95	98.3	0.994 (0.985-0.998)	0-1351
	Light-Moderate	-	-	-	1352-5695
	Vigorous	92.5	95.7	0.972 (0.958-0.982)	>5696

*cpm = counts per minute

Table 2.3 Sensitivity, specificity and area under the ROC curve for the development of accelerometer cut-points in dogs (n = 20)

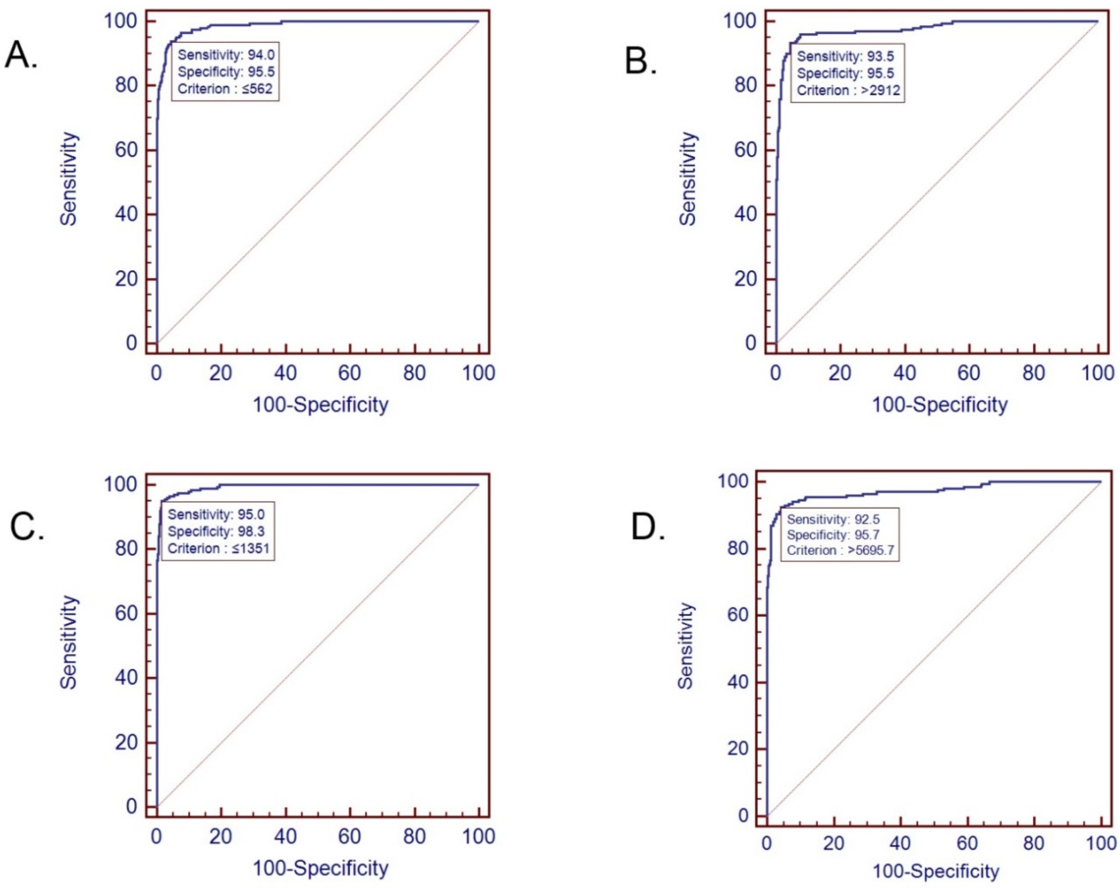

Figure 2.2 ROC curves of the sensitivity and specificity of ActiGraph cut-points for dogs. Vertical axis sedentary cut-point (A), vertical axis vigorous cut-point (B), integrated axes sedentary cut-point (C), and integrated axes vigorous cut-point (D)

2.3.3 Cross-validation study

When these cut-points were applied to the cross validation subset of dogs overall agreement between direct observation and accelerometer cpm was ‘very good’, as defined by κ scores (Altman, 1991), for both the vertical axis (κ = 0.81, Table 2.4) and integrated axis output (κ = 0.83, Table 2.5). When the vertical axis data were analysed, 91/100 (91%) minutes were correctly classified as sedentary behaviour, with the remaining nine (9%) minutes incorrectly classified as light-moderate intensity PA. In the light-moderate intensity PA category 159/200 (80%) minutes were correctly classified, 15/200 (8%) minutes were incorrectly classified as sedentary behaviour and 26/200 (13%) minutes were incorrectly classified as vigorous intensity PA. In the vigorous intensity PA category, 91/100 minutes (91%) were correctly classified, and the remaining nine (9%) minutes were incorrectly classified as light-moderate intensity PA. When the integrated axis data were analysed, 92/100 (92%) minutes were correctly classified as sedentary behaviour, and the remaining eight (8%) minutes were incorrectly classified as light-moderate intensity PA. In the light-moderate intensity PA category 168/200 (84%) minutes were correctly classified, 7/200 (4%) minutes were incorrectly classified as sedentary behaviour and 25/200 (13%) minutes were incorrectly classified as vigorous intensity PA. Finally, in the vigorous intensity PA category, 89/100 (89%) minutes were correctly classified, and the remaining 11 (11%) minutes were classified as light-moderate intensity PA. Overall 341/400 (85%) minutes were correctly classified using the vertical axis output, and 349/400 (87%) minutes were correctly classified using the integrated output.

		Direct observation			Total
		Sedentary	Light-Moderate	Vigorous	
Accelerometry	Sedentary	91	15	0	106
	Light-Moderate	9	159	9	177
	Vigorous	0	26	91	117
Total		100	200	100	400
Measurement of agreement: κ (95% CI) = 0.81 (0.77-0.86)					

Table 2.4 Rating of physical activity by direct observation and accelerometry in cross validation study (vertical axis only, n = 10)

		Direct observation			Total
		Sedentary	Light-Moderate	Vigorous	
Accelerometry	Sedentary	92	7	0	99
	Light-Moderate	8	168	11	187
	Vigorous	0	25	89	114
Total		100	200	100	400
Measurement of agreement: κ (95% CI) = 0.83 (0.79-0.88)					

Table 2.5 Rating of physical activity by direct observation and accelerometry in cross validation study (integrated output, n = 10)

2.4 Discussion

The primary aim of this chapter was to determine accelerometer cut-points in order to categorise PA by intensity in pet dogs. A secondary aim was to test for agreement between the accelerometry output and direct observation of PA in a separate cross-validation sample of pet dogs. Yam *et al.* (2011) have previously shown that the practical utility, reliability and validity of the ActiGraph GT3X are all high in dogs, indicating the potential for using this monitor in dog PA research. To the authors knowledge this is the first study to generate cut-points for the ActiGraph GT3X that can characterise PA in dogs by intensity. The ability to categorise PA by intensity will: facilitate the use of dog PA as a process measure in dog walking interventions in humans (see Chapter 6); facilitate a clearer understanding of what particular dimensions of PA are most important for canine health; allow for the monitoring of population trends in dog PA; allow for the monitoring of PA levels in dogs in the clinical setting such as post surgery and post chemotherapy; and measure the effect of interventions aimed at improving the PA and weight management of dogs (see Chapter 5). Until now monitoring of the intensity of PA in dogs has been restricted to the use of owner questionnaires (Slater *et al.*, 1995, Robertson, 2003), or the Actical accelerometer (Michel and Brown, 2011). The ability to use the ActiGraph accelerometer now offers more choice for researchers when deciding which accelerometer to use to measure dog PA objectively.

Accelerometers typically measure acceleration in either the vertical plane (uniaxial) or a combination of the anteroposterior, mediolateral and vertical planes (triaxial). In theory triaxial accelerometry should provide a superior measure of daily PA than uniaxial accelerometry as uniaxial accelerometers do not take into account movement in either the anteroposterior or mediolateral planes. Some studies have shown that triaxial accelerometers are more accurate at predicting PA and energy expenditure in humans (Eston *et al*., 1998, Plasqui *et al*., 2005), whereas a recent study found no difference between triaxial and uniaxial accelerometers when measuring PA (Vanhelst *et al.,* 2012). It must be noted that in two of the aforementioned studies (Eston *et al.,* 1998, Vanhelst *et al.*, 2012) different models of accelerometer were used to assess PA thus it is difficult to draw meaningful conclusions. The ActiGraph GT3X is capable of measuring movement in either the vertical plane or all three described above. The ROC analyses conducted in the present study produced cut-points with very high accuracy for both the vertical and integrated axes, with sensitivity and specificity both higher than those often reported in human studies (van Cauwenberghe *et al.*, 2011b, Davies *et al*., 2012). When the vertical and integrated axis output were tested for agreement against the gold standard direct observation of movement in cross-validation, both showed 'very good' agreement, also indicating that both the vertical and integrated output from the ActiGraph GT3X are accurate when predicting the intensity of PA in dogs. In this study the position of the accelerometer on the dogs' collar was monitored closely. However, it is possible that when dogs are left unattended the collar may slip and thus cause the plane of movement being measured to be altered; in that case if only uniaxial data were reported the results may be unreliable. The choice of accelerometer (uniaxial or triaxial) may therefore come down to more practical reasons, rather than the accuracy of uniaxial or triaxial modes *per se*.

A strength of the present study is the use of direct observation of movement to categorise PA in dogs, a recognised gold standard when used as a criterion measure in accelerometer calibration studies (Sirard and Pate, 2001). It is notoriously difficult to determine the types of activity to use in calibration studies that will encompass a wide variety of intensities while also covering the most common movements undertaken in everyday life (Welk, 2005). However, it is likely that as the present study included a range of activities, both indoors and outdoors, and on lead and off lead, the activities undertaken by dogs in everyday life have been mimicked across a full range of intensities. A limitation of this study is that due to the varying methods of converting raw data to activity counts employed by different manufacturers of accelerometers, it is usually not possible to compare accelerometer counts between different models. Including other models of accelerometer in this study would have allowed comparison with other published cut-points. However, the ActiGraph GT3X was deemed a sensible choice for determination of cut-points because of its previously established high practical utility, validity, and reliability in free-living dogs (Yam *et al.*, 2011). This study included a wide variety of breeds and age of dogs, thus the cut-points presented should predict PA relatively well among the general canine population. However, it is possible that accelerometer counts during specific intensity levels may differ by breed/size, therefore future studies would be needed to examine this.

2.5 Conclusion

The ActiGraph GT3X is capable of accurately measuring the intensity of PA in pet dogs. The cut-points of 562 cpm for sedentary behaviour and 2912 cpm for vigorous PA using vertical axis data, and 1351 for sedentary behaviour and 5696 for vigorous PA using integrated output are all accurate when classifying PA in dogs. This facilitates the use of the ActiGraph GT3X to describe the frequency, intensity and duration of dog PA in Chapters 3-6 of this thesis. The ActiGraph GT3X can now also describe the intensity of dog PA in future research with diverse applications including using dogs as the agent of lifestyle change in human PA interventions, assessing population trends in PA, and when examining the extent to which the benefits of PA in dogs depend on PA intensity, as in humans. Furthermore, the results of this study pave the way for ActiGraph GT3X to be used when measuring PA in dogs undergoing treatment for a variety of conditions.

3 Associations between obesity and objectively measured physical activity in dogs: a preliminary investigation

3.1 Introduction

It has been reported that dogs are overweight when their body weight exceeds 'optimal weight' by 15% (Laflamme, 2001). In canine research there is no longitudinal evidence on the trends in prevalence of overweight and obesity, but the available data from published cross sectional studies suggest that a significant proportion of the canine population is affected by overweight and obesity, ranging from 15-60% (McGreevy *et al.*, 2005, Colliard *et al.*, 2006, Lund *et al.*, 2006, Holmes *et al.*, 2007, Courcier *et al.*, 2010).

As well as causing difficulties with veterinary examinations, overweight and obesity in dogs has been associated with a number of diseases including, but not limited to; orthopaedic disorders (Edney and Smith, 1986, Kealy *et al*., 1997, Kealy *et al*., 2000, Smith *et al*., 2001); diabetes mellitus (Klinkenberg *et al*., 2006); abnormalities in serum lipid profile (Bailhache *et al*., 2003); and cardiorespiratory disease (White and Williams, 1994, Bodey and Michell, 1996). It has also been reported that in dogs that have restrictions placed on their diet and feeding habits, BCS is improved and lifespan is increased compared to dogs that are fed ad libitum (Kealy *et al*., 2002, Lawler *et al*., 2005). Kealy *et al.* (2002) examined the effect of 25% diet restriction on lifespan in a sample of Labrador Retrievers. Forty-eight Labradors were recruited and each dog paired with another. One dog in each pair was fed ad libitum and the other dog in the pair was fed 75% of the amount of food its pair-mate had consumed the previous day. This protocol was carried out from 8 weeks of age until death. Mean body weight was 26% lower in dogs fed a restricted diet compared to dogs fed ad libitum ($P < 0.01$), and median lifespan was significantly longer in dogs fed a restricted diet compared to their pair-mates (13.0 years versus 11.2 years; $P < 0.01$). Therefore, there is an urgent need to improve our understanding of the factors associated with overweight and obesity in dogs, and in turn how PA may impact on obesity.

To date, very little is known about PA levels in dogs whether they are ideal weight, overweight or obese. One study reported that obese dogs receive less exercise than non-obese dogs (owner reported) (Courcier *et al*., 2010). However, the type and intensity of PA was not ascertained and self-report of PA is often hampered by response bias which may over or underestimate PA levels (Pereira *et al.*, 1997, Sirard and Pate, 2001). An emerging body of recent research in humans confirms that obesity may reduce PA, particularly moderate-vigorous intensity PA (Davis *et al.*, 2006, Hughes *et al.*, 2006, Hughes *et al.*, 2008). This suggests that obesity may be a determinant of PA levels and therefore may also be a major driver of the pandemic of low PA in humans (Bauman *et al.*, 2012). It is also possible that a bi-directional relationship exists between PA and obesity in humans, i.e. low PA may promote obesity and obesity may in turn reduce PA (Ekelund *et al.*, 2008). This bidirectional relationship could also exist in dogs.

It is also of interest to note the potential for using dogs to help prevent and treat obesity in humans (Kushner *et al.*, 2006). Dog owners who participate in regular bouts of dog walking have been shown to walk more than non-owners (Bauman *et al.*, 2001). They also engage in more MVPA than those who do not own a dog (Reeves *et al.*, 2011). Furthermore, children in dog owning families have been found to walk more steps each day than those who do not own a dog (Owen *et al.*, 2010), and adolescents who own a dog participate in more MVPA than those who do not (Sirard *et al.*, 2011). Longitudinal evidence in human dog-interaction studies suggests that dog acquisition results in new dog owners increasing the amount of minutes they walk each week (Serpell, 1991), but not overall PA (Cutt *et al.*, 2008c). The evidence to date suggests that intervention studies involving humans and pet dogs are warranted, although it would first be desirable to gain a better understanding of factors associated with PA in dogs.

Hence, the primary aim of this chapter was to carry out a preliminary investigation to examine the association between obesity and PA, measured objectively with accelerometry, in pet dogs.

3.2 Materials and Methods

3.2.1 Participants and inclusion criteria

A convenience sample of 39 pet dogs were recruited over a six week period while visiting free pet check vehicles (Figure 3.1) in Glasgow in 2010. The pet check service is run by the Peoples Dispensary for Sick Animals (PDSA) who provide free health checks to pet dogs around the UK. All owners who brought their dog to the pet health check service were approached and those willing to take part and whose dog met the inclusion criteria were recruited. Dogs were eligible for inclusion in the study if they: were healthy and not receiving any medication or did not have a history of a medical disorder; were over one year of age; and fell within categories 3 (ideal weight, Figure 3.2), 4 (overweight) and 5 (obese, Figure 3.2) of the 5 point BCS system (Appendix C) (Edney and Smith, 1986).

Written informed consent was given by all dog owners and the study was approved by the University of Glasgow Ethics and Welfare Committee.

Figure 3.1 A PDSA pet check vehicle (PDSA, 2009).

Figure 3.2 Comparison between an obese dog (left) and an ideal weight dog (right) (Thomas, 2001).

3.2.2 Accelerometer placement and settings

ActiGraph GT3X accelerometers (ActiGraph, USA) were used to measure habitual PA. The GT3X is a lightweight and compact device capable of measuring and reporting movement on the vertical axis only, or on the integrated axes (a combination of the anteroposterior, mediolateral and vertical planes). The accelerometers were attached to the dorsal aspect of each dog's collar in accordance with Yam *et al.* (2011) and set to record activity in 15 second intervals, or as is commonly referred to in accelerometry research an epoch of 15 seconds (Reilly *et al.*, 2008). Accelerometer data were recorded for both the vertical axis and integrated output, but all analysis carried out using the integrated output because slippage of the dogs' collars may result in erroneous measurement of PA when only the vertical axis is used.

Accelerometers were attached for seven consecutive days, 24 hours per day, and owners asked to ensure that the device remained attached for the full monitoring period unless during periods of torrential rain or when the dog was swimming/bathing, as the ActiGraph GT3X is not waterproof. In this case owners were shown how to remove and reattach the device and asked to record these periods in an activity diary (Appendix B). After the seven day measuring period accelerometers were removed and returned by post. The accelerometers were attached 24 hours per day, but results are shown using daytime wear only (6am-11pm). To be eligible for inclusion in data analysis each dog had to have a minimum of three consecutive days of accelerometry, because three days is the minimum period for measurement of habitual PA with acceptable precision (Yam *et al.*, 2011).

3.2.3 Accelerometry data reduction and interpretation

Data were downloaded from the devices using the accompanying Actilife software package (ActiGraph, USA). The raw data files were imported into a spreadsheet and data expressed as activity counts per minute (cpm). All accelerometer records identified periods of zeros which represented the dog sleeping or lying still, each period of zeros was checked against the activity diaries to determine whether the device was being worn.

Four constructs were calculated from the PA data recorded by the accelerometer: total volume of PA, expressed as mean counts per minute (cpm); time spent in sedentary behaviour (no movement of the trunk, e.g. when lying still or sleeping, <1351 cpm); time in light-moderate intensity PA (slow to moderate translocation of the trunk, e.g. slow walking with the dog on a lead, 1352-5695 cpm); and time in vigorous intensity PA (rapid translocation of the trunk, e.g. running outdoors when off lead, >5696 cpm). Sedentary behaviour, light-moderate intensity PA and vigorous intensity PA were calculated using the cut-points determined in Chapter 2 of this thesis.

3.2.4 Statistical analysis

For statistical analyses, one-way ANOVAs were used to test for differences in PA variables between ideal weight, overweight and obese dogs. Homogeneity of the variance and normal distribution of the data were tested and any PA variables that did not meet the assumptions of ANOVA were analysed using the Kruskal-Wallis test followed by Mann Whitney-U post hoc test. A post-hoc power calculation was performed using the maximum difference in total volume of PA. Power was set at 90%, alpha at 0.05 and the square root of the mean square error used to estimate sample standard deviation. All analyses were carried out using Minitab 16.1.1 (Minitab Inc, USA).

3.3 Results

3.3.1 Participant characteristics

In total, 39 dogs were recruited, but insufficient data to provide a measure of habitual PA (<3 days wear) were returned for 4 dogs and so the results are displayed for 35 dogs only. Descriptive characteristics of the sample are shown in Table 3.1. In total, six dogs were aged two years old or younger (17%), 21 were between three and eight years old (60%) and 8 were nine years or older (23%), the median age was 5 years (interquartile range (IQR) 3-8). The overall sex distribution was five (14%) entire male, five entire females (14%), 10 (29%) male neutered and 15 (43%) female neutered. A wide variety of breeds were included in the sample.

Variable	Sample size	%
Sex		
Male Entire	5	14
Male Neutered	10	29
Female Entire	5	14
Female Neutered	15	43
Age		
1 to 2	6	17
3 to 8	21	60
9+	8	23
Breed		
Airedale terrier	1	3
Border Collie	6	17
Border Terrier	1	3
Cavalier King Charles	3	9
Cocker Spaniel	5	14
Flat Coated Retriever	1	3
German Shepherd	1	3
Jack Russell Terrier	2	6
Labrador	7	20
Lhasa Apso	2	6
Rottweiler	1	3
Springer Spaniel	2	6
Staffordshire Terrier	2	6
West Highland Terrier	1	3
BCS		
3 (Ideal)	18	51
4 (Overweight)	9	26
5 (Obese)	8	23

Table 3.1 Descriptive characteristics and body condition score of dogs (n = 35)

3.3.2 Physical activity of the whole sample

In the final analysis median duration of accelerometer monitoring was seven days (IQR 7-7) with median duration of 17 h (IQR 16-17) per day. The mean total volume of PA was 662 cpm (SD 230) and dogs spent a high proportion of the day (between the hours 6am-11pm) in sedentary behaviour, 858 mins (SD 62), which is equivalent to > 14 hours. Mean time spent in light-moderate intensity PA was 147 mins/d (SD 55) and dogs spent a mean of 15 mins/d (SD 13) in vigorous intensity PA.

3.3.3 Physical activity by Body Condition Score

Table 3.2 compares PA variables between dogs classified as ideal weight, overweight and obese. Obese dogs were significantly less vigorously active than ideal weight dogs (6 ± 3 mins/d vs. 20 ± 14 mins/d, $p = 0.01$). There was no evidence of a significant difference in the amount of time obese dogs spent in sedentary behaviour or light-moderate intensity PA compared to ideal weight dogs. There was no evidence of statistically significant differences in PA between overweight dogs and ideal weight dogs, or between overweight and obese dogs.

3.3.4 Post-hoc power calculation

The maximum difference in total volume of PA was 177 cpm (Table 3.2), and the estimated standard deviation was 226 cpm. The post-hoc power calculation (Appendix D) indicated that a sample size of approximately 43 dogs per factor level (ideal weight, overweight and obese) would be needed to detect differences in total volume of PA.

Physical Activity	Total (n=35)	Ideal weight (n=18)	Overweight (n=9)	Obese (n=8)	P value (One-way ANOVA)
Total PA (mean cpm)	662 (230)	718 (250)	656 (232)	541 (138)	0.19
Sedentary behaviour (mins/d)*	858 (62)	852 (71)	851 (59)	878 (47)	0.58
Light-Moderate PA (mins/d)†	147 (55)	146 (60)	158 (55)	136 (45)	0.72
Vigorous PA (mins/d)‡**	15 (13)	20 (14)	11 (10)	6 (3)§	0.01

Values are mean ± standard deviation

Mins/d includes day time wear only (6am – 11pm).

One-way ANOVA used to test for differences between means

*<1351 accelerometer cpm

†1352 to 5695 accelerometer cpm

‡>5696 accelerometer cpm

**Statistical comparisons on non-normally distributed variables were performed using Kruskal-Wallis test followed by the Mann Whitney-U post hoc test, means shown for ease of interpretation

§Significantly different from ideal weight dogs using One-way ANOVA

Table 3.2 Dog physical activity variables for the sample as a whole and by body condition using daytime wear only (6am-11pm)

3.4 Discussion

To the authors knowledge, this is the first study to demonstrate that obesity in dogs is associated with lower ActiGraph accelerometer measured habitual PA. The finding that obese dogs spent significantly less time in vigorous intensity PA compared to healthy weight dogs is novel and not directly comparable with any previous studies in this species. The difference in PA between obese and ideal weight dogs, while statistically significant, was quite small and was restricted to vigorous intensity PA only. The biological significance of a difference in vigorous PA of around 14 mins/day between obese versus ideal weight dogs is unclear. Obesity might suppress vigorous PA in dogs even in the absence of obvious ill health or co-morbidities of obesity. These findings are consistent with an emerging body of evidence from human studies showing that obesity reduces PA (Davis *et al.*, 2006, Hughes *et al.*, 2006). Further studies will be needed to confirm these findings, which support the hypothesis advanced by Bauman *et al.* (2012) that not only does low PA lead to obesity but that obesity may also lead to low PA.

The most common approach to weight management in dogs is dietary therapy (German, 2010), but it is recognised that regular PA should be recommended as part of obesity prevention and treatment (Laflamme, 2006). Increasing the amount and intensity of PA may be a useful strategy in the weight management of dogs and it has been shown that incorporating regular exercise alongside dietary therapy can improve the rate of weight loss (Chauvet *et al*., 2011). Although causality cannot be determined in the present study, these findings are the first step towards understanding the contribution of objectively measured PA to the aetiology, prevention and treatment of obesity and lend support to the practice of including regular PA in weight management programmes in dogs.

In the present study there was no evidence of statistically significant differences in either sedentary time or light-moderate intensity PA. This may be due to a lack of power and future studies are justified as these constructs of PA may turn out to be important, just as in humans (Henson *et al*., 2013). Recruitment of a larger sample of the canine population would be required if constructs of PA other than vigorous PA are of interest (e.g. effects of obesity on total volume of PA or time spent sedentary). For example this study suggests that a sample size of 129 dogs (43 per factor level: ideal weight; overweight; and obese) would be required to detect differences in total volume of PA. Therefore, with the current sample size there was no chance of detecting a statistically significant difference in total volume of PA between ideal weight and obese dogs. Future studies might also consider whether overweight (as distinct from obesity) has an impact on PA in dogs and would be needed to explore more subtle associations of canine overweight and obesity with total volume of PA and light-moderate intensity PA. Furthermore, there are a number of risk factors associated with obesity in dogs including age (Colliard *et al.*, 2006), gender (McGreevy *et al.*, 2005) and neuter status (McGreevy *et al.*, 2005), therefore it would also be worth considering whether these factors have a specific impact on PA in the dog. Future studies would also be required to examine the mechanisms of any effect of obesity on PA in dogs since this issue was beyond the scope of the present study. However, the author considers it unlikely that reduced PA in the obese group of dogs was related to gross physical impairment of movement by morbid obesity as no participating dogs suffered from impaired locomotion and all were otherwise healthy at the time of the study.

The major strength of this study was the objective nature of PA measurement. In most previous studies only subjective measures such as questionnaires and telephone interviews with owners have been used to assess PA levels in dogs (Slater *et al.*, 1995, Robertson, 2003, Courcier *et al.*, 2010). Such methods are likely to be very prone to a high degree of both imprecision and bias. Accelerometry, an objective measure of habitual PA has been widely used to monitor PA levels in humans (Trost *et al*., 2001, Reilly *et al.*, 2008, Troiano *et al.*, 2008, Colley *et al*., 2011b, Colley *et al*., 2011a) and is now emerging as the method of choice for canine PA assessment (Hansen *et al.*, 2007, Dow *et al.*, 2009, Michel and Brown, 2011, Yam *et al.*, 2011). This study used the ActiGraph GT3X accelerometer, which is a valid, practical and reliable method of measuring PA volume and intensity in dogs (see Chapter 2 for more details). The accelerometer data were analysed using daytime wear only (6am-11pm) as this is the most commonly employed method in human studies (Trost *et al*., 1998, Jackson *et al*., 2003) and dogs were only included in the analysis if they provided a minimum of three consecutive days of accelerometry data as this is the minimum period for measurement of habitual PA with acceptable precision (Yam *et al.*, 2011).

The BCS system was used to quantify body composition. Other techniques are available for assessing adiposity in dogs, e.g. doubly-labelled water (Speakman *et al.*, 2001b) and dual energy x-ray absorptiometry (DXA) (Speakman *et al*., 2001a). DXA is the gold standard for measuring body composition in dogs and is more accurate than BCS, but the equipment is expensive to purchase and operate. However, the BCS system is non-invasive, inexpensive and has high owner acceptance, as well as being more standardised between breeds than body weight. Furthermore, several studies have shown significant associations between BCS and outcomes such as morbidity and mortality. Dogs with condition scores above ideal are at greater risk of several diseases (Lund *et al.*, 2006) and early death (Kealy *et al.*, 2002) than those dogs with ideal BCS (see Chapter 3, Section 3.1).

A limitation of the present study was the relatively small sample size, preventing stratification of the sample in order to explore confounding factors such as age and breed. Another limitation was the cross-sectional nature and so causality could not be determined (e.g. if low PA predisposed the obese dogs to obesity and/or obesity reduced PA): for this longitudinal and/or intervention studies would be required.

These results may also be useful when planning and delivering dog-walking interventions in humans. Exercising with pet dogs represents a potentially fruitful strategy for promoting PA in humans (Bauman *et al.*, 2001, Owen *et al.*, 2010, Salmon *et al.*, 2010, Reeves *et al.*, 2011) and the results of this study will allow researchers to better understand the PA patterns of dogs when studying human-dog interactions (See Chapter 6). For instance, as obese dogs have been shown to be less vigorously active than ideal weight dogs, owners of obese dogs may have greater scope for increasing their own PA through dog walking.

3.5 Conclusions

As with the association between obesity and PA in humans, any relationship in dogs is likely to be complex. The present study shows that obesity is associated with reduced vigorous intensity PA in the canine, as is the case in the human. This preliminary study begins to tease out differences in PA between dogs of varying body condition. Future studies with larger sample sizes to tease out other factors that may impact on PA such as age, breed, and gender are now justified.

4 Correlates of objectively measured physical activity in dogs

4.1 Introduction

An epidemic of obesity has affected the canine population in recent years (Courcier *et al.*, 2010) and there is increasing interest in the potential role of PA and energy requirements for the prevention and treatment of canine obesity (German, 2010, Wakshlag *et al.*, 2012). Variations in PA and sedentary behaviour influence the energy requirements of humans, and a wide variety of factors are associated with PA and sedentary behaviour in humans including sex, weight status or various psychosocial characteristics such as stress or self-efficacy (Bauman *et al.*, 2012). Furthermore, correlates of PA and sedentary behaviour are not always the same. For instance, King *et al.* (2011) reported that having an older mother was correlated with sedentary behaviour but not MVPA in children.

An accurate measurement of PA and sedentary behaviour and an understanding of their correlates in dogs are important not only from a PA perspective, but also from a nutritional perspective. Obesity develops in dogs when energy intake exceeds energy expenditure over time (German, 2010). Tailoring diets and energy requirements or adjusting already recommended diets/nutritional products based on correlates of PA may be useful for targeting obesity in various demographic groups/subgroups such as breed type, age or sex. For instance, evidence suggests that certain breeds of dog are predisposed to obesity, such as Labrador Retrievers, Cairn Terriers and Cocker Spaniels (Edney and Smith, 1986, German, 2010). Furthermore, regular PA in combination with dietary therapy promotes fat loss and assists in lean tissue preservation in humans (van Dale and Saris, 1989, Phinney, 1992).

Despite this, there is a dearth of information on the correlates of PA in the canine population, and PA research in dogs has historically been hampered by the reliance on subjective methods of measuring PA such as owner questionnaires and interviews (see Chapter 1, section 1.2.2) (Slater *et al.*, 1995, Robertson, 2003, Courcier *et al.*, 2010). Recently, more objective methods for accurate quantification of PA and sedentary behaviour in dogs have been validated. ActiGraph accelerometry has been validated for measuring habitual PA in dogs (see Chapter 1, section 1.2.2.3) and is capable of classifying PA by intensity (see Chapter 2) thus facilitating the use of ActiGraph accelerometry to examine the correlates of objectively measured PA in the canine population.

The results of Chapter 3 suggest that obesity is associated with reduced vigorous intensity PA in dogs. However, a wide variety of dog breeds were included in the sample, meaning that breed specific associations with PA could not be explored. The primary aim of this chapter was therefore to identify significant correlates of objectively assessed PA and sedentary behaviour in a sample of two common breeds of free living dogs, namely Labrador Retrievers and Cocker Spaniels (Figure 4.1), using ActiGraph accelerometry. These two breeds were chosen because they are the two most registered breeds with the Kennel Club in the United Kingdom (The Kennel Club, 2014) and are predisposed to obesity (German, 2010).

Figure 4.1 A Labrador Retriever and Cocker Spaniel shown together (Press Association, 2011)

4.2 Materials and methods

4.2.1 Participants and inclusion criteria

A convenience sample of 62 dogs (35 Labradors and 27 Cocker Spaniels) was recruited to the study. Dogs receiving medication, or that had a history of medical disorders, or were ≤ 1 year-old, were excluded as in previous studies (Mason, 1970, McGreevy *et al.*, 2005, Courcier *et al.*, 2010). Written informed consent was given by all dog owners and the study was approved by the University of Glasgow Ethics and Welfare Committee.

4.2.2 Accelerometer placement and settings

ActiGraph GT3X+ accelerometers (ActiGraph, USA) were used to measure PA and sedentary behaviour. Previous studies in dogs have used the ActiGraph GT3X model although that model is not waterproof and had to be removed when dogs were swimming or bathing. The ActiGraph GT3X+ is waterproof and did not have to be removed and the re-attached, therefore reducing the burden placed on owners of dogs participating in this study. It has been shown that there is strong agreement between the output from the GT3X and GT3X+ (Robusto and Trost, 2012), meaning that both models can be used and results will not be significantly altered. The accelerometers were attached to the dorsal aspect of each dogs collar, in accordance with previous studies, and set to record activity in 15 s intervals (epochs) (Yam *et al.*, 2011). Accelerometer data are shown using the integrated axes output from the GT3X+, a method that has very high accuracy when measuring PA and classifying intensity of PA (see Chapter 2).

Accelerometers were attached for seven consecutive days, 24 h/day, and owners were asked to ensure that the device remained attached for the full monitoring period. If the accelerometer had to be removed for any reason, then owners were shown how to remove and reattach the device and asked to record these periods in an activity diary (Appendix B). Dogs were excluded if they did not have a minimum of three consecutive days of accelerometry, since this is the minimum period for measurement of habitual PA with acceptable precision (Yam *et al.*, 2011). Although the accelerometers were attached 24 h/day results are shown using day time wear only (6 am-11 pm), as this is the most commonly employed method in humans and provides a reliable sampling period, sufficient to represent usual PA (Trost *et al.*, 1998, Jackson *et al.*, 2003, Penpraze *et al*., 2003).

4.2.3 Accelerometry data reduction and interpretation

Data were downloaded from the devices using the accompanying Actilife software package (ActiGraph). Raw data files were imported into a spreadsheet and data expressed as activity counts per min (cpm). All accelerometer records were analysed for periods of zeros which represented the dog sleeping or lying still; each period of zeros was checked against the activity diaries to confirm that the device was actually being worn or not.

Strings of zeros which corresponded to non-wear time noted in the activity diaries were removed from further analysis. Time spent in each category of PA was calculated using previously identified cut- points for the integrated axis data: 0-1351 cpm for sedentary behaviour, 1352-5695 cpm for light-moderate intensity PA, and > 5696 cpm for vigorous intensity PA (see Chapter 2).

4.2.4 Potential correlates of PA and sedentary behaviour

Physical activity/sedentary behaviour outcomes and potential correlates are listed in Table 4.1. The following characteristics were included: age; sex; breed; neuter status; and BCS, a simple measure of weight status (Appendix C) (Edney and Smith, 1986).

4.2.5 Statistical analysis

Simple univariable linear regression analysis was used to assess relationships between potential correlates and the following outcome variables: total volume of PA; min/day spent in light-moderate PA; min/day spent in vigorous PA; and min/day spent sedentary. Normal probability plots of the residuals were assessed and the Anderson-Darling test used to determine if they were normally distributed. To meet the assumptions of linear regression analysis, i.e. that residuals are normally distributed, $\log_{10}$ transformation was carried out on all outcome variables. All explanatory variables that had $P < 0.20$ in the univariable analysis were included in the final models and any variables that were associated significantly ($P < 0.05$) were considered to be significant correlates of PA and sedentary behaviour. Minitab 16.1.1 (Minitab, USA) was used for all statistical analyses.

4.3 Results

4.3.1 Characteristics of study participants

Sixty-two dogs were recruited to the study. Each dog was classified using the 5-point BCS system and all dogs had a BCS of 3 (ideal weight), 4 (overweight) or 5 (obese). Insufficient accelerometry data (< three days wear) were returned for three dogs, data were deemed invalid for a further four dogs due to accelerometer malfunction and one dog was injured during the course of the study and had to withdraw. Therefore, data are presented for a total of 54 dogs (29 Labradors and 25 Cocker Spaniels).

In total 16 dogs were aged ≤ 2years-old (30%), 20 were between 3 and 8 years-old (37%), and 18 were ≥ 9 years-old (33%). The overall sex distribution was five (9%) entire male, five (9%) entire female, 18 (33%) male neutered and 26 (49%) female neutered dogs. Twenty two (41%) dogs were ideal weight, 24 (44%) were overweight and the remaining 8 (15%) were obese. There was no evidence of a statistically significant difference in sex distribution between the breeds (P = 0.73). There was also no evidence of a statistically significant difference (P = 0.17) in age between Cocker Spaniels (6.1 years, SD, 3.3) and Labradors (4.8 years, SD 3.8).

All dogs in the final analysis wore the accelerometer for the full seven days and the mean duration of accelerometry data analysed was 16.9 h (SD 0.2) per day. The mean total volume of PA was 926 cpm (SD 321) and dogs spent a high proportion of accelerometer wear time in sedentary behaviour; 789 min/d (SD 78), which is equivalent to > 13 h. The level of light-moderate intensity PA was low, 202 min/d (SD 60) and dogs spent a mean of 27 min/d (SD 21) in vigorous intensity PA.

4.3.2 Correlates of PA

The results of the univariate analysis are shown in Table 4.1. For total volume of PA (mean cpm) only age and breed had $P < 0.2$ and these were included in the final model. Both age and breed were significantly associated with total volume of PA in the final model (Table 4.2). Total volume of PA was significantly lower with increasing age and was found to be lower in Labradors compared to Cocker Spaniels. A total of 60% of the variance in total volume of PA was explained in the final model.

Variable	Definition		Total Volume of PA (cpm)			Light-moderate intensity PA (min/day)			Vigorous intensity PA (min/d)			Sedentary behaviour (min/day)		
		n	**β–coeff. (95% CI)**	r^2	***P***	**β–coeff. (95% CI)**	r^2	***P***	**β–coeff. (95% CI)**	r^2	***P***	**β–coeff. (95% CI)**	r^2	***P***
Age	Continuous variable	54	-0.032 (-0.041, -0.023)	47.5%	<0.001	-0.020 (-0.030, -0.010)	21.6%	<0.001	-0.099 (-0.120, -0.080)	63.4%	<0.001	0.006 (0.003, 0.009)	29.8%	<0.001
Breed	Labrador, Cocker Spaniel (Ref)	54	-0.074 (-0.163, 0.015)	3.4%	0.10	-0.099 (-0.176, -0.022)	9.7%	0.01	-0.055 (-0.303, 0.193)	0%	0.66	0.023 (0.001, 0.044)	5.8%	0.04
Sex	Male, Female (Ref)	54	0.034 (-0.058, 0.125)	0%	0.45	0.021 (-0.061, 0.103)	0%	0.61	0.133 (-0.115, 0.381)	0.3%	0.29	-0.004 (-0.027, 0.019)	0%	0.75
Neutered Status	Neutered, Entire (Ref)	54	-0.068 (-0.183, 0.047)	0.8%	0.24	-0.030 (-0.134, 0.074)	0%	0.57	-0.226 (-0.539, 0.087)	2%	0.15	0.010 (-0.019, 0.039)	0%	0.52
Body Condition Score	Ideal weight, Overweight, Obese (Ref)	54	-	0%	-	-	0%	-	-	0%	-	-	0%	-
Ideal weight			0.025 (-0.041, 0.092)	-	0.44	0.014 (-0.044, 0.072)	-	0.63	0.056 (-0.123, 0.235)	-	0.53	-0.003 (-0.019, 0.013)	-	0.75
Overweight			-0.011 (-0.075, -0.053)	-	0.74	-0.024 (-0.082, 0.034)	-	0.41	-0.019 (-0.196, 0.158)	-	0.83	-0.001 (-0.017, 0.015)	-	0.86

Table 4.1 Univariable analysis (simple regression) of correlates associated with total physical activity, light intensity physical activity, vigorous intensity physical activity and sedentary behaviour (overnight wear removed)

Variable	Total PA (cpm)			Light-moderate intensity PA (min/day)			Vigorous intensity PA (min/d)			Sedentary behaviour (min/day)		
	β–coeff.	**95% CI**	***P*-value**	**β–coeff.**	**95% CI**	***P***	**β–coeff.**	**95% CI**	***P*-value**	**β–coeff.**	**95% CI**	***P***
Age (continuous)	-0.035	(-0.043, -0.027)	<0.001	-0.023	(-0.032, -0.014)	<0.001	-0.100	(-0.122, -0.079)	<0.001	0.007	(0.005, 0.010)	<0.001
Breed (Cocker Spaniel = Ref)	-0.122	(-0.179, -0.064)	<0.001	0.130	(-0.194, -0.066)	<0.001	-	-	-	0.032	(0.015, 0.050)	<0.001
Neutered Status (Entire = Ref)	-	-	-	-	-	-	0.044	(-0.157, 0.245)	0.662	-	-	-
Constant	3.191	(3.127, 3.255)		2.477	(2.406, 2.548)		1.772	(1.585, 1.959)		2.839	(2.820, 2.858)	
Adjusted r^2			60.4%			39.9%			62.9%			44.0%

Table 4.2 Final models: Multivariable analysis (multiple regression) of correlates associated with total physical activity, light intensity physical activity, vigorous intensity physical activity and sedentary behaviour (overnight wear removed)

Both age and breed were significantly associated with light-moderate intensity PA (min/day) in the univariate analysis (Table 4.1) and both remained significant in the final model (Table 4.2). Light-moderate intensity PA was significantly lower with increasing age, and in Labradors compared to Cocker Spaniels. A total of 40% of the variance in light-moderate intensity PA was explained in the final model.

For vigorous intensity PA (min/day), age and neuter status had $P < 0.2$ (Table 4.1); however, only age was significant in the final model (Table 4.2). Therefore, vigorous intensity PA was significantly lower with increasing age. A total of 63% of the variance in vigorous intensity PA was explained in the final model.

4.3.3 Correlates of sedentary behaviour

Age and breed were significantly associated with sedentary behaviour (min/day) in the univariate analysis (Table 4.1) and both remained significant in the final model (Table 4.2). Sedentary behaviour was significantly higher with increasing age and in Labradors compared to Cocker Spaniels. A total of 44% of the variance in sedentary behaviour was explained in the final model.

4.4 Discussion

This is the first study to use ActiGraph accelerometry to identify significant correlates of PA and sedentary behaviour in pet dogs. These results suggest that age is significantly associated with total volume of PA, light-moderate intensity PA, vigorous intensity PA and sedentary behaviour in dogs. Furthermore, breed was significantly associated with all of the above outcome variables except vigorous intensity PA. These data support the view that there are likely to be breed- and age-related differences in energy requirements in dogs.

The finding that PA declines with age in dogs is consistent with observations in humans (Sallis, 2000, Troiano *et al.*, 2008) and indicates that age-related decline in PA is at least partly a biological phenomenon. Sallis (2000) and Ingram (2000) reviewed age-related decline in PA in humans and animals, finding a consistent decline in PA with age in humans and a number of species of animal including insects, rodents and monkeys, further supporting the hypothesis that age-related decline in PA is biological. In the present study, for every one year increase in age, there was an 8% decrease in total volume of PA, a 5%

decrease in light-moderate intensity PA, a 26% decrease in vigorous intensity PA and a 2% increase in sedentary behaviour. Although there are no other comparable studies in free living dogs, it has been shown in caged dogs that younger dogs are more physically active than older dogs (Siwak *et al*., 2003), which is consistent with our findings. It is unclear what, if any, environmental factors are associated with a decline in PA with age in dogs, future studies are required to assess this. There was no evidence of differences in PA and/or sedentary behaviour between ideal weight and obese/overweight dogs in the present study. A possible explanation is that opportunities for exercise or PA in dogs are largely determined by their owner: social and cultural factors such as this were not assessed in the present study.

Of interest was that the explanatory variables included in the analysis explained a relatively large amount of the variation in PA and sedentary behaviour. There is no comparable evidence in pet dogs, but in studies with humans typically < 20% of the variation in objectively measured PA is explained in the final models (Gordon-Larsen *et al*., 2000, Schmitz *et al*., 2002, McMinn *et al*., 2008, King *et al.*, 2011). In studies with humans, it is increasingly recognised that while accelerometry measures PA with high precision relative to alternative methods, a degree of measurement imprecision remains. This imprecision tends to weaken the apparent associations between accelerometry measured PA and other variables, and hence means that the strength of associations observed is probably a conservative estimate (Ekelund *et al*., 2012). In dogs, similar arguments may apply and consequently the strength of the correlates observed in the present study may be an underestimate.

One reason why the percentage of variation in PA in the present study was much greater than in comparable studies in humans may be due to the fact that studies with humans concentrate on one particular age group, such as children (King *et al.*, 2011), adolescents (Schmitz *et al.*, 2002) or adults (Trost *et al*., 2002). Correlates of PA may differ by age group (Plotnikoff *et al*., 2004) and a wide range of ages were included in the present study. Future studies should therefore concentrate on only one age group of dogs, e.g. juvenile, adult or senior dogs.

ActiGraph accelerometry is a valid tool for measuring PA in a wide range of dogs (Yam *et al.*, 2011) and can categorise PA by intensity and with high accuracy across a wide range of dog breeds and sizes (Chapter 2). That, along with these findings showing that PA, as measured with ActiGraph accelerometry, reduces with increased age, will allow for a better estimation of energy requirements for dogs. Energy requirements for dogs are typically estimated using a predictive equation, one component of which is some measure of PA.

Furthermore, there is evidence that changes in body composition occur with aging in dogs and this may be linked to a decrease in energy expenditure without a concomitant reduction in energy intake (Harper, 1998). Therefore, energy requirements for older dogs may be lower than those for younger dogs and our finding that PA decreases with increased age supports the hypothesis that age-related diets, or a reduction in energy content of diets, are desirable.

Energy requirements may also differ among breeds. In the present study, PA was greater and sedentary behaviour was lower in Cocker Spaniels compared to Labradors. Future studies should include a measure of energy intake (e.g. food diaries), as this would help establish what, if any, relationships exists between PA and specifically the different intensities of PA and food intake.

In contrast to the results reported in Chapter 3 there was no evidence of an association between any of the PA variables and BCS. This may be due to the fact that only eight dogs in the sample of 54 were classed as obese, compared to 22 ideal weight dogs and 24 overweight dogs. Recruiting a larger number of obese dogs in future studies is recommended to assess whether associations such as reduced vigorous intensity PA in obese dogs are present in samples including only one or two breeds. Despite this, the finding that PA varies by age and between Labrador Retrievers and Cocker Spaniels should be considered when planning future PA interventions involving dogs and humans. It may be difficult to increase PA levels in humans who own older dogs for instance.

The use of accelerometry to measure PA levels, which is now emerging as the method of choice for canine PA assessment (Michel and Brown, 2011, Yam *et al.*, 2011), is a major strength of this study, because it provides an objective and unbiased method for measuring PA. The accelerometry cut-points used were derived from validation and calibration studies carried out in a very heterogeneous sample of dogs in usual activities, and they seem to be robust to wide variation in dog age, breed, and size (Chapter 2). The inclusion of only two breeds in this study allowed for the examination of potential correlates of PA more effectively than would have been possible if a more heterogeneous sample with a large number of breeds was used, but the sample may be less representative of the wider dog population.

The current study has several limitations. The cross-sectional design made it difficult to determine the causality of any effects found (i.e. does increasing age reduce PA or are certain dogs physically inactive throughout their lifespan?). Moreover, the extent to which differences in habitual PA of dogs translate to differences in energy requirements is not clear and studies of longitudinal nature with additional measures (e.g. total energy expenditure measured by the doubly labelled water method (see Chapter 1, section 1.2.1.1) would be required to address this question. In studies of correlates of PA and sedentary behaviour in humans, a sample size of > 20 per potential correlate is usually recommended. Although the sample size in the present study is lower than this, a number of significant correlates were found, suggesting that the study numbers were adequate to detect associations with age and breed, but not BCS.

Other factors that influence PA in dogs, such as owner characteristics, also warrant further investigations. It is possible that including owner characteristics (age, weight status, dog walking habits, and socioeconomic status) and other explanatories (e.g. environmental factors such as weather/season) would increase the ability to explain variation in PA. Ultimately, the understanding of PA correlates in dogs might be better understood by the development/adaptation of a conceptual model like that used in humans. In studies of the correlates of PA in humans, the socio-ecological model is increasingly being used to define five widely accepted domains: demographic and biological factors (e.g. gender, weight status); physiological, cognitive and emotional factors (e.g. self-esteem); behavioural factors (e.g. caloric intake); social and cultural factors (e.g. family influences); and physical environmental factors (e.g. access to facilities) with potential correlates identified in each domain (Sallis *et al.*, 2000, Trost *et al.*, 2002, Van Der Horst *et al.*, 2007, Hinkley *et al.*, 2008, King *et al.*, 2011, Bauman *et al.*, 2012). Research on the correlates of PA in dogs using such a model appears justified, but with modifications relevant to dogs.

4.5 Conclusions

The present study identified both age and breed as correlates of objectively measured PA and sedentary behaviour in pet dogs. This has implications for the understanding of variation in energy requirements in dogs, and for the future development of age- and breed-specific diets, as well as for the prevention and treatment of obesity. These results also have implications when using dogs in PA interventions in humans. Future studies could include a wider range of potential correlates, similar to those in studies with humans but relevant to the canine species.

5 A 6 month observational study of changes in objectively measured physical activity during weight loss in dogs

5.1 Introduction

In small animal veterinary practice, obesity is considered to be the leading cause of malnutrition (Legrand-Defretin, 1994). In line with rising rates of human obesity, the prevalence of companion animal obesity is accepted to be increasing (German, 2006), with studies estimating that 15-60% of dogs are overweight or obese (McGreevy *et al.*, 2005, Colliard *et al.*, 2006, Lund *et al.*, 2006, Holmes *et al.*, 2007, Courcier *et al.*, 2010). As with humans there are a number of deleterious effects of obesity in dogs with substantial impacts on health. Conditions associated with obesity in dogs include orthopaedic problems, endocrine disorders and cardiovascular disease (German, 2010).

The most common approach to weight management in dogs is dietary therapy (German, 2010) and a number of studies have shown that reduced caloric intake results in weight loss in dogs (Borne *et al*., 1996, Laflamme *et al*., 1997). Combined dietary therapy and physical activity (PA) weight loss programmes have also been used successfully in dogs with losses of 18% of body weight reported (German *et al.*, 2007). In humans, weight loss resulting from diet and PA interventions is typically between 5 and 10% (Shaw *et al*., 2006, Oude Luttikhuis *et al*., 2009) and the amount of weight loss found in the canine studies described is usually only seen in surgical interventions in humans (Picot *et al*., 2012).

There is little information in veterinary literature regarding the association between weight status and PA levels in dogs. Low PA may increase risk of obesity in dogs, but this relationship might be bi-directional with obesity leading to a suppression of PA, as has been suggested to be the case in humans (Bauman *et al.*, 2012). Furthermore the energy intake of active dogs is greater than inactive dogs even when maintaining weight loss goals (Wakshlag *et al.*, 2012). Obese dogs receive less exercise than non-obese dogs according to an owner questionnaire on exercise levels (Courcier *et al.*, 2010), and when measured objectively, there is some evidence that obese dogs spend less time in vigorous intensity PA than ideal weight dogs (see Chapter 3). However, there are no published studies describing the change in PA levels measured objectively using accelerometry in dogs undergoing substantial weight loss.

The aim of this chapter was to evaluate long-term changes in PA and sedentary behaviour in pet dogs enrolled in a calorie controlled weight loss programme, and therefore to test the hypothesis that substantial weight loss is associated with an increase in PA and decrease in sedentary behaviour in dogs.

5.2 Materials and Methods

5.2.1 Study participants

Dogs participating in the PDSA's (The Peoples Dispensary for Sick Animals) 'Pet Fit Club', an annual pet slimming competition for overweight and obese pets in the UK, between November 2010 and June 2012 were enrolled in the study. All dogs participating in the Pet Fit Club were overweight or obese and fell within categories 4 (overweight) and 5 (obese) of the 5 point body condition scoring (BCS) system (Edney and Smith, 1986) (Appendix C). Written informed consent was given by all dog owners and the study was approved by the University of Glasgow Ethics and Welfare Committee.

5.2.2 Weight-loss programme

Owners of dogs, cats and rabbits are eligible to apply for the Pet Fit Club competition, but only dogs who took part were included in this study (Figure 5.1). The Pet Fit Club takes place over 6 months each year and dogs were switched to a therapeutic weight loss diet for the duration of the competition. Dogs were fed either Hill's Prescription Diet r/d (Hill's Pet Nutrition Inc, USA) or Bakers Complete Weight Control (Purina, Nestlé Purina PetCare Company, USA). Ideal weights and food rations were determined by a veterinary surgeon and owners were asked to weigh food allocation for each day by using kitchen scales. No formal PA counselling took place. Dogs were seen every 4-6 weeks throughout the course of the weight loss program and change in body weight monitored between baseline and 6 months for all dogs.

Figure 5.1 A comparison showing change in weight from baseline (20.5kg (top)) to completion (14.1kg (bottom)) in one of the participants included in this study (PDSA, 2012)

5.2.3 Accelerometer placement and settings

ActiGraph GT3X accelerometers (ActiGraph, FL) were used to measure habitual PA. The GT3X is a lightweight and compact device capable of measuring and reporting movement on the vertical axis only, or on the integrated axis (a combination of the anteroposterior, mediolateral and vertical planes). The accelerometers were attached to the dorsal aspect of each dogs collar in accordance with Yam *et al.* (2011) and set to record activity in 15 second intervals (epoch). Accelerometer data was recorded for both the vertical axis and integrated output, but all analysis was carried out using the integrated output because slippage of the dog’s collar may result in erroneous measurement of PA when only the vertical axis is used.

Accelerometers were mailed to participants once every month during the weight loss programme and owners asked to attach them for three consecutive weekdays, 24 hours per day. Attaching the accelerometers for three weekdays was sufficient to provide a stable estimate of usual levels of PA (reliability 91%) compared to three days including one weekend day (reliability 81%) (Yam *et al.*, 2011). Owners were asked to ensure that the device remained attached for the full monitoring period unless during periods of torrential rain or when the dog was swimming/bathing, as the ActiGraph GT3X is not waterproof. In this case, owners were shown (by the veterinary surgeon at the initial consultation) how to remove and reattach the device and asked to record these periods in an activity diary (Appendix B). Although the accelerometers were attached 24 hours per day, results are shown using daytime wear (6am-11pm) in accordance with previous Chapters and Yam *et al.* (2011). Data were downloaded from the devices using the accompanying Actilife software package (ActiGraph, FL). The raw data files were imported into a spreadsheet and data expressed as activity counts per minute (cpm). All accelerometer records identified periods of zeros which represented the dog sleeping or lying still, each period of zeros was checked against the activity diaries to determine whether the device was being worn. To be eligible for inclusion in data analysis each dog had to have a minimum of three consecutive days of accelerometry.

Four constructs were calculated from the PA data recorded by the accelerometer: total volume of PA, expressed as mean counts per minute (cpm); time spent in sedentary behaviour (no movement of the trunk, e.g. when lying still or sleeping, <1351 cpm); time in light-moderate intensity PA (slow to moderate translocation of the trunk, e.g. slow walking with the dog on a lead, 1352-5695 cpm); and time in vigorous intensity PA (rapid translocation of the trunk, e.g. running outdoors when off lead, >5696 cpm) (see Chapter 2).

5.2.4 Statistical analysis

For each dog, body weight was compared between baseline and month six of the weight loss programme using paired t-tests. General linear models with participant entered as a random effect were used to test for changes in PA variables from baseline to month six. Any PA variables that did not follow a normal distribution were analysed using the Friedman test. The number of dogs participating in the Pet Fit Club was fixed and so sample size was fixed in this long-term observational study. All analyses were carried out using Minitab 16.1.1 (Minitab Inc, PA).

5.3 Results

Sixteen dogs were recruited to the study. One dog was excluded due to its owner not returning the accelerometer sent to them in month 1 and the owner subsequently withdrew due to ill health. One other dog would not wear a collar with the accelerometer attached and so was also excluded from this study. All remaining dogs returned sufficient accelerometry data (greater than or equal to three days wear) at each month and were included in the final analysis.

Characteristics of the study sample are shown in Table 5.1. Two dogs were aged two years or younger (14%), 11 were between three and eight years old (79%) and one was nine years or older (7%). The overall sex distribution was 10 (71%) male neutered and four (29%) female neutered. At baseline 10 (71%) dogs were classed as obese (BCS 5) and four (29%) were classed as overweight (BCS 4). Mean body weight at baseline was 40.1kg (SD 16.1) compared to 34.1kg (SD 14.7) at month six, a difference of 6kg, or 15% reduction in mean body weight between baseline and month six ($P < 0.001$).

Variable	Number of study dogs	% of study dogs
Sex		
Male Entire	0	0
Male Neutered	10	71
Female Entire	0	0
Female Neutered	4	29
Age (years)		
1 to 2	2	14
3 to 8	11	79
9+	1	7
Breed		
Labrador	3	21
Rottweiler	3	21
Cavalier King Charles	2	14
Cocker Spaniel	2	14
Border Collie	1	7
German Shepherd	1	7
Shiba Inu	1	7
Springer Spaniel	1	7
BCS		
4 (Overweight)	4	29
5 (Obese)	10	71

Table 5.1 Descriptive characteristics of dogs (n = 14)

In the final analysis, mean duration of accelerometer wear was 1020 mins/day (SD 0) at month one, 1019 mins/day (SD 5) at month two, 1019 mins/day (SD 3) at month three, 1020 mins/day (SD 0) at month four, 1015 mins/day (SD 20) at month five, and 1018 mins/day (SD 16) at month six. Table 5.2 compares PA variables across all six months for all dogs. There were no evidence of statistically significant differences in any PA variables between baseline and month six. Dogs spent a high proportion of waking hours (between 6am – 11pm) in sedentary behaviour during measured days each month; mean time spent sedentary was greater than 14 hours/day in each month. In contrast the amount of time spent in vigorous intensity PA was relatively low, ranging from six to nine mins/day.

	Month 1	**Month 2**	**Month 3**	**Month 4**	**Month 5**	**Month 6**	***P***
Accelerometer wear time (mins/d)	1020 (0)	1019 (5)	1019 (3)	1020 (0)	1015 (20)	1018 (16)	0.67
Total volume of PA (mean cpm)	577 (128)	560 (107)	533 (136)	586 (142)	607 (98)	611 (142)	0.14
Sedentary time (mins/d)*§	872 (33)	877 (31)	875 (45)	863 (43)	853 (34)	855 (50)	0.20
Light-moderate intensity PA (mins/d)†§	140 (28)	134 (31)	139 (44)	149 (39)	152 (26)	155 (38)	0.13
Vigorous intensity PA (mins/d)‡§	8 (7)	9 (7)	6 (4)	7 (6)	8 (5)	8 (6)	0.82

Values are mean ± standard deviation

Mins/d includes day time wear only (6am – 11pm).

*<1351 accelerometer cpm

†1352 to 5695 accelerometer cpm

‡>5696 accelerometer cpm

§Statistical comparisons on non-normally distributed variables were performed using the Friedman Test, means shown for ease of interpretation

Table 5.2 Physical activity and sedentary time during daytime hours (6am-11pm) in dogs during a 6 month weight loss programme (n = 14)

5.4 Discussion

To the authors knowledge this is the first study to assess changes in PA using ActiGraph accelerometry in a sample of pet dogs undergoing a calorie controlled weight loss programme. There was no evidence of a significant change in total volume of PA, light-moderate intensity PA, vigorous intensity PA or sedentary behaviour between baseline and month six, even though dogs lost, on average, 15% of their initial body weight. This finding suggests that there is no evidence that substantial weight loss alone leads to a spontaneous increase in PA or a reduction in sedentary behaviour.

A recent review concluded that PA increases spontaneously in humans after bariatric surgery (Jacobi *et al*., 2011) which is the most successful method in humans of achieving the kind of substantial weight loss found in the present study (Eldar *et al*., 2011). However, most of the studies included in the review used subjective measures of PA such as self-assessment. In the few studies measuring PA pre and postoperatively using objective methods such as pedometry and accelerometry, PA did not increase significantly (King and Bond, 2013), as was the case in this canine study.

Even though PA may have been discussed at monthly weigh-ins this did not constitute PA counselling in the present study as owners were not asked to increase their dog's PA by specific amounts, given any formal guidance, nor advised on behaviour change techniques such as goal setting and rewards to increase PA as would normally be used in PA interventions in humans (Ward *et al*., 2006, Sallis *et al*., 2008).

It has been suggested that obesity suppresses PA in humans (Bauman *et al.*, 2012). However, the present study indicates that this may not be the case in dogs, since substantial weight loss alone did not lead to increased PA. However, the findings must be interpreted with caution; owner habits including the amount and type of opportunities for PA they provide for their dogs, including whether or not dogs are exercised on or off lead, were not assessed in this study, and could explain the lack of any detectable increase in dog PA. Furthermore, when left alone dogs are often confined to one room or area of the house (Westgarth *et al*., 2008). Opportunities for PA in dogs may therefore be largely determined by their owner, and any tendency for substantial weight loss to produce increases in PA in dogs may be constrained by owner-related factors. These factors should be considered in future studies of weight loss and effects on PA in dogs. Future studies are also required to assess whether combined PA and diet weight loss programmes will not only result in clinically significant weight loss but also increase the amount of PA dogs do.

A recent pilot study of a dog walking intervention designed to increase PA in owners found that owners in the intervention group increased the amount of steps taken per day more than those in the control group (Rhodes *et al.*, 2012). Unfortunately PA was not measured in the dogs participating in the study by Rhodes *et al.*, but it is reasonable to assume that since both owner PA and the amount of dog walking increased, PA also increased in the dogs.

However, evidence to date would indicate that owner compliance may be a problem even if more information is given about the benefits of PA; a recent study where owners were encouraged to walk their dog two miles per day during a weight loss programme, did not result in an increase in step count by the dogs (Wakshlag *et al.*, 2012). The PA component of a weight loss intervention in dogs might need to be a more intense, theory based intervention and include techniques widely used in human behaviour change interventions (Hughes *et al.*, 2008). These include techniques such as decisional balance (comparative potential gains and losses of increasing PA), self-monitoring of dog walking, goal setting and rewards, behavioural contracting, problem solving, and relapse prevention. Testing the efficacy of an intervention of this nature would require a large sample size to compensate for poor compliance and would require a PA research assistant trained in these techniques to deliver the intervention.

There are a number of strengths in the present study. PA was assessed objectively using ActiGraph accelerometry, a valid, practical and reliable method for assessing PA in pet dogs (Yam *et al.*, 2011) that is able to categorise PA by intensity (Chapter 2). The longitudinal design of the study was advantageous compared to cross sectional designs and allowed for the assessment of long term changes in PA and sedentary behaviour, and the longitudinal design combined with an intervention focused on diet (not PA) permitted a useful test of the hypothesis that substantial weight loss alone would increase PA. Despite the obvious strengths of the study there is no suggestion of a marked increase in PA associated with substantial weight loss in dogs and therefore the results do not support this hypothesis. Although the animals in this study did lose a substantial amount of weight it is still important to promote PA for other reasons besides weight loss. Increased PA is likely to have a positive impact on cardiovascular risk factors, will maintain muscle mass and RMR, which may prevent subsequent weight gain (assuming calorie intake remains stable), and is likely to improve quality of life (German, 2010).

The Pet Fit Club is a well-established weight loss competition in the UK and the weight loss programme was designed by the PDSA prior to conception of the present study. Therefore it was not the authors’ intention to test whether dogs taking part lost weight during a calorie controlled weight loss programme, but solely to observe changes in PA and sedentary behaviour during substantial weight loss in such a programme. As such there was no need for a control group in the present study. Future studies with randomised controlled designs would be able to answer questions that the present study cannot; for example, would a more structured, theory based PA component increase PA and/or weight loss more than in the present study? Although this study did not detect any significant changes in PA or sedentary behaviour, it is useful for clinical practice in suggesting that to bring about change in PA during dieting some form of additional PA counselling or advice is required.

5.5 Conclusions

The present study shows that there was no evidence that objectively measured PA and sedentary behaviour changed markedly during six months of substantial weight loss in dogs. Habitual PA may not be supressed by obesity in dogs, and to facilitate an increase in PA and reduction in sedentary behaviour during a weight loss programme, specific PA promotion may be needed, as is the case in humans.

6 Children, parents and pets exercising together (CPET): exploratory randomised controlled trial.

6.1 Introduction

Levels of objectively measured MVPA are much lower than recommended in UK children (Riddoch *et al.*, 2007, Basterfield *et al.*, 2008, McLure *et al.*, 2009, Basterfield *et al.*, 2011), a worrying observation considering that MVPA is associated with numerous health benefits including significant improvements in blood lipids, BMI and body fatness according to a recent systematic review (Janssen and LeBlanc, 2010). Evidence from the UK suggests that objectively measured PA declines and sedentary behaviour increases before adolescence (Owen *et al.*, 2009, Corder *et al*., 2010, Janssen and LeBlanc, 2010, Basterfield *et al.*, 2011). Furthermore, the incidence of obesity (rate of appearance of new cases of obesity) and the degree of excessive weight gain in those who do not become obese is greatest in mid-late childhood (ages 7-11 years old) (Hughes *et al*., 2011b, Hughes *et al*., 2011a). Recent reviews of interventions to promote PA in children have questioned both the magnitude and sustainability of intervention effects (Dobbins *et al.*, 2009, Reilly, 2011, van Sluijs *et al.*, 2011). Few family/home based interventions have been carried out to date (Ward *et al.*, 2006, McMinn *et al*., 2011), even though some family and home factors are associated with low levels of objectively measured PA in mid-late childhood (Ward *et al.*, 2006, King *et al.*, 2011, McMinn *et al.*, 2011). Therefore, there is an opportunity for novel approaches to the promotion of PA in mid-late childhood incorporating a family/home based intervention.

The use of pet dogs represents a potentially valuable and underutilised resource to promote PA in children and their families (Bauman *et al.*, 2001) (see Chapter 1, section 1.6). In Scotland there are approximately 800,000 dogs and 360,000 children of primary school age, and UK dog ownership is estimated to be around 25% of households, with higher dog ownership among families of lower socio-economic status (Westgarth *et al*., 2013). A number of cross sectional studies have shown that PA levels are higher in adults who walk their dogs regularly (Christian *et al*., 2013b) and in children who own a dog (Owen *et al.*, 2010, Christian *et al.*, 2013a) (see Chapter 1, section 1.6.1). However, the prevalence of dog walking among dog owners is often low (see Chapter 1, section 1.6.2). A study carried out in Australia reported that only 23% of 5-6 year olds and 37% of 10-12 year olds ever walked with their dog (Salmon *et al.*, 2010). In addition, a recent North American study found that adult dog owners receiving a low intensity dog walking intervention, which focused on the benefits of walking for the dog, increased their PA levels more than owners who did not receive the intervention (Rhodes *et al.*, 2012). Promotion of more walking and play with the dog could be a useful strategy to promote family, and in particular, child PA.

There is a dearth of objective information on the type of dog walking by owners and their families; previous estimates of the frequency and duration of dog walking are derived solely from subjective measures such as questionnaires. One recent Australian study found that only 23% of owners walked their dog five or more times per week (Cutt *et al.*, 2008b) and a study in North America found that, among those who reported walking their dog, the median frequency was three times per week with a median duration of 25 minutes (Reeves *et al.*, 2011). Another Australian study found that children who owned a dog walked the dog on average 1.7 times per week and 32% of owners reported that they rarely or never walked their dog as a family (Salmon *et al.*, 2010). None of these studies measured dog walking objectively, or assessed the intensity of PA achieved during dog walking, which is an important consideration for maximal health benefits.

The UK Medical Research Council Framework for the development and evaluation of complex interventions in public health recommends that definitive trials should be preceded by exploratory trials to provide information about the design, feasibility and acceptability of a trial and intervention (Craig *et al.*, 2008). Information regarding the delivery of the intervention, recruitment and retention rates, and effect sizes of outcomes can also be gleaned to help inform future more definitive trials. For example, a recent pilot study exploring the feasibility and acceptability of an intervention aimed at promoting movement skill and PA in children found that recruitment and retention rates, collection of outcome data and delivery of intervention sessions were all high, and staff involved in implementing the intervention reported high satisfaction with the program (Jones *et al.*, 2011). In contrast, a feasibility study evaluating an adolescent sexual health intervention found that the intervention was unlikely to be deliverable, leading to substantial changes to both the content and delivery of the original intervention (Power *et al.*, 2004). Therefore, an exploratory evaluation of an intervention is required to ensure that subsequent interventions are appropriately designed and developed.

The aim of this chapter is therefore to report on the feasibility of the Children Parent’s and Pets Exercising Together (CPET) intervention and trial, the acceptability of the trial and intervention, preliminary evidence of its potential efficacy, planning and powering a future intervention, and to improve our understanding of the frequency, intensity and duration of dog walking among dog owning families in Scotland.

6.2 Materials and methods

6.2.1 Design, Randomisation, Blinding

CPET was an individual, exploratory RCT, and followed guidance on the conduct and reporting of RCT outlined in the CONSORT[1] statement (Schulz *et al.*, 2010). After baseline outcome measures were made, participating families were allocated randomly to intervention or control group in the ratio of 1.5: 1, respectively, using random number generation in Minitab.

Allocation concealment was ensured by separation of the process of allocation from the researchers involved in the outcome measures. Blinding of researchers who made the outcome measures was achieved by having two researchers at separate sites, one responsible for carrying out the intervention, and the other responsible for carrying out the outcome measures.

6.2.2 Trial Feasibility

6.2.2.1 Study sample, recruitment, and inclusion criteria

Invitation letters were sent to approximately 350 dog-owning parents, with children attending mainstream primary schools, in one local authority area, East Dunbartonshire, in the West of Scotland. Families that responded to the letter were included only if they: provided consent to participation; had children age 9-11 years; owned a dog; children and parents had no physical or intellectual impediment to participating; at least one parent was willing to be the focus of the intervention (and be responsible for taking part in the intervention sessions and outcome measurement sessions); and if their dogs were deemed physically and psychologically safe to participate in the intervention.

Parents were asked to complete a dog behaviour screening questionnaire (Appendix E), developed and assessed by two members of the Association of Pet Behaviour Counsellors which examined whether it was appropriate for each dog to take part in the study. Dogs

[1] The CONSORT statement is an evidence based minimum set of recommendations for reporting randomised trials

that did not pass the screening questionnaire and those which were physically unable to take part were excluded.

The Carstairs Score (McLoone, 2004) was used as a proxy for socio-economic status of study participants. The Carstairs score is a deprivation measure derived from UK census data and each postcode area is classified into a deprivation category (DEPCAT for short) ranging from 1 (most affluent) to 7 (most deprived). Finally, a CONSORT study flow diagram (Schulz *et al.*, 2010) was used to summarise sample attrition and missing data for all of the outcome measures. Data on exclusion, recruitment, retention, number of missed intervention sessions and number of completed outcome measures are provided as an indicator of trial feasibility.

6.2.2.2 Intervention and Control Groups

The intervention group participated in a staggered 10-week intervention, from March 2012 to June 2012, which aimed to increase the frequency, intensity, and duration of dog-walking/ playing with the family dog. The intervention relied most heavily on modification of the family environment, and the importance of parental support for child PA was emphasised throughout (Ward *et al.*, 2006, King *et al.*, 2011, McMinn *et al.*, 2011, van Sluijs *et al.*, 2011). The intervention used the principal client-centred behavioural change techniques which derive from social cognitive theory (Ward *et al.*, 2006). These included decisional balance (the balance between comparative pros and cons of behaviour change), self-monitoring of dog walking/physically active play with the family dog (including a simple dog walking activity chart), goal setting, rewards, behavioural contracting, problem solving, and relapse prevention. All of these techniques are well established in adult behaviour change interventions, and are also used widely in behaviour change interventions with children of this age (Hughes *et al.*, 2008). Self-monitoring in the intervention group was facilitated by the use of child and parent accelerometry data collected at baseline. The baseline PA data was shared with intervention families to encourage an awareness of the true rather than perceived levels of PA and sedentary behaviour which may help motivate families to increase their PA (Corder *et al*., 2011). Sharing of baseline accelerometry data with the intervention group also facilitated the setting and monitoring of more realistic PA and dog-walking goals by families. Families in the intervention group were also shown a lay summary of baseline accelerometry data for their dog to encourage a realistic understanding of current dog walking behaviour and baseline levels of PA of their dog.

The intervention targeted parents and children being physically active together, using their pet dog to aid this process. It consisted of: promotion of child play with the dog by provision of a portfolio of suggested games such as 'hide and seek' and 'obstacle course' to be played outdoors and indoors; the provision of greater access to dog walking opportunities in the wider environment by providing intervention group families with information on dog walking routes, dog waste bins, and maps, describing outdoor spaces in the immediate environment and further afield; promotion of parental support for PA involving the dog, both modelling of PA and parental encouragement and logistical support; and the provision of <£15 worth of toys to promote PA, such as Frisbees, and dog walking equipment per family intended to facilitate play with the dog outdoors and more controlled walking with the dog, with guidance on the appropriate use of these materials from the Animal Behaviourist.

The intervention is outlined in brief in Table 6.1. Intervention families received one 60-minute home visit in week zero (at baseline following measures) from a qualified Animal Behaviourist consisting of a dog-walking/play/training session to help screen dogs and families for safety aspects of the intervention, to provide support for the practical physical aspects of dog walking (e.g. best use of equipment) and to train families and dogs to interact in ways most likely to promote the PA of both family and dog. Families in the intervention group received two further home visits in weeks one and six from a PA research assistant to provide an overview of the intervention timeline and content, and to discuss progress and review goals etc. In addition, intervention families received telephone calls (weeks two and eight) and text messages (weeks four and 10) to review goal progress, address questions and provide encouragement.

Each family in the intervention group were given a CPET intervention booklet (Appendix F) at baseline which contained: information regarding the content of the intervention; the intervention timeline; information on the benefits of PA; ideas for incorporating more PA in to their lifestyle; ideas for being more active with their dog (games, safe places to walk etc.); and a dog walking diary and reward chart (Appendix G) to record activities with the dog and for children to place stickers on to keep track of rewards.

The control group did not receive any of the information/content delivered to the intervention group and were asked to carry on as normal for the duration of the study.

Week	Contact Type	Personnel	Content
0	Visit	Animal Behaviourist	Safety screening for family and dog; best practice of equipment use; practical training aspects of PA interactions with child and dog.
1	Visit	PARA	Overview of intervention timeline; decision balance; discussion of individual physical activities and sedentary behaviours; identifying alternative behaviours; goal setting; reward structure; self-monitoring (Activity Chart).
2	Telephone (verbal)	PARA	Review goal progress and self-monitoring; address other questions; review social support; provide positive reinforcement.
4	Telephone (text)	PARA	Statement of positive encouragement relating to individual goals plus a helpful hint to becoming more active.
6	Visit	PARA	Review goal progress, self-monitoring and rewards; relapse prevention.
8	Telephone (verbal)	PARA	Review goal progress, self-monitoring; address any questions; positive encouragement.
10	Telephone (text)	PARA	Statement of positive encouragement relating to individual goals plus reminder of forthcoming post intervention measurements.

PARA: Physical activity research assistant

Table 6.1 Content of CPET intervention

6.2.2.3 Acceptability of the intervention

As part of the study's process evaluation and to inform future interventions, a brief study exit questionnaire (Appendix H) was used to obtain feedback on the intervention from all families in the intervention group. This was used to identify: perceived barriers and facilitators of the intervention; perceptions of the acceptability of the intervention and the outcome measures; and suggestions for future interventions.

A qualitative study was conducted once the intervention was complete involving a focus group with 6 participating parents from the intervention group, a separate focus group with 6 participating children from the intervention group, and interviews with four key stakeholders (a vet; a pet behaviour counsellor; a walking development officer; and a public health policy manager). A qualitative study of this kind is useful in exploratory studies (Campbell *et al*., 2007b) and in the context of the present study was used to: inform the process evaluation of the intervention; obtain participant views on the acceptability of the intervention and outcome measures; and obtain participant suggestions for the intervention to be developed for a future larger, longer term trial.

6.2.2.4 Baseline dog walking

Parents were asked about the frequency and duration of dog walking (included in dog screening questionnaire, Appendix E). Dog walking was also identified by analysis of simultaneous accelerometer records, both parent only dog walking (assessment of parent and dog accelerometer records) and family dog walking (assessment of participating parent, child and dog accelerometer records) at baseline.

6.2.3 Potential efficacy

6.2.3.1 Outcome Measures

Outcomes were measured at baseline and 11 weeks later (in the week after the end of the intervention for the intervention group) and are listed in Table 6.2.

	Outcomes
Children ***Primary outcome***	• 10 week change (baseline-1 week post-intervention) in objectively measured total volume of PA with the ActiGraph GT3X accelerometer (The ActiGraph, Florida) using the accelerometry count per minute (cpm) averaged over 7 days.
Children ***Secondary outcomes***	• Changes in objectively measured light intensity PA (800-3200 cpm (Puyau *et al.*, 2002)), MVPA (≥3200 cpm (Puyau *et al.*, 2002)) and sedentary behaviour (<800 cpm (Puyau *et al.*, 2002)) with the ActiGraph GT3X accelerometer (The ActiGraph, Florida); • Changes in sitting time using the pragmatic cut-point, not yet validated and calibrated, of 150 cpm (Salmon *et al*., 2011) with the ActiGraph GT3X accelerometer (The ActiGraph, Florida); • Changes in body composition (fat mass index and lean mass index) and in whole body and lumbar spine bone mineral content using a Lunar Prodigy whole-body DXA scanner (GE Medical Systems, Madison, WI) in conjunction with encore software version 13; • Changes in body weight and in BMI z scores expressed relative to UK 1990 reference data. Height measured using a Seca Leicester Stadiometer (Seca, Birmingham, United Kingdom) and weight measured using Seca digital scales (Seca, Birmingham, UK); • Changes in Child Health Related Quality of Life, as reported separately by both the children and their parents, using the PedsQL which is practical, valid and sensitive to change resulting from lifestyle interventions (Hughes *et al*., 2007, Hughes *et al.*, 2008).
Parents ***Secondary outcomes***	• Changes in objectively measured total volume of PA, over 7 days, with the ActiGraph GT1M accelerometer (The ActiGraph, Florida) using the accelerometry cpm; • Changes in light intensity PA (100-1951 cpm (Freedson *et al.*, 1998)) , MVPA (≥ 1952 cpm (Freedson *et al.*, 1998)) and sedentary behaviour (<100 cpm (Freedson *et al.*, 1998)) with the ActiGraph GT1M accelerometer (The ActiGraph, Florida); • Changes in body weight and BMI
Dog ***Secondary outcomes***	• Changes in objectively measured total volume of PA, over 7 days, with the ActiGraph GT3X+ accelerometer (The ActiGraph, Florida) using the accelerometry cpm; • Changes in light-moderate intensity PA (1352-5695 cpm; see Chapter 2), vigorous intensity PA (≥5696 cpm; see Chapter 2) and sedentary behaviour (<1352 cpm; see Chapter 2) with the ActiGraph GT3X+ accelerometer (The ActiGraph, Florida); • Changes in body weight and body condition score (Edney and Smith, 1986).

Table 6.2 CPET outcome measures

In addition to the primary and secondary outcome measures listed in Table 6.2, changes in family dog walking behaviour were also measured (number of walks/week; total duration of walking time; average duration of walking time; child mean accelerometer cpm; percent time child spent in MVPA; parent mean accelerometer cpm; percent time parent spent in MVPA; dog mean accelerometer cpm; and percent time dog spent in vigorous intensity PA) by assessing simultaneous ActiGraph accelerometry data from parent, child, and dog, identifying periods when all three were physically active together.

Valid accelerometry data (see Chapter 1, section 1.2.2.3.6) was defined as a minimum of three consecutive days and a minimum of six hours per day in children (Penpraze *et al.*, 2006), a minimum of three consecutive days (Trost *et al.*, 2005) and a minimum of 10 hours per day in adults (Troiano *et al.*, 2008), and a minimum of three consecutive days in dogs (Yam *et al.*, 2011). Participants were asked to record periods when the accelerometer was not worn in an activity diary (Appendix I) and these were removed from the accelerometry data.

6.2.3.2 Statistical Analysis and Sample Size Considerations

At the time of designing this study the effect of a dog walking intervention with children and their families was unknown and there were no comparable intervention data to inform a power calculation. The aim of this study was to enter approximately 40 families, a sample size that would be appropriate for an exploratory trial and indeed would be larger than many previous PA intervention studies in childhood (Dobbins *et al.*, 2009, van Sluijs *et al.*, 2011). While no comparable data exist to inform a sample size calculation, an estimate of the sample size required to detect a statistically significant difference in the primary outcome measure (child total volume of PA (accelerometry cpm)) can be calculated by assuming a moderate effect size, equivalent to the pooled mean paired difference between primary school age children with a variety of mild chronic diseases and matched healthy controls (using unpublished data from Penpraze *et al*.). This estimate involves an increase in daily accelerometry count in the intervention group equivalent to 187 cpm with no change in the control group, and an SD of 160 cpm for the difference in the change between groups. With 80% power at $p = 0.05$, this difference would be detectable in the present study with 15 families per group. The difference between groups is 18% when expressed as a difference in the change in accelerometry cpm between intervention and control groups. This is not equivalent to a difference in total volume of PA of 18% as there is not a 1:1 relationship between total volume of PA and accelerometer cpm (Basterfield *et al.*, 2011). The difference between groups in the change in PA assumed for the power calculation is equivalent to around a 6% difference (40 minutes/day) in total volume of PA between groups, equivalent to a difference in total time spent sedentary between groups of approximately 40 minutes per day (Basterfield *et al.*, 2011).

Statistical analysis was carried out on both an intention to treat and per protocol basis. For the intention to treat analysis missing data were replaced using the last measure carried forward method. Any family with missing child, parent or dog accelerometry data were excluded from analysis of family dog walking behaviour. The intervention and control groups were compared using analysis of covariance, with the follow-up measure as the dependent variable, group as the independent variable, and the baseline measure as the covariate (Vickers and Altman, 2001). All analyses were carried out using Minitab 16.1.1.

6.2.3.3 Planning and powering future interventions

CPET is an exploratory study, with the main focus to report on the feasibility and acceptability of the intervention. However, CPET was also intended in part to inform future sample size calculations for the outcome measures used. A post-hoc power calculation was carried out using Minitab 16.1.1 to estimate the sample size needed to detect differences in the primary outcome measure (child total volume of PA (accelerometry cpm)) in a future, larger scale trial. Power was set at 80%, alpha at 0.05 and the square root of the mean square error used to estimate sample standard deviation.

6.2.4 Ethical and safety considerations

The study was approved by the University of Glasgow College of Medical, Veterinary, and Life Sciences Ethics Committee, the University of Glasgow School of Veterinary Medicine Ethics and Welfare Committee, and the University of Liverpool Leahurst Research Ethics Committee. Informed written consent to participation was received from each participating child, and from each participating parent.

Safety of the intervention was enhanced by emphasising throughout the recruitment phase, and the intervention sessions, that the focus of the intervention was the family and dog being active together and that children should not walk the dog alone without the parent. Safety was further enhanced by the dog screening process prior to the intervention commencing. All families providing signed consent had to complete the dog screening questionnaire and all participating families received a visit from a certified clinical Animal

Behaviourist. This process was intended to exclude dogs which were physically unable to take part, and those which were behaviourally unsuitable for the intervention because of their tendency towards nervousness, aggression, or other behaviours which might make the intervention unsafe (e.g. strong drive to chase).

6.3 Results

6.3.1 Feasibility of the trial

The flow of study participants and sample attrition are summarised in Figure 6.1. Of the 37 primary schools approached, all but two gave permission for researchers to discuss with and give information to children about the study. One-hundred and twenty-seven dog owning families returned a note of interest in the study and were subsequently sent information packs and consent forms. Of those 127 families, 36 (28%) returned signed consent forms. Four (11%) of the 36 families who returned consent subsequently declined to participate, three (8%) did not meet our inclusion criteria (one family was excluded on the grounds of their dog being too aggressive and the other two due to medical conditions with their dog), and one family did not respond to repeated attempts to contact them (3%).

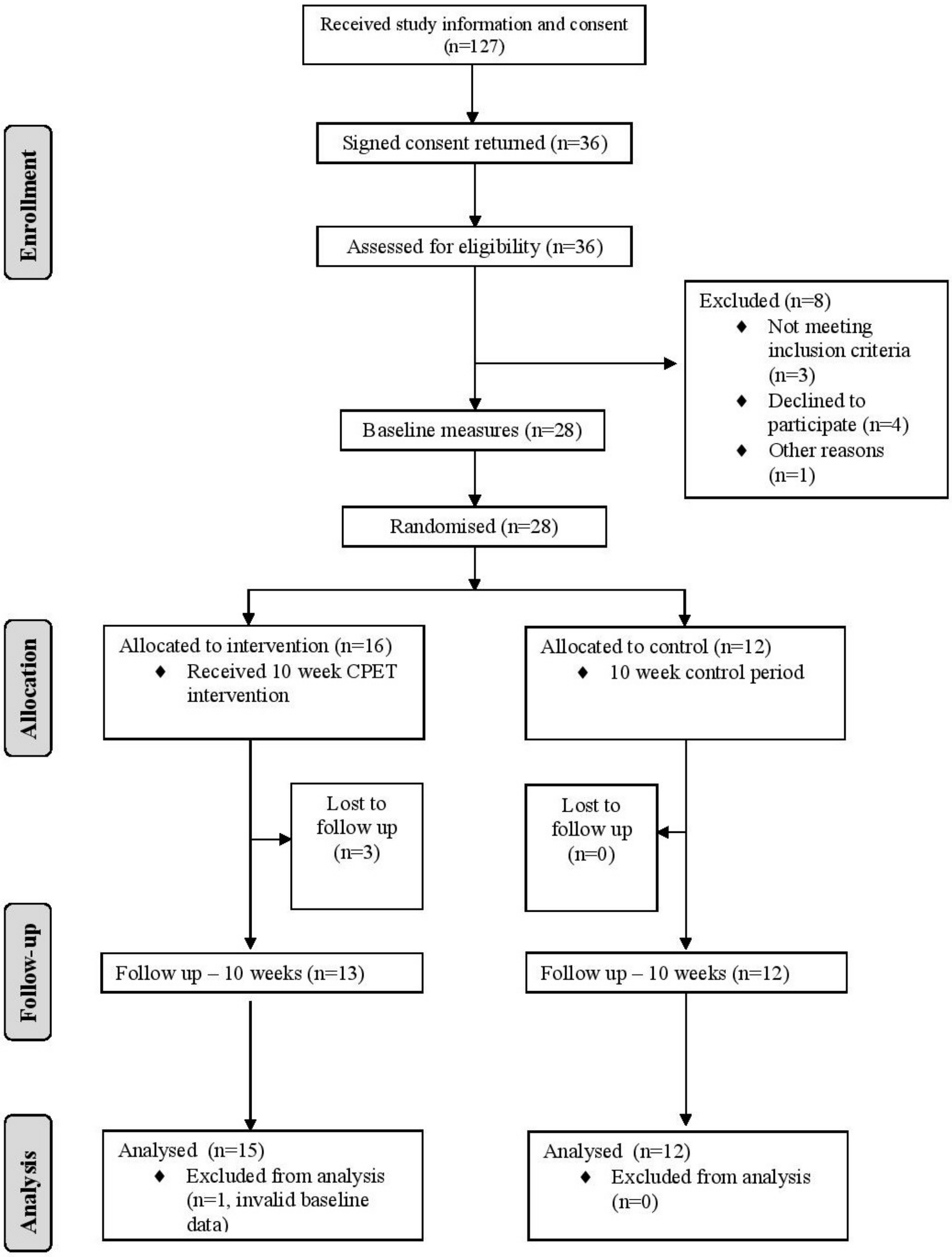

Figure 6.1 Flow of the CPET study participants

Twenty-eight families (22% of those who expressed an interest), two of which had two eligible children, were recruited in the study and 25 (89%) were retained at follow up. One family became disengaged very early on in the intervention and withdrew, another family had to withdraw due to medical reasons and the third family did not respond to telephone calls and it was not possible to arrange follow up measures. Body weight, BMI, body BCS and child health related quality of life data were collected for all 28 families (100%) at baseline and all 25 families (100%) at follow up. There was only a small number of available dual energy X-ray absorptiometry (DXA) appointments after school hours and suitable appointments for some families were unavailable, therefore body composition (lean mass index and fat mass index) and bone mineral content data were collected for 25/30 children (82%) at baseline and for 23/27 children (84%) at follow up.

Objectively measured PA data were collected for 30/30 children (100%), 27/28 parents (96%) and 27/28 dogs (96%) at baseline, and 27/27 children (100%), 24/25 parents (96%) and 24/25 dogs (96%) at follow up. At baseline, one parent wore the accelerometer for less than two days and one accelerometer being worn by a dog malfunctioned. Therefore, these accelerometry data could not be included in the analysis (these participants were from the same family who later withdrew due to disengagement with the intervention).

Immediately after baseline measures were carried out, all 15 intervention families were available for the first intervention session delivered by the Animal Behaviourist. All 15 intervention families were available for the first visit by the PA research assistant, and 14/15 were available for the second visit. Thirteen of 15 intervention families were available for all home visits and telephone calls/text messages, one family missed only one text message and another missed one telephone call and two text messages. Overall 85/90 PA sessions were delivered, with all families who were available at follow up (12) attending all sessions, meaning that 12/15 (80%) families were engaged in the intervention.

6.3.2 Characteristics of participants

Twenty-eight families were recruited to the study, two of these families had two eligible children, therefore 30 children, 28 parents and 28 dogs were included in the study sample. The mean age of children in the sample was 10.9 years with 80% (24/30) classified as healthy weight, 13% (4/30) as overweight and 7% (2/30) as obese. The mean age of parents in the sample was 44.8 years with 50% (14/28) classified as healthy weight, 36% (10/28) as overweight and 14% (4/28) as obese. The mean age of dogs in the sample was 3.7 years with 89% (25/28) classified as healthy weight, 11% (3/28) as overweight and 0% as obese. Sixty-seven percent (20/30) of children and 82% (23/28) of parents who participated were female. Thirty-nine percent (11/28) of families were classified as DEPCAT 1, 39% (11/28) were classified as DEPCAT 2, 18% (5/28) were classified as DEPCAT 3, and the remaining 4% (1/28) classified as DEPCAT 6.

6.3.3 Baseline PA and dog walking

Mean total volume of PA in children was 522 (SD 125) cpm at baseline. Children spent 80% (SD 4) of accelerometer wear time sedentary (equivalent to > nine hours/d), 16% (SD 3) in light intensity PA (equivalent to ~ 1 hour 53 mins/d), and 3% (SD 2) in MVPA (equivalent to ~ 21 mins/d). The mean length of sitting bouts in children was 5 (SD 1) minutes, with a mean of 12 (SD 2) breaks per sitting hour and children spent 14% (SD 6) of wear time sitting in bouts longer than 30 minutes. Mean total volume of PA in parents was 430 (SD 148) cpm at baseline.

Parents spent 59% (SD 8) of accelerometer wear time sedentary (equivalent to > eight hours/d), 35% (SD 7) in light intensity PA (equivalent to > 4 hours/d), and 6% (SD 3) in MVPA (equivalent to ~ 50 mins/d). The mean length of sedentary bouts in parents was 6 (SD 2) minutes, with a mean of 10 (SD 2) breaks per sedentary hour and parents spent 17% (SD 8) of wear time in sedentary bouts longer than 30 minutes. Mean total volume of PA in dogs was 818 (SD 230) cpm at baseline. Dogs spent 80% (SD 5) of wear time sedentary (equivalent to > 13 hours), 17% (SD 4) in light-moderate intensity PA (equivalent to > two hours), and 3% (SD 1) in vigorous intensity PA (equivalent to ~ 30 mins/d).

At baseline parents reported that they walked their dog two to three times daily with a mean duration of 34 minutes (SD 23) per walk. However, analysis of simultaneous parent and dog (parent only dog walking) accelerometry data suggests parents walked their dog one to two times per day with a total duration of 20 (SD 13) minutes total dog walking per day. When analysis of simultaneous accelerometry data were extended to include children (i.e., family dog walking) dog walking decreased further to an average of less than one family walk per day with a total duration of six (SD 7) minutes per day. At baseline children spent 21% (SD 19) of dog walking time in MVPA and parents spent 39% (SD 38) in MVPA.

6.3.4 Acceptability of the intervention

All parents in the intervention group were asked to complete a short study exit questionnaire which was completed by 13/14 (93%) intervention parents who were available at follow up. Eleven of 13 parents (85%) agreed that the intervention content delivered by the Animal Behaviourist was sufficient to allow them to participate in a safe manner; no parents disagreed. Furthermore, 12/13 (92%) parents agreed that the PA aspects of the intervention content were sufficient to raise awareness of current PA levels.

Moreover, 10/13 (77%) parents agreed that the intervention content was sufficient to motivate them to increase the amount of dog walking they did previously, and 12/13 (92%) agreed that it was sufficient to increase the amount of dog walking that their children did. Parents were also asked about barriers to participation in CPET (lack of motivation, lack of enjoyment, injury/illness, lack of time etc.); 7/13 (54%) parents agreed that they were restricted from taking part due to a lack of time. Finally, parents were asked for their thoughts on the CPET outcome measures. Only 1/13 parents (8%) reported that there were too many outcome measures and none reported that they were asked to do too much PA during the intervention.

Small focus groups were carried out, one with children in the intervention group (n=6) and the other with parents in the intervention group (n=6). Both children and parents reported that the acceptability of the intervention and outcome measures was high. Children enjoyed taking part in the CPET study and felt that it made them more active because of the fun games that they played outside and they enjoyed filling in the reward chart. They highlighted that it was a way to decrease screen time and that they bonded more with their dog. Overall, the children reported that CPET "makes you healthy, happy and is lots of fun". Parents felt that the reward chart and knowledge of their baseline PA levels were the catalysts in motivating them to adhere to the 10 week intervention. They reported that they had experienced longer, more fun family walks. Some parents reported that their children were more physically active whilst others felt it had replaced other forms of PA, e.g. playing with friends outdoors. All parents mentioned that the behaviour of their dog was better and they were "happier knowing that my dog and my child were being more active". Finally, four key stakeholders were interviewed: a vet; a pet behaviour counsellor; a walking development officer; and a public health policy manager. All four were in agreement that the CPET intervention had great potential to improve health for children, their parents and pet dogs. Challenges highlighted by these stakeholders were around how to motivate families to take part, particularly those from less affluent areas where their immediate environment may not feel safe or attractive for families to explore. Stakeholders repeatedly highlighted practical time issues and when to fit in bouts of dog walking as barriers, particularly for working parents.

6.3.5 Potential efficacy

The results of the intention to treat analyses are shown in Tables 6.3-6.6. Change in family dog walking behaviour, sedentary behaviour, total volume of PA and time spent in different intensities of PA are shown in tables 6.3-6.4 and changes in body composition and child health related quality of life in tables 6.5-6.6.

6.3.5.1 Change in family dog walking behaviour

Changes in family dog walking behaviour for intervention and control groups are shown in Table 6.3. There was no evidence of significant differences in the number of walks per week or total duration of walks per week. There were also no evidence of significant changes in mean accelerometer cpm for children or parents during dog walking, or the amount of time spent in MVPA. However, there was a significant difference in the amount of time spent in vigorous intensity PA for dogs during dog walks ($p = 0.03$), although the reported effect size was small ($d = 0.24$). Effect sizes were also small for all other outcomes except the amount of time dogs spent in light-moderate intensity PA ($d = 0.53$).

6.3.5.2 Sedentary behaviour and PA

Table 6.4 shows the results of PA related outcomes. Mean duration of accelerometry monitoring at baseline in children was 6.8 days (SD 0.6) with mean duration of 12.2 h (SD 1.6) per day. At follow up mean duration of accelerometry monitoring in children was 6.0 days (SD 1.1) with mean duration of 12.3 h (SD 1.8) per day. Mean duration of accelerometry monitoring in parents at baseline was 6.7 days (SD 0.9) with mean duration of 14.3 h (SD 1.3) per day. At follow up, mean duration of accelerometry monitoring in parents was 6.5 days (SD 1.2) with mean duration of 14.0 h (SD 2.0) per day. Mean duration of accelerometry monitoring in dogs at baseline was 6.8 days (SD 0.9) with mean duration of 16.8 h (SD 0.5) per day. At follow up, mean duration of accelerometry monitoring in dogs was 6.9 days (SD 0.9) with mean duration of 16.6 h (SD 1.0) per day.

There was no evidence of significant differences in the total volume of PA, amount of time being sedentary or the amount of time in light intensity PA or MVPA for children or their parents. Small effect sizes were reported for all PA outcomes in children and parents except for total volume of PA in parents ($d = 0.60$). However, the reported effect is negative, i.e., control group parents increased PA from baseline to follow up whereas PA decreased in intervention group parents. There was no evidence of significant differences in any of the PA outcomes for dogs, but medium to large effect sizes were reported for total volume of PA ($d = 0.71$) and amount of time spent in vigorous intensity PA ($d = 0.70$).

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P* ‡**	**Effect size (Cohen's d)**
	N = 15	**N = 12**	**N = 15**	**N = 12**			
Number of walks per week	2.7 (2.1)	2.6 (2.6)	2.6 (1.2)	2 (1.7)	0.5 (-0.4, 1.4)	0.19	0.23
Total duration of dog walking (mins/week)	53 (58)	25 (29)	47 (37)	23 (23)	-4 (-25, 17)	0.12	0.10
Child mean accelerometer cpm* during dog walking	2117 (1289)	1953 (1136)	2784 (1279)	2490 (1724)	130 (-539, 799)	0.41	0.10
% time child spent walk in MVPA†	22.1 (21.4)	18.9 (18.6)	26.1 (21.7)	15.2 (21.7)	7.7 (-1.7, 17.1)	0.12	0.32
Parent mean accelerometer cpm* during dog walking	1996 (1673)	1518 (1205)	2216 (1237)	1601 (976)	137 (-486, 760)	0.39	0.10
% time parent spent walk in MVPA§	45.3 (41.2)	31.7 (34.5)	42.0 (30.8)	20.3 (23.8)	8.1 (-6.4, 22.6)	0.11	0.22
Dog mean accelerometer cpm* during dog walking	3595 (2031)	3549 (2572)	4558 (1746)	3766 (2155)	746 (-345, 1837)	0.39	0.27
% time dog spent in light-mod PA¶	60.4 (34.5)	69.4 (39.3)	55.2 (32.4)	37.6 (40.1)	26.6 (6.8, 46.4)	0.06	0.53
% time dog spent in vigorous PA**	19.6 (17.7)	13.9 (23.2)	24.7 (17.3)	12.7 (19.6)	6.3 (-4.2, 16.8)	0.03	0.24

*cpm = counts per minute

† ≥3200 accelerometer cpm

§ ≥1952 accelerometer cpm

¶ 1352-5965 accelerometer cpm

** ≥5696 accelerometer cpm

‡ Intervention and control groups were compared using analysis of covariance

Of the 28 families recruited, 1 parent and 1 dog (from the same family) returned invalid accelerometry data at baseline and were excluded from analysis.

Table 6.3 Changes in objectively measured family dog walking behaviour for intervention and control groups

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P* ****	**Effect size (Cohen's d)**
Children	**N = 17**	**N = 13**	**N = 17**	**N = 13**			
Total volume (mean cpm)*	521 (112)	524 (144)	548 (216)	521 (147)	30 (-23, 82)	0.62	0.21
% time sedentary†	80.9 (3.4)	80.2 (4.9)	80.7 (5.0)	80.1 (5.3)	-0.1 (-1.8, 2.0)	0.90	0.02
% time in light PA†	16.0 (2.9)	16.7 (3.8)	15.9 (3.6)	16.5 (4.3)	0.1 (-1.5, 1.7)	0.84	0.02
% time in MVPA†	3.1 (1.6)	3.1 (1.9)	3.3 (2.7)	3.0 (1.3)	0.3 (-0.3, 0.9)	0.60	0.20
% time sitting†	56.5 (5.4)	57.0 (7.3)	57.3 (7.7)	56.5 (9.1)	1.3 (-1.6, 4.3)	0.70	0.17
Length of sitting bouts (minutes)	5 (0.5)	6 (1.4)	6 (4.9)	6 (2.1)	1.0 (-0.2. 2.2)	0.66	0.30
Breaks per sitting hour	12.5 (1.4)	12.1 (3.3)	12.0 (2.9)	12.5 (2.9)	-0.1 (-1.3, 1.1)	0.60	0.03
% of wear time in bouts > 30 minutes	12.3 (4.9)	15.8 (7.6)	15.2 (15.7)	17.4 (9.7)	1.3 (-3.0, 5.7)	0.90	0.11
Parents	**N = 15**	**N = 12**	**N = 15**	**N = 12**			
Total volume (mean cpm)*	470 (156)	380 (126)	447 (154)	394 (113)	-37 (-62, -13)	0.30	0.60
% time sedentary§	59.9 (7.7)	58.7 (8.8)	61.0 (7.2)	58.1 (6.70)	2.2 (0., 4.3)	0.18	0.42
% time in light PA§	33.7 (6.8)	36.3 (7.3)	32.2 (6.3)	36.6 (5.3)	-1.9 (-4.0, 0.2)	0.10	0.35
% time in MVPA§	6.9 (3.0)	5.0 (2.9)	6.9 (3.2)	5.3 (2.4)	-0.3 (-1.0, 0.4)	0.96	0.19
Length of sedentary bouts (minutes)	6 (1.2)	6 (2.0)	7 (1.5)	6 (1.6)	1.0 (0.3, 1.2)	0.11	0.60
Breaks per sedentary hour	10.3 (1.8)	10.9 (2.6)	10.0 (1.9)	11.2 (2.2)	0.6 (-0.1, 1.3)	0.20	0.33
% of wear time in bouts > 30 minutes	16.2 (6.)	17.6 (9.7)	19.3 (8.9)	16.3 (6.7)	4.4 (1.3, 7.5)	0.18	0.56
Dogs	**N = 15**	**N = 12**	**N = 15**	**N = 12**			
Total volume (mean cpm)*	606 (169)	636 (208)	631 (217)	582 (147)	79 (35, 123)	0.09	0.71
% time sedentary¶	85.8 (3.6)	85.6 (4.3)	84.9 (5.2)	85.9 (3.6)	-1.2 (-2.3, -0.1)	0.31	0.45
% time in light-moderate PA¶	12.5 (3.2)	12.7 (3.7)	13.4 (4.3)	12.8 (3.1)	0.9 (-0.2, 1.9)	0.47	0.34
% time in vigorous PA¶	1.74(1.0)	1.7 (1.0)	1.8 (1.3)	1.4 (0.8)	0.4 (0.2, 0.6)	0.08	0.70

* cpm = count per minute

† Sedentary <800 accelerometer cpm; light PA 800-3200 accelerometer cpm; MVPA ≥3200 accelerometer cpm; sitting <150 accelerometer cpm

§ Sedentary <100 accelerometer cpm; light PA 100-1951 accelerometer cpm; MVPA ≥1952 accelerometer cpm

¶ Sedentary <1352 accelerometer cpm; light-moderate PA 1352-5695 accelerometer cpm; vigorous PA ≥5696 accelerometer cpm

** Intervention and control groups were compared using analysis of covariance

Of the 28 families recruited, 1 parent and 1 dog (from the same family) returned invalid accelerometry data at baseline and were excluded from analysis.

Table 6.4 Changes in objectively measured habitual physical activity and sedentary behaviour for intervention and control groups

6.3.5.3 Body composition

Changes in child, parent and dog body composition are shown in Table 6.5. There was no evidence that any of the child variables assessed (body weight, BMI, fat mass index, lean mass index, bone mineral content) changed significantly from baseline to follow up. Also, there was no evidence of significant changes in parent (body weight, BMI) or dog (body weight, BCS) variables. All effect sizes were small, except for lean mass index (d = 0.51), whole body bone mineral content (d = 0.50) and lumbar spine bone mineral content (d = 0.50) in children. Lean mass index increased from 12.2 kg/m^2 to 13.3 kg/m^2 in intervention group children compared to a slight increase of 0.1 kg/m^2 in control group children. Both whole body and lumbar spine bone mineral content decreased slightly by 0.01 g/cm^2 in intervention group children compared to a slight increase of 0.01 g/cm^2 in control group children.

6.3.5.4 Child health related quality of life

Changes in child health related quality of life are shown in Table 6.6. There was no evidence of significant differences in physical health score, psychosocial health score or total score using the child self-report results. There was also no evidence of differences in any of the variables when the parent-proxy report results were used. Effect sizes were small for all variables assessed.

6.3.5.5 Per protocol analysis

When participants without both baseline and follow up data were removed, the per protocol analyses showed that results of the statistical significance tests and calculation of effect sizes did not change. These results are shown in tables 6.7-6.10.

6.3.5.6 Post-hoc power calculation

The difference in change between intervention and control groups for total volume of PA in children was 30 accelerometer cpm (Table 6.4), and the estimated standard deviation was 156 accelerometer cpm. The post-hoc power calculation (Appendix J) indicated that this difference would be detectable with 215 families in each group (intervention and control).

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P* ¶**	**Effect size (Cohen's d)**
Children	**N = 17**	**N = 13**	**N = 17**	**N = 13**			
Body weight (kg)	37.3 (6.1)	39.8 (11.9)	38.3 (6.7)	40.6 (11.8)	0.2 (-0.3, 0.8)	0.69	0.14
BMI* (kg/m^2)	18.4 (2.2)	18.7 (4.7)	18.5 (2.3)	18.7 (4.6)	0.1 (-0.1, 0.3)	0.71	0.15
BMI* z-score	0.32 (0.90)	0.11 (1.65)	0.28 (0.90)	0.06 (1.51)	0.01 (-0.08, 0.10)	0.77	0.04
	N = 14	**N = 11**	**N = 14**	**N = 11**			
Fat Mass Index (kg/m^2)	5.0 (1.9)	5.5 (3.8)	5.1 (2.0)	5.4 (3.8)	0.2 (0.0, 0.4)	0.33	0.39
Lean Mass Index (kg/m^2)	12.2 (0.9)	12.4 (1.3)	13.3 (4.2)	12.5 (1.3)	1.1 (0.2, 1.9)	0.38	0.51
Whole body BMC† (g/cm^2)	0.90 (0.04)	0.93 (0.08)	0.89 (0.07)	0.94 (0.08)	-0.02 (-0.04, -0.01)	0.41	0.50
Lumbar spine BMC† (g/cm^2)	0.74 (0.08)	0.76 (0.09)	0.73 (0.05)	0.77 (0.09)	-0.02 (-0.03, 0.01)	0.28	0.50
Parents	**N = 16**	**N = 12**	**N = 16**	**N = 12**			
Body weight (kg)	75.0 (15.8)	64.6 (9.5)	74.8 (15.4)	64.4 (9.6)	0.0 (-0.7, 0.7)	0.71	0.00
BMI (kg/m^2)	26.5 (3.9)	23.8 (2.9)	26.5 (3.9)	23.7 (3.0)	0.1 (-0.1, 0.3)	0.85	0.17
Dogs	**N = 16**	**N = 12**	**N = 16**	**N = 12**			
Body weight (kg)	18.2 (10.1)	15.0 (7.9)	17.9 (10.0)	14.8 (8.3)	-0.1 (-0.2, 0.5)	0.63	0.17
Body condition score	2.9 (0.4)	3.1 (0.5)	3.0 (0.0)	3.1 (0.3)	0.1 (-0.1, 0.3)	0.38	0.25

* BMI = body mass index

† BMC = bone mineral content

§ Intervention and control groups were compared using analysis of covariance

Five children were not available for DXA scans at baseline and so were excluded from analysis of fat mass index, lean mass index and bone mineral content.

Table 6.5 Changes in body composition related outcome measures for intervention and control groups

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P****	**Effect size (Cohen's d)**
Self-report	**N = 17**	**N = 13**	**N = 17**	**N = 13**			
Physical health	82.1 (20.7)	88.7 (12.8)	86.2 (9.4)	87.7 (13.4)	5.1 (0.1, 10.1)	0.80	0.38
Psychosocial health	84.2 (11.3)	82.6 (15.3)	80.5 (13.8)	80.3 (18.6)	-1.4 (-5.7, 2.9)	0.78	0.12
Total score	83.5 (10.7)	84.7 (13.7)	82.5 (11.0)	82.9 (15.5)	0.9 (-2.9, 4.6)	0.88	0.01
Proxy report	**N = 17**	**N = 13**	**N = 17**	**N = 13**			
Physical health	84.2 (12.4)	90.6 (12.6)	84.7 (20.2)	87.5 (17.7)	3.6 (-4.7, 12.0)	0.74	0.16
Psychosocial health	79.2 (10.3)	80.9 (11.4)	83.2 (12.2)	81.8 (13.3)	3.1 (-1.5, 7.7)	0.58	0.25
Total score	81.0 (9.4)	84.3 (10.6)	83.7 (12.9)	83.8 (14.0)	3.3 (-2.3, 8.8)	0.84	0.22

* Intervention and control groups were compared using analysis of covariance

Table 6.6 Changes in Child Health Related Quality of Life for intervention and control groups

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Intervention – control difference (95% CI)**	***P* ‡**	**Effect size (Cohen's d)**
	N = 13	**N = 12**	**N = 13**	**N = 12**			
Number of walks per week	2.5 (2.1)	2.6 (2.6)	2.5 (1.3)	2.0 (1.7)	0.6 (-0.4, 1.6)	0.28	0.26
Total duration of dog walking (mins/week)	56 (62)	25 (29)	48 (40)	23 (23)	-6 (-29, 17)	0.15	0.11
Child mean accelerometer cpm* during dog walking	2094 (1379)	1954 (1136)	2863 (1352)	2490 (1724)	233 (-491, 957)	0.45	0.13
% time child spent walk in MVPA†	21.8 (22.3)	18.9 (18.6)	26.4 (22.6)	15.2 (21.7)	8.3 (-2.0, 18.6)	0.18	0.33
Parent mean accelerometer cpm* during dog walking	1976 (1692)	1519 (1205)	2230 (1177)	1601 (976)	172 (-506, 850)	0.40	0.10
% time parent spent walk in MVPA§	45.4 (40.6)	31.7 (34.5)	41.5 (27.8)	20.3 (23.8)	7.5 (-8.3, 23.3)	0.08	0.20
Dog mean accelerometer cpm* during dog walking	3591 (2194)	3549 (2572)	4702 (1841)	3766 (2155)	894 (-277, 2065)	0.26	0.32
% time dog spent in light-mod PA¶	56.0 (34.9)	69.4 (39.3)	49.9 (31.5)	37.6 (40.1)	25.7 (4.2, 47.2)	0.10	0.49
% time dog spent in vigorous PA**	20.9 (18.6)	13.9 (23.2)	26.8 (17.6)	12.7 (19.6)	7.1 (-15.6, 29.8)	0.03	0.24

*cpm = counts per minute

† ≥3200 accelerometer cpm

§ ≥1952 accelerometer cpm

¶ 1352-5965 accelerometer cpm

** ≥5696 accelerometer cpm

‡ Intervention and control groups were compared using analysis of covariance

Table 6.7 Changes in family dog walking behaviour for intervention and control groups (per protocol)

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean**	**Intervention Mean (SD)**	**Control Mean**	**Difference in change between intervention**	***P*****	**Effect size (Cohen's**
Children	**N = 14**	**N = 13**	**N = 14**	**N = 13**			
Total volume (mean cpm) *	523 (144)	524 (144)	555 (235)	521(147)	35 (-25, 95)	0.59	0.23
% time sedentary†	80.9 (3.6)	80.2 (4.9)	80.7 (5.5)	80.1 (5.3)	-0.1 (-2.3, 2.0)	0.92	0.03
% time in light PA†	16.1 (3.0)	16.7 (3.8)	15.9 (3.8)	16.5 (4.3)	0.1 (-1.7, 1.8)	0.85	0.02
% time in MVPA†	3.1 (1.7)	3.1 (2.0)	3.4 (2.9)	3.0 (1.3)	0.4 (-0.3, 1.0)	0.58	0.23
% time sitting †	56.5 (5.9)	57.0 (7.3)	57.4 (8.5)	56.5 (9.1)	1.5 (-1.8, 4.8)	0.69	0.18
Length of sitting bouts (minutes)	5.1 (0.6)	5.6 (1.4)	6.4 (5.4)	5.7 (2.1)	1.2 (-0.1, 2.5)	0.60	0.29
Breaks per sitting hour	12.5 (1.5)	12.1 (3.3)	11.9 (3.2)	12.5 (3.0)	-0.2 (-1.5, 1.1)	0.60	0.27
% of wear time in bouts > 30 minutes	12.0 (2.9)	15.8 (7.8)	15.5 (16.8)	17.4 (9.7)	1.9 (-2.8, 6.6)	0.86	0.14
Parents	**N = 13**	**N = 11**	**N = 13**	**N = 11**			
Total volume (mean cpm) *	467 (156)	390 (128)	440 (153)	405 (112)	-42 (-69, -15)	0.26	0.64
% time sedentary§	59.4 (8.26)	58.0 (8.9)	61.2 (7.7)	57.3 (6.5)	2.5 (0.2, 4.9)	0.14	0.45
% time in light PA§	33.7 (7.3)	36.9 (7.4)	31.9 (6.7)	37.2 (5.2)	-2.2 (-4.6, 0.3)	0.08	0.38
% time in MVPA§	6.9 (3.0)	5.2 (3.0)	6.9 (3.3)	5.5 (2.5)	-0.4 (-1.1, 0.4)	0.99	0.19
Length of sedentary bouts	6.2 (1.2)	6.0 (1.7)	6.7 (1.5)	5.9 (0.8)	0.6 (0.1, 1.2)	0.17	0.44
Breaks per sedentary hour	10.3 (1.9)	11.3 (2.3)	9.9 (1.9)	11.6 (1.6)	-0.7 (-1.5. 0.1)	0.09	0.37
% of wear time in bouts > 30 minutes	16.4 (6.7)	16.0 (8.4)	20.0 (9.4)	14.6 (3.5)	5 (1.5, 8.5)	0.08	0.60
Dogs	**N = 12**	**N = 12**	**N = 12**	**N = 12**			
Total volume (mean cpm) *	622 (173)	636 (208)	653 (228)	582 (147)	85 (35, 135)	0.09	0.71
% time sedentary¶	85.7 (3.7)	85.6 (4.3)	84.6 (5.5)	85.9 (3.6)	-1.5 (-2.7, -0.2)	0.28	0.49
% time in light-moderate PA¶	12.4 (3.3)	12.7 (3.7)	13.5 (4.6)	12.8 (3.1)	1.1 (-0.1, 2.3)	0.42	0.39
% time in vigorous PA¶	1.9 (1.0)	1.7 (1.0)	1.9 (1.3)	1.4 (0.4)	0.4 (-0.1, 0.9)	0.11	0.67

* cpm = count per minute

† Sedentary <800 accelerometer cpm; light PA 800-3200 accelerometer cpm; MVPA ≥3200 accelerometer cpm; sitting <150 accelerometer cpm

§ Sedentary <100 accelerometer cpm; light PA 100-1951 accelerometer cpm; MVPA ≥1952 accelerometer cpm

¶ Sedentary <1352 accelerometer cpm; light-moderate PA 1352-5695 accelerometer cpm; vigorous PA ≥5696 accelerometer cpm

** Intervention and control groups were compared using analysis of covariance

Of the 28 families recruited, 1 parent and 1 dog (from the same family) returned invalid accelerometry data at baseline and were excluded from analysis, a further 3 parents, and 3 dogs either dropped out or returned invalid accelerometry data at follow up and were also excluded. Three children either dropped out or returned invalid accelerometry data at follow-up and were excluded.

Table 6.8 Changes in objectively measured habitual physical activity and sedentary behaviour for intervention and control groups (per protocol)

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P* ¶**	**Effect size (Cohen's d)**
Children	**N = 14**	**N = 13**	**N = 14**	**N = 13**			
Body weight (kg)	38.9 (5.3)	39.8 (11.9)	40.2 (5.7)	40.6 (11.8)	0.5 (-0.1, 1.0)	0.47	0.30
BMI* (kg/m^2)	18.9 (2.1)	18.7 (4.7)	19.0 (2.2)	18.7 (4.6)	0.1 (-0.2, 0.4)	0.66	0.14
BMI* z-score	0.53 (0.78)	0.11 (1.65)	0.48 (0.79)	0.06 (1.51)	0.001 (-0.103, 0.105)	0.71	0.00
	N = 11	**N = 10**	**N = 11**	**N = 10**			
Fat Mass Index (kg/m^2)	5.4 (1.9)	5.8 (3.9)	5.5 (2.0)	5.6 (3.9)	0.3 (0.0, 0.5)	0.34	0.47
Lean Mass Index (kg/m^2)	12.4 (0.9)	12.4 (1.4)	13.8 (4.7)	12.5 (1.4)	1.5 (0.3, 2.4)	0.37	0.58
Whole body BMC† (g/cm^2)	0.91 (0.04)	0.94 (0.08)	0.90 (0.08)	0.95 (0.08)	-0.02 (-0.04, 0.00)	0.42	0.44
Lumbar spine BMC† (g/cm^2)	0.75 (0.08)	0.77 (0.09)	0.74 (0.04)	0.77 (0.09)	-0.01 (-0.04, 0.02)	0.25	0.18
Parents	**N = 13**	**N = 12**	**N = 13**	**N = 12**			
Body weight (kg)	78.4 (15.5)	64.6 (9.5)	78.2 (15.1)	64.4 (9.6)	0.0 (-0.8, 0.8)	0.68	0.01
BMI (kg/m^2)	27.0 (4.1)	23.8 (2.9)	26.9 (4.1)	23.7 (3.0)	0.0 (-0.3, 0.3)	0.89	0.01
Dogs	**N = 13**	**N = 12**	**N = 13**	**N = 12**			
Body weight (kg)	18.5 (9.2)	15.0 (7.9)	18.1 (9.1)	14.8 (8.3)	-0.2 (-0.6, 0.1)	0.49	0.26
Body condition score	2.9 (0.5)	3.1 (0.5)	3.0 (0.0)	3.1 (0.3)	0.1 (0.0, 0.2)	0.45	0.31

* BMI = body mass index

† BMC = bone mineral content

§ Intervention and control groups were compared using analysis of covariance

Five children were not available for DXA scans at baseline and so were excluded from analysis of fat mass index, lean mass index and bone mineral content, a further 4 children either dropped out or were not available for DXA scans at follow-up and were also excluded. Three children, 3 parents and 3 dogs either dropped out or were not available for body weight and height measurements at follow-up and were excluded from analysis.

Table 6.9 Changes in body composition related measures for intervention and control groups (per protocol)

	Baseline		Follow-up		10-week differences		
	Intervention Mean (SD)	**Control Mean (SD)**	**Intervention Mean (SD)**	**Control Mean (SD)**	**Difference in change between intervention and control (95% CI)**	***P***	**Effect size (Cohen's d)**
Self-report	**N = 14**	**N = 13**	**N = 14**	**N = 13**			
Physical health	81.12 (22.7)	88.7 (12.8)	86.16 (10.09)	87.74 (13.41)	6.00 (0.37, 11.63)	0.77	0.42
Psychosocial health	84.28 (11.66)	82.56 (15.25)	79.75 (14.46)	80.26 (18.56)	-2.23 (-6.96, 2.50)	0.68	0.19
Total score	83.18 (11.17)	84.70 (13.86)	81.98 (11.55)	82.86 (15.46)	0.64 (-3.50, 4.78)	0.95	0.06
Proxy report	**N = 14**	**N = 13**	**N = 14**	**N = 13**			
Physical health	84.15 (11.59)	90.63 (12.56)	84.78 (21.15)	87.52 (17.67)	3.74 (-5.59, 13.07)	0.65	0.16
Psychosocial health	78.22 (10.88)	80.90 (11.42)	83.04 (13.28)	81.79 (13.29	3.93 (-1.09, 8.95)	0.56	0.31
Total score	80.28 (9.46)	84.28 (10.60)	83.64 (13.73)	83.78 (13.99)	3.86 (-2.27, 9.99)	0.87	0.25
Three families dropped out and were not available to complete the PedsQL at follow-up							

Table 6.10 Changes in Child Health Related Quality of Life for intervention and control groups (per protocol)

6.4 Discussion

To the authors knowledge this is the first RCT to assess the feasibility, acceptability and potential efficacy of a dog-based PA intervention in children and their families. CPET was an exploratory, assessor-blinded RCT as recommended in the UK MRC framework for developing and evaluating complex interventions (Craig *et al.*, 2008), and was developed to inform a future more ‘definitive’ trial. The results show that the CPET trial was feasible and the intervention was acceptable to participants. Eighty-nine per cent of families were retained in the present study and greater than 90% of data were collected for all outcome measures except those deriving from DXA scans. Children and parents who participated in the intervention group agreed that the outcome measures and intervention content were acceptable. Despite this, there was no evidence of a significant change in the primary outcome measure (child PA) or the majority of the secondary measures (parent and dog PA, child BMI, bone health and health related quality of life). Furthermore, small effect sizes were found for the primary outcome measure and all secondary outcome measures except total volume of PA in dogs and the amount of time they spent in vigorous intensity PA.

The retention rates in CPET are comparable to those reported in other PA studies in children and their families. Chen *et al.* (2010) retained 85% of participants at follow up and Sacher *et al.* (2010) reported that 90% of children randomised to a 9 week intervention were available at the end of the intervention. Few family based studies have reported the level of adherence to the intervention programme. Morgan *et al.* (2011) reported that 81% of intervention sessions were attended and Sacher *et al.* (Sacher *et al.*, 2010) reported that 86% of sessions were attended during the intervention. The level of adherence to the CPET intervention programme and the results from our qualitative study suggests that acceptability of the outcome measures and intervention content was high. One possible explanation for the high rate of adherence to the intervention in CPET may be that all intervention sessions were home/telephone based whereas other intervention programmes have required attendance at group sessions outside the home (Sacher *et al.*, 2010, Morgan *et al.*, 2011). The CPET intervention was therefore flexible in terms of delivery, participants were not required to travel in order to receive the intervention and all intervention sessions were delivered to suit the availability of participants.

The number of completed outcome measures in CPET was high for all outcomes except measurement of fat mass, lean mass and bone mineral content in children. Body weight, BMI, BCS and child health related quality of life data were collected for all participants at baseline and all available participants at follow up, indicating that feasibility of collecting these outcomes was high. Furthermore, objectively measured PA data were collected on all children at baseline and all those available at follow up. PA data was collected on all but one parent and dog at baseline, and all but one parent and dog that were available at follow up. One reason why only 82% of DXA related outcome data was collected at baseline and from 84% of the available children at follow up was because participants were asked to attend a local children's hospital to have DXA scans carried out but only limited appointments were after school hours. Some participants were therefore unable to make a suitable appointment due to other commitments.

Although a dog-walking intervention such as CPET may be both feasible and acceptable on a small scale and in the short term, the relatively low conversion of expressions of interest (n = 127) into signed consent (n = 36) suggests that alternative methods of recruitment may be required to implement CPET on a larger scale. Prior to a definitive trial a formative evaluation of the reasons why those who initially expressed an interest and subsequently did not choose to take part in the study might highlight reasons for the low conversion rate. It may be that the expansion of CPET will require recruitment to be carried out over a larger area with access to more potential participants. Alternatively a completely different approach to recruitment such as advertising in local media or veterinary practices may be necessary. The primary concern with regards to recruitment was a potentially high rate of exclusion due to behavioural issues with dogs, but this did not seem to be the case as only one of the 36 families who consented to participation was excluded for this reason.

No statistically significant differences in either the number or duration of dog walks, or child or parent PA during periods of dog walking were detected and effect sizes were small for all dog walking outcomes. However, a statistically significant difference in the amount of time dogs spent in vigorous intensity PA during dog walks was found. It should be noted that although this was statistically significant, it equates to a mean difference of ~ two minutes during total dog walking time for the week, and is therefore unlikely to be of any biological significance. However, if the number of dog walks in intervention families had increased the amount of time dogs spent in vigorous intensity PA may have been much greater. Previous reports on the amount of family dog walking have relied on subjective measures such as questionnaires (Salmon *et al.*, 2010), which are often subject to response bias (Pereira *et al.*, 1997, Sirard and Pate, 2001). The present study presents data not only on the amount, but the intensity at which dog walking takes place among families, and suggests that dogs are walked two to three times per week as a family when measured objectively. This suggests that in our sample, family dog walking was more common than elsewhere, as one Australian study recently reported that, when measured subjectively, family dog walking took place, at most, once or twice per month (Salmon *et al.*, 2010).

Nevertheless, the amount of family dog walking in this study was still low considering that the average total duration per week of accelerometry-measured dog walking for the sample as a whole was 41 minutes at baseline and 37 minutes at follow up. Despite this, the extent to which dog walking might contribute to accumulated MVPA in children and/or their parents suggests that increasing the frequency and duration of dog walking is a promising strategy for increasing PA in families. Children spent between 15 and 26% of family dog walking time in MVPA compared to only 3% of total wear time; parents spent between 20 and 45% of dog walking time in MVPA compared to between 5 and 7% of total wear time; and dogs spent 13-25% of dog walking time in vigorous intensity PA compared to only 1-2% of total wear time. This suggests that, if carried out for a sufficient duration, family dog walking represents an opportunity to increase MVPA across the whole family and might in future be valuable for PA promotion more widely.

However, it should be noted that the amount of time spent sedentary or physically active can vary widely depending on the cut point used to define intensities of PA in both children and adults (Loprinzi *et al*., 2012). There are at least four commonly used sets of ActiGraph cut-points in children (Puyau *et al.*, 2002, Freedson *et al*., 2005, Mattocks *et al*., 2007, Evenson *et al.*, 2008), each of which define the categories of PA at different accelerometer cpm. The threshold for sedentary behaviour suggested by Puyau *et al.* (2002) for example is <800 cpm, compared to <100 cpm suggested by Freedson *et al.* (2005). At the time of developing the protocol for this study the cut points of Puyau were widely used in studies of child PA (Kelly *et al.*, 2006, Hughes *et al.*, 2008, Mendoza *et al.*, 2011, Robertson *et al.*, 2011) and were deemed the most appropriate to use in this study. The most widely used cut points for measuring PA in adults are those by Freedson *et al.* (1998), which suggest a threshold of <100 cpm for defining sedentary behaviour. The considerable difference in the cut-points used in this study to define the threshold between sedentary behaviour and light intensity PA in children (800cpm) and adults (100cpm) makes it difficult to say with certainty that periods when the parent and child were being physically active together with their dog were correctly identified.

Although effect sizes were small for our primary outcome measure (total volume of PA in children) they were not too dissimilar to many other PA interventions in children. A recent meta-analysis which assessed the effectiveness of 30 PA interventions where PA was measured objectively using accelerometry, concluded that such interventions have had a small to negligible effect on total volume of PA (d = 0.12) and had resulted in small increases in MVPA, ~ four minutes per day (d = 0.16) (Metcalf *et al.*, 2012). The CPET intervention resulted in a mean difference in total volume of PA of 30cpm in children (d = 0.21) and a mean difference in MVPA of ~ two mins/day (d = 0.20). Although given the lack of power in the present study it is questionable whether these differences are real. In contrast, the effect sizes reported here for PA in parents did not compare favourably with other PA interventions in adults, with a recent review concluding that the pooled intervention effect on overall PA between intervention and control groups was small (d = 0.19) (Conn, 2011). The results for the efficacy of the intervention on dogs were more positive, with medium to large effect sizes reported for total volume of PA (mean difference of 79cpm, d = 0.71) and vigorous intensity PA (mean difference of ~ six minutes/day, d = 0.70). To the authors knowledge there are no published studies assessing the efficacy of a PA intervention on objectively measured PA levels of pet dogs and therefore comparison with other studies is not possible. Furthermore, the biological significance of an increase in vigorous intensity behaviour of six minutes/day in dogs is unclear.

There are also no comparable studies assessing the efficacy of a dog walking intervention on PA in children, although there are two published studies assessing the efficacy of a dog walking programme in adults. Kushner *et al.* (2006) reported that overweight adults taking part in a 16 week intervention with pet dogs had significant increases in PA and significant decreases in body weight. PA was not measured objectively and this was a clinical trial in overweight adults, and it is therefore difficult to make comparisons with CPET. Rhodes *et al.* (2012) carried out a pilot study of a dog walking intervention in adults who did not regularly walk their dog: their intervention appears to have resulted in significantly higher step counts compared to control. In contrast, the results of CPET do not provide any evidence of an increase in objectively measured PA in either children or their parents, or the number or duration of dog walks. In the present study, children and their parents were asked to participate in dog walking/active play with the dog together and this may be logistically more difficult than asking a lone adult to increase dog walking time and thus PA (Rhodes *et al.*, 2012). In addition, a number of parents taking part in CPET noted at baseline that it was difficult for them to change their habits of dog walking. These parents liked to walk the dog early in the morning or late at night, i.e. when their child would be less likely to take part. Future dog walking interventions should attempt to help families reduce barriers (e.g. lack of time) and create more opportunities for additional dog-walking opportunities as a family.

Despite the overall lack of effect that CPET had on PA outcomes the results of the qualitative study were promising. The vast majority of parents in the intervention group agreed that the intervention content was sufficient to motivate them and their children to increase PA through dog walking. In addition, children who took part in the focus groups highlighted that they enjoyed taking part in CPET and felt that they increased the amount of PA they did. Similarly, parents who took part in the focus groups suggested that they had experienced longer family walks. Key stakeholders interviewed as part of the qualitative study suggested that it may be difficult to motivate families from less affluent areas to take part. The distribution of DEPCAT scores among the study population suggests that this was not an issue in this study. Ninety-six percent (27/28) of CPET families were classified as DEPCAT 1, 2 or 3 compared to 87% of the population of East Dunbartonshire and 42% of the population of Scotland (McLoone, 2004). This suggests that motivation was not a factor in the lack of change in PA.

There is some evidence that behaviour change interventions such as CPET, which are intended to alter behaviour at the individual level, may actually widen the health inequalities between the highest and lowest risk groups (Katikireddi et al., 2013). That is, rather than closing the gap in health inequalities, behaviour change interventions targeting individuals widen this gap as uptake of interventions is often less common among the most derived compared to the middle class for example. The distribution of DEPCAT scores among the CPET participants shows that all but one family were classified as DEPCAT 1, 2, or 3. Although this suggests that lack of motivation was not a factor in the lack of effect on PA in the current study, it also means that uptake of the intervention was very low among the most deprived. There is substantial disparity between the number of people classed as DEPCAT 1, 2, or 3 in Scotland as a whole (42%) and East Dunbartonshire

(87%), meaning that the number of people eligible for CPET that were among the most deprived was low. Future studies should therefore target other areas of Scotland and the UK with demographics which are more representative of the population as a whole. Nevertheless, there is evidence to suggest that children who own a dog are more likely to be among the most deprived (Westgarth et al., 2013), suggesting that interventions which target children in dog owning families may be a good bet for narrowing health inequalities. Future studies are required to determine whether uptake of dog walking interventions can be increased among those of lower socioeconomic status.

It is possible that the short duration of the intervention prevented an increase in PA in the intervention group compared to controls and a future more definitive trial should include an intervention period of longer than 10 weeks. It may also be possible that intervention families did increase PA during the intervention, as suggested in the focus groups, but failed to maintain this when PA was measured post intervention. This could be viewed as a flaw in the study design and future trials should, if possible, measure PA at multiple time points, i.e. at baseline, mid-intervention and post intervention, for longer periods i.e. two weeks instead of one, or even continuously throughout the intervention period to overcome this, although the increased burden of wearing accelerometers for longer periods may not be acceptable to participants. However, it was expected that any effect of the intervention would have lasted until at least the first week post intervention. A recent review on the maintenance of behaviour change following PA interventions concluded that a number of studies had reported that statistically significant effects have lasted three or more months post intervention (Fjeldsoe *et al*., 2011). However, the review did also state that this was more likely following interventions with a duration of greater than 24 weeks. Continuous or multiple measurement of PA would also help reduce any effect of variations in weather. Clearly adverse weather conditions can have an effect on outdoor PA, and data from the nearest UK Met Office weather station to the geographical area where the intervention took place estimates that rainfall in the period when many of the post intervention measurements were taken was almost double that at baseline (Met Office, 2012). The failure to detect any significant changes in child or parent PA may also have been due to PA compensation, the theory that study participants may compensate for imposed bouts of PA by reducing PA at other times (Wilkin *et al*., 2006, Fremeaux *et al*., 2011). This was highlighted by some of the parents who took part in the focus groups who suggested that CPET had replaced other forms of PA. Future studies should therefore highlight that, although participants may do some PA habitually, they should maintain this while also increasing the amount of dog walking, in an effort to meet the recommended guidelines for PA.

This study had a number of strengths and limitations. First, it was an exploratory RCT as set out in the CONSORT statement (Schulz *et al.*, 2010) and the UK Medical Research Council Framework for the development and evaluation of complex interventions in public health (Craig *et al.*, 2008). Second, trained blinded assessors were used to carry out the outcome measures and were independent of the research assistant who delivered the intervention. Furthermore, the study methods included validated instruments for measuring our primary and secondary outcomes, including the objective measurement of PA. Although it was not one of our aims to recruit a large sample size, the relatively small sample size prevented assessment of any effects of the intervention on boys and girls separately, or by type of dog owned (breed, age etc.) and is symptomatic of an exploratory trial. The small sample size also prevented conclusions with any certainty as to whether any of the small differences found are real. In addition, the intervention at this stage was resource intense to deliver (for example using a session with a qualified behaviourist). This study was designed as an exploratory RCT that will inform the design of a future, larger and longer term trial, not to report solely on the potential efficacy of such a study. Studies of this nature are needed to determine if dog based PA interventions have any effect on habitual PA over the longer term. Since outcomes were measured in the period immediately after the intervention rather than during the final week this might have reduced any apparent impact of the intervention. Finally, no formative evaluation of the intervention and recruitment strategy was carried out prior to the actual trial itself. Had this been done a more promising intervention may have been developed. Future studies should aim to overcome these limitations, only then will it become clear if the potential for using pet dogs to increase PA in children and their families can be realised.

6.5 Conclusions

This study suggests that using pet dogs as the agent of lifestyle change in PA interventions in children and their parents is both feasible and acceptable. These results will be used to inform the design, development and implementation of future, larger scale trials.

7 General discussion and conclusions

7.1 Background

Physical inactivity has been identified as a major contributor to non-communicable diseases globally (Lee *et al.*, 2012), with many adults and children insufficiently active to maintain good health (Hallal *et al.*, 2012). Despite numerous attempts to alter PA behaviours in children and adults, reported effect sizes for change in PA levels have generally been small or moderate (Conn *et al.*, 2011, van Sluijs *et al.*, 2011, Metcalf *et al.*, 2012). Novel approaches to PA promotion are therefore needed. In recent years there has been growing interest in the relationship between dog ownership/dog walking and PA (Cutt *et al.*, 2008b, Salmon *et al.*, 2010, Reeves *et al.*, 2011, Levine *et al.*, 2013). Previous observational work suggests that there may be some potential for using pet dogs to increase PA in children and adults in PA interventions (Owen *et al.*, 2010, Salmon *et al.*, 2010). This thesis represents the first attempt to assess the feasibility and acceptability of using pet dogs to increase PA in children and their parents during an exploratory RCT. In addition, no previously published peer-reviewed studies had assessed which factors are associated with ActiGraph measured PA in dogs. This thesis aimed to facilitate a clearer understanding of the associations between dog characteristics such as overweight/obesity, age, sex, and neutered status, and objectively measured PA.

From a veterinary perspective it also desirable to know how PA levels change during weight loss in dogs. With the exception of Wakshlag *et al.* (2012) no previously published studies have described changes in objectively measured PA during weight loss in dogs, and none have been published using ActiGraph accelerometry. This thesis investigated whether PA levels change significantly during a calorie controlled weight loss programme in dogs. Additionally, prior to carrying out the studies described and in order to describe changes in the intensity of PA in dogs there was a need to develop and validate ActiGraph cut-points that could categorise dog PA by intensity as no previous published studies had undertaken this in dogs.

7.2 Calibration and cross-validation of ActiGraph accelerometer cut-points in dogs (Chapter 2)

It has been shown previously that the ActiGraph GT3X accelerometer is a practical, reliable, and valid method for measuring PA in dogs (Yam *et al.*, 2011), but no previously published studies had established cut-points that could classify PA by intensity. The results of Chapter 2 show that the GT3X can accurately measure the amount of time a dog spends sedentary, in light-moderate intensity PA and in vigorous intensity PA. The sensitivity and specificity of the sedentary and vigorous intensity cut-points when using the integrated axes accelerometry data were high. Similarly, high sensitivity and specificity was found for both the sedentary cut-point and vigorous intensity cut-point when using the uniaxial (vertical axis) data. It was considered more appropriate to use the integrated axis data because although the position of the accelerometer on the dogs collar was monitored closely during data collection, in real life situations it would not be possible to do this for extended periods and the position of the accelerometer may alter and therefore the direction of the measured accelerations could change.

Agreement between the integrated accelerometer data and direct observation in the cross-validation subset was 'very good' ($\kappa = 0.83$). Ninety-two out of 100 (92%) minutes were correctly classified as sedentary behaviour, 168/200 (93%) minutes were correctly classified as light-moderate intensity PA and 89/100 (89%) minutes were correctly classified as vigorous intensity PA, leaving a total of 349/400 (87%) minutes correctly classified. These results indicate that the ActiGraph GT3X accelerometer is accurate when measuring the intensity of PA in dogs. The study sample in Chapter 2 included a wide variety of breeds and size of dogs, suggesting that these cut-points are generalisable across a wide range of breeds. However, it could be hypothesised that the acceleration measured during light-moderate or vigorous intensity PA for a giant dog breed such as a St. Bernard may be substantially different to that of a small dog breed such as a Yorkshire Terrier. Further studies are needed to investigate whether accelerometer counts during specific intensity levels differ by breed/size and the impact this would have on cut-point selection.

7.3 Association between dog characteristics and PA (Chapters 3 and 4)

For this thesis it was deemed appropriate to carry out a preliminary investigation of the association between overweight/obesity and PA in dogs, and then carry out another study which would allow for the assessment of other associations such as dog breed, age, sex and neutered status in addition to overweight/obesity. The results of Chapter 3 showed that there was no evidence of a significant difference in total volume of PA (mean accelerometer cpm) between ideal weight dogs and either overweight or obese dogs. Using the cut-points developed in Chapter 2, the results of Chapter 3 also showed that there was no evidence of a significant difference in sedentary time or light-moderate intensity PA between ideal weight dogs and overweight or obese dogs. However, there was a statistically significant difference in the amount of time dogs spent in vigorous intensity PA. Ideal weight dogs spent 20 minutes per day, on average, in vigorous intensity PA, compared to six minutes per day for obese dogs, a difference of 14 minutes per day. Although no other significant differences were found, a post-hoc power calculation indicated a difference of 177 accelerometer cpm between ideal weight and obese dogs would be detected with a sample size of 43 in each factor level.

In Chapter 4 only two breeds of dog were recruited in order to explore whether overweight/obesity and other factors such as age, neutered status, breed and gender were correlated with PA. The two breeds chosen, Labrador Retrievers and Cocker Spaniels, were selected because they are the two most commonly registered breeds with the Kennel Club in the United Kingdom (The Kennel Club, 2014) and both are predisposed to obesity (German, 2010). In this narrow sample of dog breeds, age was identified as a significant correlate of all measured PA variables. For every one year increase in age there was an 8% decrease in total volume of PA, a 5% decrease in light-moderate intensity PA, a 26% decrease in vigorous intensity PA and a 2% increase in sedentary behaviour. This finding that PA declines with age in dogs is consistent with results from human (Sallis, 2000, Troiano *et al.*, 2008) and dog studies (Siwak *et al.*, 2003). Chapter 4 also showed that breed was related to some, but not all PA variables. There was evidence that total volume of PA and light-moderate intensity PA was greater in Cocker Spaniels compared to Labradors, and that Cocker Spaniels spent less time per day sedentary than Labradors.

In the final model of correlates associated with PA there was no evidence that neutered status or sex were associated with PA, and unlike in Chapter 3, there was also no evidence of an association between BCS (ideal weight, overweight and obese) and any PA variable. The lack of any apparent association between BCS and PA in Chapter 4 may be explained by the small number of obese dogs in the sample. In Chapter 4 only eight out of 54 dogs were classed as obese, compared to 22 ideal weight dogs and 24 overweight dogs. Future studies should include a larger number of obese dogs in order to determine more clearly whether obese dogs are less vigorously active than ideal weight dogs as shown in Chapter 3.

7.4 Change in PA during weight loss in dogs (Chapter 5)

It was of interest to determine what, if any, effect weight loss had on PA in dogs. Chapter 5 formed the basis of the first published study to use ActiGraph accelerometry to assess changes in PA during substantial weight loss in dogs. All 14 dogs completing the study were overweight or obese and took part in a six month calorie controlled weight loss programme, which did not include any formal PA counselling.

Mean weight loss from baseline to month six was 15% of body weight. This is a substantial amount of weight loss and compares favourably with studies involving overweight and obese humans; a recent review of calorie restriction on weight loss in humans concluded that studies of comparable duration resulted in a 10%-16% reduction in body weight (Varady, 2011). The results of Chapter 5 show that total volume of PA (mean accelerometer cpm) increased by 34 cpm and the number of minutes dogs spent per day in light-moderate intensity PA increased by 15 minutes from baseline to month six. However, neither of these changes were statistically significant and the results suggest that there is no evidence that PA increases spontaneously as a result of weight loss in dogs. One possible reason for a lack of effect of substantial weight loss on PA may be the small sample size; only 14 dogs completed the study. However the differences in PA were small and may not be biologically significant even if a larger sample size resulted in a statistically significant effect of weight change on PA. The calorie restricted weight loss programme used in Chapter 5 did not include any formal PA counselling which may be another reason why PA did not increase significantly.

Combined dietary and PA weight loss programmes are often recommended in both veterinary and human medicine in order to realise the greatest potential weight loss (Donnelly *et al.*, 2009, German, 2010). As well as the positive impact on weight loss, increased PA has other benefits in dogs such as maintenance of muscle mass and cardiovascular benefits (German, 2010). Including PA counselling in a weight loss programme such as that described in Chapter 5 may therefore have led to increased PA and would have other positive health benefits for dogs. Future studies are required to determine whether combined PA and calorie restricted weight loss programmes can increase dog PA during weight loss and how owner related factors, such as walking the dog on/off lead, impact on dog PA.

7.5 Children, parents and pets exercising together (Chapter 6)

Chapter 6 of this thesis aimed to determine whether a dog walking intervention with children and their parents was feasible and acceptable. The CPET trial was an exploratory RCT as recommended by the Medical Research Council Framework for the development and evaluation of complex interventions in public health (Craig *et al.*, 2008) and was the first trial of a dog walking intervention involving children and their parents.

The results show that the CPET intervention was both feasible and acceptable to study participants. Eighty-nine percent of families were retained at follow up which compares favourably with other PA studies involving children and their families. In a RCT of a family based intervention to promote healthy behaviours in children Chen *et al.* (2010) reported that 85% of participants were retained at follow up, while Sacher *et al.* (2010) reported that 90% of children were retained at follow up in a family based childhood obesity trial. CPET consisted of seven intervention sessions per family and 105 intervention sessions in total. Of these sessions 100 (95%) were delivered. These data also compare favourably with other studies such as those carried out by Morgan *et al.* (2011) and Sacher *et al.* (2010) who reported that 81% and 86% of intervention sessions were attended, respectively. The number of completed outcome measures was high for the majority of outcomes measured in CPET. Objectively measured PA data were collected for 100% of children, 96% of parents and 96% of dogs at baseline, and 100% of children, 96% of parents and 96% of dogs available at follow up for example. The exceptions to this were fat mass, lean mass and bone mineral content in children, which all derived from DXA measurements. The likely reason for this is that there were only a limited number of DXA appointments available and some families were unable to make suitable appointments.

The results of the study exit questionnaire and focus groups indicated that the trial and outcomes were acceptable. None of the 13 (0%) parents who completed the questionnaire reported that they were asked to do too much during the intervention (i.e. PA), and only one of 13 (8%) reported that they were asked to do too many outcome measures. The focus groups carried out with intervention children and parents also indicated that the trial and intervention were acceptable. In addition, children reported that they enjoyed taking part in the intervention and it made them more active. Parents reported that they took part in longer, more fun family walks, although some parents indicated that they felt the CPET intervention had replaced other forms of PA for their children.

Despite the apparent feasibility and acceptability of CPET there was no evidence of a significant change in the primary outcome measure (child PA) or the majority of the secondary measures. There was a mean difference in change between intervention and control groups of 30 accelerometer cpm for children (P = 0.62). Although the difference in change was small the effect size is comparable to other PA interventions in children (Metcalf *et al.*, 2012). To the authors knowledge no other studies have assessed the efficacy of a dog walking intervention in children and their families, although the published studies using only adult participants suggest that PA interventions with pet dogs can lead to an increase in PA in intervention group participants compared to controls (Kushner *et al.*, 2006, Rhodes *et al.*, 2012). These results indicate that the intervention, although feasible and acceptable, may need to be adapted prior to a more definitive trial. A formative evaluation, as recommended by the MRC framework on developing and evaluating complex interventions, carried out prior to a future trial, may identify that a dog walking intervention should be shaped by the families involved rather than designed by the researchers and then imposed on the participants.

7.6 Applications of the results of this thesis

The results of this thesis enhance the knowledge of the association between a number of dog characteristics and PA, and the feasibility and acceptability of using pet dogs to increase PA in children and their families. The findings suggest possible future ideas for research and are applicable to both veterinary and human medicine.

The results show that in addition to being a valid, reliable and practical method for measuring PA objectively in dogs, as has been shown previously, the ActiGraph GT3X is also able to classify PA by intensity in dogs. The calibration of the ActiGraph accelerometer output and PA intensity allows the ActiGraph to be used in a wide range of future studies that aim to measure PA intensity in dogs.

It appears that older dogs are less physically active and more sedentary than younger dogs and that objectively measured PA levels vary by breed, with Cocker Spaniels more active and less sedentary than Labradors. These results reinforce that age and breed specific diets may be necessary to compensate for differences in habitual PA levels, although further studies are required to investigate the association between breed and PA in a wider range of dog breeds.

The results of Chapter 3 provide evidence that obese dogs are less vigorously active than ideal weight dogs; however Chapter 4 failed to show the same association. This apparent conflict between studies makes it difficult to suggest that there is in fact a difference in PA between ideal weight dogs and obese dogs as was shown in Chapter 3. Understanding why this disparity was found may help clarify the relationship between obesity and PA. The cross sectional nature of Chapters 3 and 4 also make it difficult to confirm the causation of any apparent relationships between PA and obesity, but they do improve the understanding of canine PA. Further studies are required to disentangle the relationship between PA and obesity in dogs, a relationship which is made complex by the wide number and variety of breeds, and also to assess the causality of any such relationships.

The relationship between obesity and PA is often thought to be bi-directional, i.e. low PA increases the risk of obesity, and obesity suppresses PA. The results of Chapter 5 suggest that there is no evidence that this is the case in dogs and PA does not increase spontaneously as a result of substantial weight loss. It may therefore be necessary to actively promote PA during weight loss in dogs in order to increase PA levels and allow dogs to gain the additional benefits of increased PA independent of weight loss.

Chapter 6 showed that an exploratory RCT of a dog walking intervention involving children and their parents was both feasible and acceptable to study participants. These results can now be used to inform a future, more definitive trial as recommended by the Medical Research Council framework for developing and evaluating complex interventions. Such a trial would be better equipped to evaluate the potential efficacy of the CPET intervention.

7.7 Limitations of this thesis and suggestions for future studies

There are a number of limitations in this thesis that may affect both the validity and generalisability of the results.

The accelerometers used to measure PA in this thesis were the ActiGraph family of accelerometers. The decision to use the ActiGraph was discussed in Chapter 1, Section 1.2.2.3.1. A number of different models are available, but only two models have been validated for use in dogs to date, the ActiGraph and the Actical. The manufacturers of the ActiGraph and Actical use different algorithms to convert raw accelerometry data to activity counts, making it impossible to compare output between the two. This prevents comparison between the findings of this thesis and any studies using the Actical to measure PA in dogs. The field of PA research in dogs is in its infancy and as a result there are no studies comparing the accuracy of the ActiGraph or the Actical when measuring PA in dogs. Having access to this information would have facilitated a more informed decision on which accelerometer to use in this thesis when measuring PA in dogs.

Despite the fact that the results of Chapter 2 showed that the ActiGraph GT3X could classify dog PA by intensity with a high level of accuracy, the study population included a wide variety of dog breeds. It could be hypothesised that there is a breed or size effect on accelerometry output which would affect the generalisability of the cut-points developed in Chapter 2 to all dogs. It would have been useful to have access to a study population with adequate numbers of dogs within each size grouping (toy, small, medium, large and giant). The accuracy of the GT3X when classifying intensity could have then been assessed within each subgroup and any differences compared. This would have increased the validity and generalisability of the cut-points when applied to the ActiGraph output of dogs in Chapters 3-6. In addition, the accelerometer output in Chapter 2 was calibrated against direct observation which is a gold standard technique for monitoring human PA. Dogs were observed during four intensities of movement either indoors (sedentary and light intensity PA) or outdoors (moderate and vigorous intensity PA). It could be hypothesised that direct observation may not be appropriate for measuring PA in dogs due to their often unpredictable nature of activity. However, all activities were video recorded and any discrepancies between the completed DPAF forms and accelerometry output were checked retrospectively. Nonetheless, a more controlled method such as treadmill walking/running may be more appropriate when observing PA in dogs. However, in human studies relationships between PA and accelerometry output differ between treadmill exercise and free living exercise, and the generalisability of treadmill based exercise to free-living movement in dogs may be questionable.

Furthermore, there is increasing interest surrounding new methods for processing accelerometry output. It has been suggested that the method of using accelerometer cut-points does not fit all modes of PA and therefore leads to errors when categorising PA (Staudenmayer *et al*., 2009). To try and overcome this issue, methods such as machine learning and artificial neural networks have been proposed (Staudenmayer *et al.*, 2009, Freedson *et al*., 2011). Machine learning essentially involves the process of using advanced statistical software and pattern recognition techniques to classify an accelerometer time series into a type of PA. The use of such pattern recognition techniques has not yet become commonplace in PA research. However, work in this field is ongoing and future studies of both human and dog PA should seek to employ these methods if they become the standard. It has also been suggested that studies of accelerometry measured PA should use the raw acceleration signal recorded by the accelerometer rather than the activity count which is calculated from the raw signal (see Chapter 1, Section 1.2.2.3.). This is because the algorithms used to convert the raw signal to activity counts are usually proprietary and not released to the academic community, and results from studies which use different types of accelerometer cannot be compared. Future studies which use a combination of the raw accelerometry signal and pattern recognition techniques to define PA are recommended, may lead to a clearer understanding of the determinants and benefits of PA, and would allow comparisons to be made between studies using different accelerometers.

One of the aims of this thesis was to explore the relationship between PA and overweight/obesity in dogs. Throughout the thesis weight status was assessed by BCS, a non-invasive and inexpensive method of classifying dogs as overweight or not. There are a number of different systems available including the 5-point, 7-point and 9-point scoring systems, each of which have been used in the academic literature. This thesis employed the 5-point system, and therefore it may be difficult to compare the results of Chapters 3, 4 and 5 with future studies that assess the relationship between PA and overweight/obesity using a different BCS system to classify obesity. Furthermore, there are other more robust methods of measuring adiposity in dogs, such as DXA, which are more accurate than BCS when classifying dogs as overweight or obese. Using DXA rather than BCS to measure dog overweight and obesity in this thesis would have enhanced the validity of the results. However, DXA is a much more expensive and time consuming method than BCS and did not fit within the limited budget, timeframe and resource availability of the studies described in this thesis.

Another limitation of this thesis is that the relationship between owner-related factors and dog PA was not explored. Opportunities for dog PA are largely determined by their owners. It is an owner that determines the frequency, duration, and often the intensity of dog walks for example. Whether an owner allows an obese dog to exercise vigorously or not was not assessed and it is therefore difficult to say whether the results of Chapter 3 which show that obese dogs are less vigorously active than ideal weight dogs is because they are obese, or because they are not allowed to exercise vigorously through fear of causing injury or illness. The same can be said for the results of Chapter 4, did PA decrease with age as a result of a biological phenomenon, or are owners of older dogs wary of allowing their dog to exercise? In addition, other owner related factors likely to impact dog PA, such as whether a dog was walked on or off lead, or whether owners actively encourage dog PA during walks (e.g. playing fetch) were not assessed in this thesis and such factors could certainly have had an impact on the results of Chapters 3, 4 and 5. Furthermore, as with humans, the amount of time spent sedentary may turn out to be more important than first imagined in dogs. The amount of time a dog spends sedentary may be directly related to the amount of time they are left alone indoors or the type of house they live in (e.g. size of rooms, size of garden etc.).

It would also have been useful to have information on owner factors that impact on their own PA levels. A wide number and variety of factors have been shown to be associated with PA in humans. These include biological variables such as age, gender and weight status and psychosocial variables such as self-efficacy. The effect of owner characteristics such as these on dog PA were not explored in this thesis, therefore limiting the generalisability of the results to the wider dog population. Assessing the dog walking habits of owners, as well as the opportunities for PA when dogs are left alone would be useful and help to explain variations in dog PA.

The design of a study has implications for the validity and generalisability of the results. Chapters 3 and 4 were cross sectional studies which assessed the association between PA and a number of dog related factors. Although cross sectional studies are useful when exploring associations and building hypotheses they cannot show causality. Thus, it is impossible to say with absolute confidence that obese dogs are less vigorously active than ideal weight dogs (Chapter 3) or that PA levels decrease as dogs age (Chapter 4). However, these results do expand the understanding of PA levels in dogs.

The small sample sizes used in Chapters 3-6 of this thesis limit the generalisability of the findings. Larger sample sizes may have been more representative of the wider dog population and the differences in PA between overweight/obese dogs and ideal weight dogs may be may be larger or smaller than reported in this thesis. Chapter 5 reported the change in PA levels during weight loss in overweight and obese dogs. However, only 14 dogs returned valid accelerometry data. It could be hypothesised that these 14 dogs did not reflect the true change in PA of all overweight and obese dogs as they lose weight. It would have been useful to have data on more dogs in order to determine whether the small sample sizes did in fact affect the results. Another issue with the results of Chapter 5 is the study design. The dog owners effectively knew they were in an experimental group and therefore may have increased the amount of dog walking at baseline, leading to higher amounts of PA than usual when PA was measured. This would introduce bias into the study. A better design would be a RCT where dogs were randomly assigned to a control or experimental group. However, the weight loss programme was already in place prior to study design and it was not possible to do this.

There are two types of error that are possible when conducting hypothesis testing. The first kind of error is a Type 1 error which means that the null hypothesis has been rejected when it is actually true. The second kind of error is a Type 2 error, which occurs when the null hypothesis has not been rejected when it is false, and these are often the result when studies are statistically underpowered. The general lack of statistically significant effects in Chapters 3-6 may therefore be a result of Type 2 errors. For instance, the difference in total volume of PA between ideal weight dogs and obese dogs in Chapter 3, while statistically insignificant, was 177 cpm which is equivalent to a difference in cpm of 25%. It is therefore likely that such a difference in accelerometer count between ideal weight and obese dogs has biological significance, and a post hoc power calculation suggested that this difference would be detectable with a sample size of 129 dogs. Therefore, it is possible that future studies which are sufficiently powered will detect statistically significant differences that this thesis could not, although it may be difficult to carry these studies out due to the large sample sizes required.

Related to the issue of sample size is the composition of the study population. Studies of correlates of PA in humans are usually carried out on one specific age group for example, i.e. children, adolescents, adults. In Chapter 4 the study population included juvenile, adult and senior dogs. This prevented the assessment of the impact of other factors on PA within each age group. It may be that obesity has an effect on PA in one age group of dogs and not others for example. Similarly, Chapters 3 and 5 included a wide variety of dog breeds. Chapter 4 showed that PA levels of Cocker Spaniels are different from Labradors and differences like this will likely exist between many of the breeds recruited in Chapters 3 and 5. This limits the generalisability of these results.

The limitations specific to Chapter 6 have been discussed previously (See Chapter 6 Section 6.4), however the aim of the CPET trial was to inform a future, more definitive trial and those limitations warrant further discussion in this section of the thesis. A number of demographic, biological, behavioural, psychosocial and environmental factors are associated with PA in both children and adults (For a review see Bauman *et al.* (2012)). For instance, it has been shown previously in studies of the correlates of PA, that boys in the age range of 9-11 years old (the age group included in CPET) are more physically active than girls of the same age (Sallis *et al.*, 2000, Van Der Horst *et al.*, 2007). Furthermore, an adult's health status or perceived fitness, and self-efficacy have consistently been shown to be a correlate of PA (Trost *et al.*, 2002, Kaewthummanukul and Brown, 2006, Allender *et al*., 2008). None of these factors, or any of the others identified in the review by Bauman *et al.*, were explored in this study.

The intervention content was deemed acceptable to participants and the number of completed outcome measures was high indicating that the intervention was feasible. However, CPET was a short term intervention (10 weeks) and definitive trials of PA interventions generally have follow up periods of at least six months (van Sluijs *et al.*, 2007). A more definitive version of CPET would therefore be longer in duration than the current exploratory trial and the feasibility of delivering the intervention, and the acceptability of the outcome measures over such a duration is unclear. Furthermore, the intervention content and outcome measures were resource intense, possibly making the intervention difficult to deliver on a larger scale as would be required in a more definitive trial.

Although exploring the potential efficacy of CPET was not the major aim of the trial it is important to consider the reasons why there was no significant change in the primary outcome measure (child PA). PA was measured in the week after the intervention, rather than the last week of the intervention. Clearly, PA levels may have been different between these two weeks and therefore any apparent increase in PA may have been missed. Measuring PA throughout the intervention or at multiple time points would overcome this issue. The short duration of CPET may also have had an impact on the effectiveness of the intervention. If CPET was implemented over a longer period then differences between the intervention and control groups may become apparent.

The limitations discussed thus far identify a number of areas for future research. Studies comparing the accuracy of different models of accelerometer when measuring PA in the same sample of dogs are required. A sensible comparison would be between the ActiGraph and Actical accelerometers as these two models have already been validated for use in dogs. Knowing which of these accelerometers is most accurate when predicting PA would allow researchers to make an informed decision on which model to choose when designing a study. In addition, further calibration studies are required that develop cut-points that are specific to dog breed or size, and/or are age-specific as is the case in humans. This would allow researchers to know if accelerometer output during walking is the same for large dogs compared to small dogs for example, meaning that dog PA could be measured with greater confidence and facilitating a clearer understanding of the complex nature of PA in dogs. Studies validating the use of raw accelerometry data when measuring dog PA are also required. These would allow for comparison between the output of different types of accelerometer. In addition, future validation studies of accelerometry in dogs should explore whether other methods of data processing such as machine learning are more accurate when predicting dog PA than the use of traditional cut-points.

It is also important that studies exploring the relationship between owner related factors and objectively measured dog PA are carried out. These studies should aim to determine whether factors such as the mode of dog walking (on- or off-lead) has any significant impact on the volume and intensity of dog PA. It would also be useful to determine whether owners of obese dogs offer their dog enough opportunities for PA and whether dogs that are kept outside when alone are more active than those confined indoors. If studies like these were to show any significant difference in dog PA as a result of owner factors then these could be controlled for in future studies.

The major limitation of Chapters 3 and 4 in this thesis is the cross sectional nature of the studies carried out, resulting in the inability to establish causality. A cohort study would be able to answer some of the questions arising from the results of Chapters 3 and 4. Such a study would be able to show whether weight gain predates physical inactivity, and whether low levels of PA predate old age for example. Human cohort studies often only track outcomes over a specific age group (e.g. childhood) or time period (e.g. five or 10 years). The advantage of carrying out a cohort study in dogs is their average life span, which varies with breed but is typically between 6 and 14 years, meaning that outcomes could be tracked throughout the lifespan in a relatively short period of time. Studies of this nature would also be able to examine other outcomes in detail besides PA, e.g. the association between obesity and neutering, although large sample sizes would be required.

Studies are also required that assess the effectiveness of PA interventions in dogs during weight loss. Chapter 5 showed that PA did not increase spontaneously during substantial weight loss in dogs. Due to the other benefits of PA besides weight loss/maintenance PA should be actively promoted during weight loss interventions. The study protocol in Chapter 5 did not include any formal PA counselling as is usually present in human PA interventions, and although combined dietary therapy and PA is often used in veterinary practice, no published peer reviewed studies have assessed the change in PA using accelerometry. Studies of this nature would be able to determine whether PA could be increased significantly during weight loss in dogs.

The Medical Research Council framework for developing and evaluating complex interventions recommends that exploratory trials such as CPET are carried out to evaluate the feasibility and acceptability of the intervention and outcome measures to participants. The results of the CPET trial described in Chapter 6 indicate that a dog walking intervention involving children, their parents and pet dog was both feasible an acceptable to the participants, at least in the short term. A future, more definitive trial should therefore be carried out using the exploratory CPET intervention as a template. However, prior to any such trial a formative evaluation is required to gather insight into the wider population's perspectives about a dog walking intervention. The relatively low conversion from expressions of interest to signed consent during the recruitment stage of CPET indicated that, although feasible and acceptable, CPET may not be generalisable. A formative evaluation would be able to answer some questions that this thesis cannot, such as: Why were potential participants interested initially, but declined to take part at a later stage prior to the intervention?; Were potential participants ultimately put off by the time they would need to commit to such an intervention?; Was the number of outcome measures a barrier to participation for those that did not sign consent? It should define whether such an intervention is desired by the population and if so guide a) the method of recruitment in a future more definitive trial, and b) the design of the intervention itself.

Despite its limitations, this thesis describes a number of novel studies which have applications in veterinary practice, and identifies a number of areas for future research. It demonstrates that the ActiGraph GT3X accelerometer is capable of classifying dog PA by intensity with a high degree of accuracy. The first peer reviewed studies suggesting an association between dog characteristics such as obesity, breed and age and ActiGraph measured PA are described. In addition the findings demonstrate that a dog walking intervention and trial involving children and their parents is both feasible and acceptable to the study participants.

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Appendices

Appendix A: Dog Physical Activity Form (DPAF)

The DPAF score is calculated by assessing how much time the dog spent at each activity level in each minute. The number of seconds in each minute was divided between the number of categories of activity that the dog exhibited during that minute. For example, if the dog spent one minute exclusively performing one level of activity, it would be assigned 60 seconds. If, for example, three activity levels were seen, the minute would be divided by three, that is, 20 seconds per level of activity. Level 1=60 activity points, level 2=120 activity points, level 3=180 activity points and level 4=240 activity points. Only "clean minutes" were used in this study, whereby only one level of activity was recorded for the full minute. If minutes were observed that included more than one level of activity the protocol continued until 10 full minutes of only one level of activity were observed.

Date: Time:

Dogs Name:

Age: Sex: Breed: BCS:

LEVEL OF ACTIVITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No Movement	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Limited movement						**X**				
Walking										
Vigorous										
DPAF Score	**60**	**60**	**60**	**60**	**60**	**90**	**60**	**60**	**60**	**60**
LEVEL OF ACTIVITY	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
No Movement	**X**									
Limited movement										
Walking										
Vigorous										
DPAF Score	**60**									

Date :   Time:

Dogs Name:

Age: Sex: Breed: BCS:

LEVEL OF ACTIVITY	1	2	3	4	5	6	7	8	9	10
No Movement										
Limited movement	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Walking										
Vigorous										
DPAF Score	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**	**120**
LEVEL OF ACTIVITY	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
No Movement										
Limited movement										
Walking										
Vigorous										
DPAF Score										

Date :   Time:

Dogs Name:

Age: Sex: Breed: BCS:

LEVEL OF ACTIVITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No Movement										
Limited movement										
Walking	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Vigorous										
DPAF Score	**180**	**180**	**180**	**180**	**180**	**180**	**180**	**180**	**180**	**180**
LEVEL OF ACTIVITY	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
No Movement										
Awake with limited movement										
Walking										
Vigorous										
DPAF Score										

Date : Time:

Dogs Name:

Age: Sex: Breed: BCS:

LEVEL OF ACTIVITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No Movement										
Limited movement										
Walking										
Vigorous	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
DPAF Score	**240**	**240**	**240**	**240**	**240**	**240**	**240**	**240**	**240**	**240**
LEVEL OF ACTIVITY	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
No Movement										
Awake with limited movement										
Walking										
Vigorous										
DPAF Score										

Appendix B: Diary for recording when accelerometer was removed from dogs

All dog owners participating in studies described in this thesis were asked to complete a diary (see next page), recording any periods that the accelerometer was removed from their dog, the reason, and when it was reattached. Any such periods were then removed from analysis.

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Owner Diary

We would be grateful of you could complete the following diary. The accelerometer should be attached it should be attached for 7 full days, e.g. if it is attached on a Saturday please do not remove it until the following Sunday. Please note below any times you have to remove the device, and when it was reattached.

Date	**Please record here the time the device was removed by you**	**Please record here the time the device was re-attached**	**Please give the reason the device was removed**
Example – Mon 15th November	2.15pm	2.55pm	Device became loose and had to re-attach

Appendix C: 5 point body condition scoring system

The 5 point BCS system is one of the most widely used systems to score body condition in veterinary practice. The technique involves comparing a dog's visual and haptic appearance to a BCS chart (Fig C.1). A dog is assessed visually from the side and above and then whoever is performing the analysis should run their hands along the dog's sides, back and hip bones. An ideal weight dog's ribs, spine and hip bones should be easy to feel. Additionally, there should be no build-up of fat around the base of the dog's tail, and its tummy should not bulge out. The ribs, spine and backbone of an overweight dog will be difficult to feel, they will be broader than an ideal weight dog, and there will be fat around the base of the tail. An obese dog will have a bulging belly, the ribs, spine and hip bones will be impossible to feel with light pressure, and they will have thick fatty pads at the base of the tail.

Figure A.C.1 5 point BCS chart. Adapted from http://www.pdsa.org.uk/files/healthy_shape_leaflet.pdf

Appendix D: Chapter 3 Post-hoc power calculation

Minitab 16.1.1 (Minitab Inc, USA) was used to perform a power calculation to estimate sample sizes required to show a statistically significant difference in total volume of PA (mean accelerometer cpm) using the data collected in Chapter 3. For a power calculation using a One-Way ANOVA, Minitab requires the following input:

- the number of factor levels, which is three in this case (ideal weight dogs, overweight dogs, and obese dogs).

- the value of the maximum difference between means. The maximum difference in total volume of PA in this study was between ideal weight dogs and obese dogs. The mean cpm for ideal weight dogs was 718 cpm, and for obese dogs was 541 cpm, leaving a difference of 177 cpm.

- the required power value, which was set at 90%

- an estimate of the standard deviation. For a One-Way ANOVA using the square root of the mean square error is appropriate. The mean square error from that ANOVA analysis of mean accelerometer cpm was 50948, meaning the square root was 226.

Inputting this data into the power and sample size calculation feature of Minitab gives the following power curve:

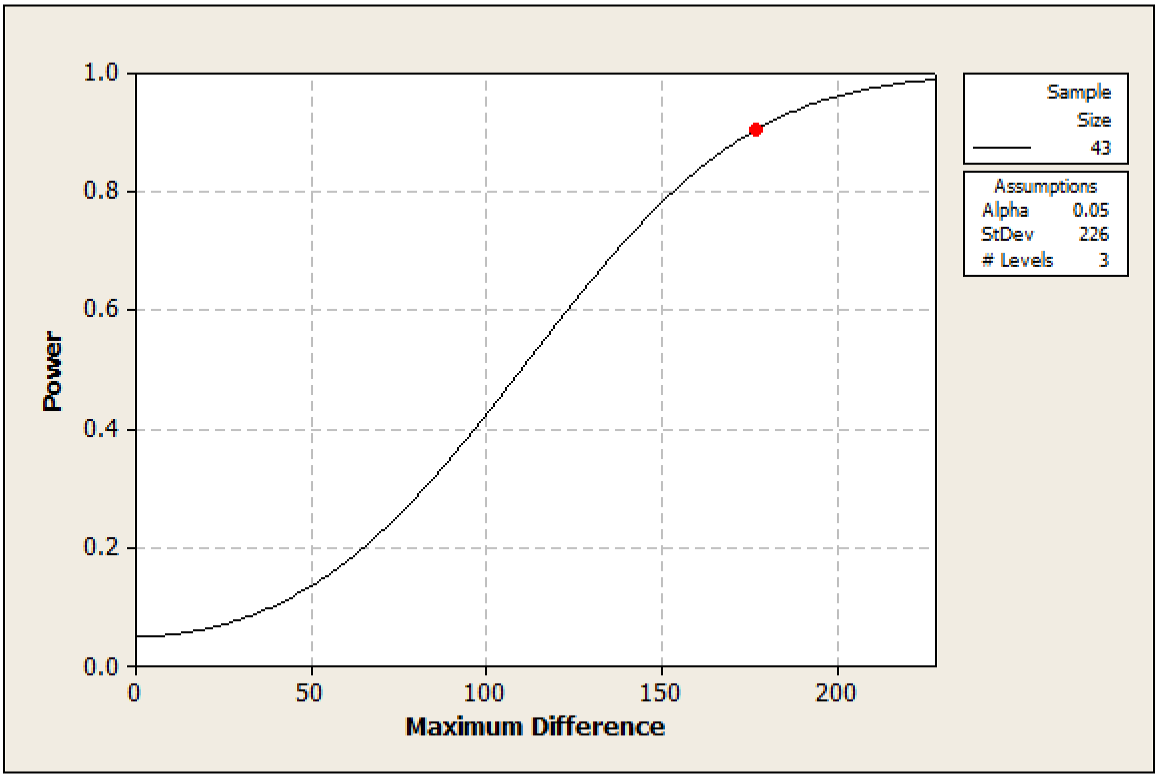


Figure A.D.1 Power curve showing sample size required to detect a statistically significant difference in total volume of PA (mean accelerometer count per minute) using One-Way ANOVA analysis.

The power curve shows that a sample size of 43 dogs per factor level would be required to detect a difference of 177 cpm between ideal weight and obese dogs, meaning a total sample of 129 dogs would be required.

Appendix E: Dog behaviour screening questionnaire developed for CPET study (Chapter 6)

Questionnaire No: 1

University of Glasgow

Yorkhill Children's Foundation

CPET Dog Assessment Questionnaire

CPET
Children Parents and Pets Exercising Together

Thank you for filling out this questionnaire, which should take around 20 minutes to complete.

Before you begin please read these important notes:

- The questionnaire should be completed by the parent/guardian who knows the dog best. A separate questionnaire should be completed for each dog that you own.
- Some of the questions require you to write your answers in the spaces provided, whereas others will require you to tick a box as appropriate.
- If possible please use a pen, and not a pencil, to fill in this questionnaire.
- Please try to answer all of the questions and use as much detail as possible.
- Please answer honestly, as it will help us to understand your family's needs better.

Thank you for your assistance

Questionnaire No: 1

About you and your dog

Your name:

Your childs name:
What School do they attend?:

Dog name:

Dog age:

Dog type (breed or cross description):

Dog Size:

Toy (e.g. Chihuahua) ☐
Small (e.g. Jack Russell Terrier) ☐
Medium (e.g. Spaniel or Collie) ☐
Large (e.g. Labrador) ☐
Giant (e.g. St Bernard) ☐

Gender: Male ☐ Female ☐

Neutered: Yes ☐ No ☐

Other pets owned:

If you own more than one dog, are the dogs walked together? (please describe):

Please tell us about who lives in your household:

Name	Relationship to child	Age

Questionnaire No: 1

<u>Please answer the following questions.</u>
1. Have you owned a dog before this one? Yes☐ No☐ If yes, please describe (e.g. breed)
2. Have you owned this breed of dog before? Yes☐ No☐
3. What were your reasons for getting this dog? (please tick all that apply) Companionship for people ☐ Companionship for other pets ☐ Security ☐ Always had a dog ☐ To walk with ☐ For the children ☐ Other (please describe) ☐
4. How old was your dog when you got him/her?
5. Where did you get your dog from?
6. Please tell us as much information as possible about how the dogs were kept in the place that you acquired this dog (e.g. if a puppy was your dog kept with or away from the mother and what was the litter size, and was your dog kept inside, outside, with or without other dogs)?
7. Have you attended any training classes with your dog? Yes☐ No☐ If yes, please describe:
8. Which commands does your dog know?

Questionnaire No: 1

9. Is your dog more obedient in some places than others? Yes☐ No☐ If yes, please describe:
10. More obedient with some people than others? Yes☐ No☐ If yes, please describe:
11. When you ask your dog to do something, how responsive is he/she to your (the parent's) command? Very good☐ Sometimes responds ☐ Poor☐
12. When your child asks your dog to do something, how responsive is he/she to their command? Very good☐ Sometimes responds ☐ Poor☐
13. Does your dog ever show any aggression (growling, snapping, or biting) towards household members? Never☐ Rarely☐ Sometimes☐ Often☐ Always☐ If at all, to whom, what does the dog do, and in what circumstances?
14. Does your dog ever show any aggression (growling, snapping or biting) towards people who visit your house or that you meet when outside the house? Never☐ Rarely☐ Sometimes☐ Often☐ Always☐ If at all, to whom, what does the dog do, and in what circumstances?
15. Does your dog have any medical problems that may prevent him from being walked or enjoying walks? Yes ☐ No ☐ If yes, please describe:
16. How often is your dog walked?
17. For how long is he/she walked?

18. Is your dog allowed to run off lead? Yes ☐ No ☐
If so, does he/she return to you when asked?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

19. Does your dog pull on the lead?

Excessively ☐ A bit ☐ Rarely ☐ Never ☐

20. Is your dog used to having your child walk with you? Yes ☐ No ☐

21. When your dog sees an adult stranger on a walk, how does he/she react (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Extremely interested in them	☐	☐	☐	☐	☐
Jumps up at them	☐	☐	☐	☐	☐
Runs over to every person he sees	☐	☐	☐	☐	☐
Friendly but not exuberant	☐	☐	☐	☐	☐
Ignores strangers	☐	☐	☐	☐	☐
Avoids strangers, chooses to not go near them	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Wary of strangers, hackles up	☐	☐	☐	☐	☐
Fearful of strangers, growls or snaps	☐	☐	☐	☐	☐

22. When your dog sees a child on a walk, how does he/she react (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Extremely interested in them	☐	☐	☐	☐	☐
Jumps up at them	☐	☐	☐	☐	☐
Runs over to every person he sees	☐	☐	☐	☐	☐
Friendly but not exuberant	☐	☐	☐	☐	☐
Ignores children	☐	☐	☐	☐	☐
Avoids children, chooses to not go near them	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Wary of children, hackles up	☐	☐	☐	☐	☐
Fearful of children, growls or snaps	☐	☐	☐	☐	☐

23. If a strange person (adult or child) tries to touch your dog whilst you are on a walk, how does he/she react (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Extremely interested in them	☐	☐	☐	☐	☐
Jumps up at them	☐	☐	☐	☐	☐
Runs over to every person he sees	☐	☐	☐	☐	☐
Friendly but not exuberant	☐	☐	☐	☐	☐
Ignores strangers	☐	☐	☐	☐	☐
Avoids strangers, chooses to not go near them	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Wary of strangers, hackles up	☐	☐	☐	☐	☐
Fearful of strangers, growls or snaps	☐	☐	☐	☐	☐

24. How does your dog react to sudden noises, for example police siren, gunshots, lorry shutter doors or hissing brakes (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Ignores them	☐	☐	☐	☐	☐
Wary, hackles up	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Nervous and fearful	☐	☐	☐	☐	☐

25. How does your dog react to strange objects, for example fallen-over wheelie bin, road signs on pavement (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Ignores them	☐	☐	☐	☐	☐
Avoids them, chooses not to go near them	☐	☐	☐	☐	☐
Wary, hackles up	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Nervous and fearful	☐	☐	☐	☐	☐

26. If your dog is allowed off the lead and meets another dog how does he/she behave (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Extremely interested in them	☐	☐	☐	☐	☐
Plays exuberantly with them	☐	☐	☐	☐	☐
Runs over to every dog he/she sees	☐	☐	☐	☐	☐
Friendly but not exuberant	☐	☐	☐	☐	☐
Ignores them	☐	☐	☐	☐	☐
Avoids them, chooses not to go near them	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Wary of other dogs, hackles up	☐	☐	☐	☐	☐
Fearful of other dogs, growls or snaps if they come close	☐	☐	☐	☐	☐

27. How does your dog behave when he/she is on lead and meets another dog (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Extremely interested in them	☐	☐	☐	☐	☐
Plays exuberantly with them	☐	☐	☐	☐	☐
Runs over to every dog he/she sees	☐	☐	☐	☐	☐
Friendly but not exuberant	☐	☐	☐	☐	☐
Ignores them	☐	☐	☐	☐	☐
Avoids them, chooses not to go near them	☐	☐	☐	☐	☐
Barks at them	☐	☐	☐	☐	☐
Wary of other dogs, hackles up	☐	☐	☐	☐	☐
Fearful of other dogs, growls or snaps if they come close	☐	☐	☐	☐	☐

28. How does your dog behave when he/she is on lead and sees another dog in the distance (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Tries very hard to get near them	☐	☐	☐	☐	☐
Ignores them	☐	☐	☐	☐	☐
Avoids them and tries to get away from them	☐	☐	☐	☐	☐
Barks or growls at them	☐	☐	☐	☐	☐
Lunges towards them	☐	☐	☐	☐	☐

29. How does your dog behave around other animals, e.g. cats, squirrels, sheep, horses (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Very interested, would chase it, cannot be distracted	☐	☐	☐	☐	☐
Will chase them if given opportunity but can be distracted	☐	☐	☐	☐	☐
Ignores it	☐	☐	☐	☐	☐
Fearful, will try to get away from it	☐	☐	☐	☐	☐

30. How does your dog behave around traffic, e.g. cars, lorries, motorcycles (Please answer for all statements and tick the boxes that apply)?

	Never	Rarely	Sometimes	Often	Always
Very interested, would chase it, cannot be distracted	☐	☐	☐	☐	☐
Will chase them if given opportunity but can be distracted	☐	☐	☐	☐	☐
Ignores it	☐	☐	☐	☐	☐
Fearful, will try to get away from it	☐	☐	☐	☐	☐

31. Does your dog behave differently when your child is with you on a walk to when you are walking without children? Yes☐ No☐

If yes, please describe:

32. Does your dog like to play games with toys when on a walk?

Yes☐ No☐ Don't know☐

Please describe what type of games/toys:

33. Do your family members enjoy owning your dog?

Yes☐ No☐ Some of them☐

If you answered no, please describe why:

34. Do your family members enjoy walking your dog?

Yes☐ No☐ Some of them☐

If you answered no, please describe why:

35. Do the dog and your child/children interact whilst on a walk?
 If so, please describe:

36. Is your dog's mood/character the same every day (please describe)?

37. If you had to choose 3 words to describe your dog, what would they be?

38. Finally, what type of diet do you feed your dog?

Dry biscuits ☐
Tinned meat ☐
A combination of dry biscuits and tinned meat ☐
Other ☐

If other please describe:

<u>Thank you for your time and for completing the questionnaire</u>

Appendix F: Intervention booklet used in CPET study (Chapter 6)

Table of Contents

Important intervention dates for your diary:

Today:	**Visit**	date & time:
in 1 week	Email Contact	
in 3 weeks	Email or Phone Contact	
in 5 weeks:	**Visit**	date & time:
in 7 weeks	Email or Phone Contact	
in 9 weeks	Email or Phone Contact	
in 10 weeks	Measurements	

3

How much activity should we do to be healthy?

To achieve health benefits we recommend:

- Children should aim for a minimum of 60 MINUTES of moderate to vigorous activity PER DAY
- Adults should aim for at least 150 MINUTES PER WEEK of moderate intensity activity or 75 MINUTES of vigorous intensity activity per week.
- Dogs should have at least one walk per day. The Kennel Club have an online list of individual exercise recommendations for different breeds.
- Have a look at this website: www.the-kennel-club.org.uk/services/public/breed/Default.aspx

Suitable activities can include things you do at home, e.g. vacuuming, walking the dog and things you do at work or school e.g. walking to work or school, running around the playground.

The activity should be of at least 'moderate' intensity. It should be hard enough to make you breath faster and deeper and your heart beat faster.

Can you recognise this feeling the next time you are out playing or walking?

Pros & Cons of being active.

Why should we be active?

- Healthy heart and mind
- Healthy weight
- Strong muscles and bones
- It makes you fitter
- It feels good
- It's fun

What might stop us being active?

- Too busy
- Too tired
- Don't like sport
- Too expensive
- The weather

5

Benefits for you?	Barriers for you?

6

Identify your activities.

What do you do that is physically active?

child	parent	dog

What do you do that is sedentary?

child	parent	dog

What could you do to replace these sedentary behaviours?

7

Physical activity ideas with your dog (indoors & outdoors)

Guidance

This section describes ways to offer children and dogs simple training and physical activity opportunities in fun, easy-to-implement ways.

Outlined in the following tables are a number of different games and activities. Not all will be suitable for, or enjoyed by, all children or all dogs. It is up to you to choose which are most suitable for your circumstances and modify as necessary. Many exercises will have to be adjusted accordingly for the size of the dog.

Activities have been designated as 'simple', 'intermediate' or 'advanced' versions. Start by teaching the dog the simple version before progressing to the more complicated versions.

Don't Force It

If either the child or the dog appears to not be enjoying the game or is very tired, please stop the game and evaluate.

Don't allow anyone to push or pull the dog to get him to do something. If the dog seems confused or resistant, look for ways to make the challenges easier (for example going back to a 'simple' version of the game).

Watch for any signs of frustration, on either the children or dog's part, and stop the games session if necessary.

Working for food

We often make reference to 'food treats' as rewards for training and motivators for playing the game. Some dogs will require these (especially at the beginning of training) whereas others will be motivated purely by the enjoyment of the game. It is important that food is not used excessively.

The best way is to get a dog to work for part of his daily portion of food.

This has many advantages:

- You can give lots of rewards throughout the day and the dog will not get fat from overfeeding.
- You do not need to worry about the diet becoming imbalanced.
- It is natural for your dog. In a wild situation, they do not receive a bowlful of food at the same time each day. In the wild, they have to earn their food. Dogs are programmed to work for their food and enjoy it.
- You are clearly in control and so it helps dogs to learn that they will be rewarded for good behaviour and hence they will enjoy doing things for you.
- It is cheaper than buying bagfuls of snacks or treats.

The only limit is your imagination!

- It encourages owners to have lots of interactions with their dogs throughout the day. These are positive times when the dog is enjoying learning.
- It gives the dog more to think about and so prevents boredom.
- Most dried foods are in small pieces which are the ideal size for rewards. Many commercially bought treats are far too big to be used. All that is needed is a tiny tasty morsel.

Follow this simple procedure.

1. After feeding your dog, put out his/her next meal and leave it somewhere inaccessible for your dog.
2. Take part of it each time you want to play the activities with your dog.
3. At the next meal time, your dog has what is left in the bowl.
4. If you find you are giving him/her the majority of his food in his bowl, you need to make an extra effort to do more activities the next day.

What if I feed my dog wet food?

This can be more difficult. In some situations, you can use a spoonful of tinned food for each reward. Some foods, e.g. Naturediet, can be cut into small squares and taken out in a plastic bag. Some dogs enjoy the mixer biscuit enough for this to be used as a reward. Alternatively, consider using some complete food and adjust the dog's meal amounts accordingly or use a semi moist food as treats and adjust the meal ration accordingly.

Using these techniques, food can be used as a reward in games without the dog becoming overweight. The dog and child will also be expending energy during the activities.

We hope you enjoy these suggested activities.

The only limit is your imagination!

9

Games to be played indoors and outdoors

Type	Name	Difficulty	Description	Tips
Find it	Find it 1	Simple	In this game, the dog finds an object such as a treat, toy or ball. To teach this game to your dogs, put him in a sit and stay position or hold him if he doesn't know these commands. Have your child hide the treat or toy, letting the dog see where it is placed, and then tell him to find it (naming individual toys if necessary). A lot of praise should be lavished on the dog when he is successful. Allow him to eat the treat or play with the ball or toy when he finds it. After doing this several times, your child can hide the object in a less visible location, so your dog has to work harder. While your dog is searching and retrieving the toy, your child should be active too- e.g. jumping or skipping or dancing on the spot until your dog returns with the toy.	Best to play just before feed time
	Hansel & Gretel Food Trails	Intermediate	Give your child a small bowl of treats for the dog and get him/her to create a trail for the dog to follow. Keep the dog near you while the child puts a treat every 2 to 4 feet. When your child has laid out the entire path, have him/her come back and tell the dog to sit before releasing the dog to follow the trail. Your child should follow (walking or skipping or jumping up and down) along behind the dog cheering and clapping for each successful find.	

Games to be played indoors and outdoors

Type	Name	Difficulty	Description	Tips
	Com-mando Crawl	Intermediate	Have your child lay a trail of treats by crawling under your coffee table (or dining table) from one end to the other. Teach the dog to belly-crawl across the floor to get the treats. This game can be modified for outdoor use by using a row of plastic patio chairs or a table or other garden toys and furniture. When your dog follows the trail, your child should follow (walking or skipping or jumping up and don or crawling where necessary) along behind the dog cheering and clapping for each successful find.	Adjust appropriately for the size of dog
	Hide & Seek	Advanced	This classic game becomes extra special when played with your child and your dog. Your child holds the dog's favourite treat and hides in another room or somewhere outside in the garden. The parent should hold on to the dog as the child is hiding so the dog doesn't automatically follow the child. As soon as your child is hidden away, let the dog go, with the words "find [insert child's name]". At first, encourage your child to help the dog find him/her by calling the dog's name. When the dog finds the child, he/she should make a huge fuss, offering lots of petting, stroking and praise as well as giving the treat. Eventually your dog will be able to play this game without having his/her name called. This can also be done to let your child get involved with the seeking part of the game. You hide an item (e.g. a toy) for your child to find and a treat for your dog to find.	

11

Games to play outdoors

Type	Name	Difficulty	Description	Tips
Recall	Recall 1	Recall	Hold the dog by the collar, ask the child to run a few paces away, stop and turn around, and then call the dog by its name as you let go. Reward your dog with a food treat when he gets there. To make this a bit more difficult, ask the dog to sit when he arrives.	
	Dog Bowling	Intermediate	This works best indoors but could also be modified for outdoors. Arrange empty plastic 2-litre bottles in a bowling triangle in the hallway, the parent should hold the dog at the other end of the hallway and have the child, jumping or skipping on the spot behind the bottles triangle, call the dog for a treat. Ideally the dog should score a 'strike' before the game is finished.	Use smaller bottles (e.g. ½L bottles) if you have a small dog
Fetch	Fetch 1	Simple	Many dogs love to chase and fetch all sorts of different items, including balls, toys, and frisbees. If playing with a ball make sure that it is small enough to fit comfortably in the dog's mouth but not so small that he could choke or swallow it. Have your child throw the item while telling the dog to 'fetch'. Whilst the dog is fetching the toy, your child should be jumping, skipping or dancing on the spot. When the dog returns with the item, tell your child to give him the 'drop it' command. He or she should give him a lot of praise when he drops the item. If the dog won't drop the item, have your child throw a different toy for him to chase, which should cause him to drop what he has in his mouth.	Make sure your child knows never to try and take the toy out of the dog's mouth because they could be bitten

Games to be played indoors and outdoors

Type	Name	Difficulty	Description	Tips
	Clean up your toys	Advanced	This game can be played by both the child and the dog whilst the parent stands by the bucket. Get a box or bucket and collect a number of toys and other dog-safe items. Scatter the toys in a small pile on the floor. Through encouragement, get the dog to pick up the items one at a time, and place them in your hand. Once the dog is lifting the items high enough to get your hand underneath to receive, you are well started. Be sure to reward each "gift" with a food treat. Make it harder and harder to put items in your hand, while maintaining the fun of this game. Each item retrieved is dumped into the bucket. The dog will leave harder ones for later, so over time make substitutions that make the items increasingly difficult for the dog. Some dogs take the leap and start putting things directly into the bucket themselves. For the entire time the dog is cleaning up his toys, you child should be performing activities such as star jumps and bunny hops on the spot and counting how many they can complete by the time the dog has cleared up their toys.	

Games to play outdoors

Type	Name	Difficulty	Description	Tips
Recall	Recall yo-yo	Simple	Advance the earlier recall game by asking the child to run a further distance. Once the dog arrives with the child, go to them, take hold of the dog again, and get the child to run off in a different direction this time. For more boisterous dogs this may require the participation of two adults, one to hold the dog and one to help the child.	
Fetch	Fetch Race	Intermediate	Advance the previous fetch game by having a race between the dog and the child to reach the toy. Make the child and the dog stand still (hold the dog if required) and throw a toy a good distance. Then release them and the winner is the first to reach the toy, or the first to bring it back to you. You may have to give the child a head start by positioning them closer to the toy than the dog.	Do not play with any dog who may get possessive over the toy
	Rounders	Advanced	Parent to hold dog on lead (asking dog to sit) and throw ball towards child. Child hits the ball and runs around the four markers. Parent releases dog to fetch the ball and then calls the dog back, trying to hit the last marker with the ball before the child completes the circuit.	

14

Games to be played indoors and outdoors

Type	Name	Difficulty	Description	Tips
Variety	Football	Simple/ Intermediate	To start, get a football or any other sort of soft ball. Have your child gently kick the ball so it rolls on the ground toward the dog. If necessary, have your child encourage the dog to get the ball. At first, the dog may try to pick up the ball but will quickly realise that he must push it with his nose for it to move. When he does this, the child should give him a lot of praise. The dog and your child can then kick and push the ball between them whilst running around.	Make sure the ball is too large for the dog to pick up in his mouth
	Circuit Training	Simple	Locate 4 obstacles in the garden or park (for example tree; bench; log and dustbin). Decide on the circuit and number of laps to be completed. The child should have the dog on a lead and run with it round the circuit. At the end of the circuit a treat can be offered to both. Some dogs will do this off the lead too!	You can make the game more competitive by timing each circuit.
	Obstacle Course	Advanced	Advance the circuit training exercise by asking your child and dog to jump over obstacles at an appropriate small height (e.g. a broom laid over two over-turned buckets) or crawl under an object (e.g. a patio table).	Please make sure neither dog nor child become too excited by the activity to avoid accidents.

15

Physical activity ideas for outside the home

Opportunities for activity in East Dunbartonshire Area

1. Walking routes:

Links to:
www.eastdunbarton.gov.uk/content/transport_and_streets/walking,_cycling_and_horse/healthy_habits/walking_and_cycling_routes.aspx

Walking maps, of differing lengths, are provided for the Kirkintilloch, Lenzie and Bishopbriggs area which anyone can access. These are provided in the pack. Other maps are available online by following the link above.

2. Explore and Enjoy Milngavie Walks Leaflet (Enclosed).

3. Healthy Walking Co-ordinator for ED Council.

For further information please contact on:
0141 578 8556

4. Mugdock Country Park (free entry & parking)

www.mugdock-country-park.org.uk/walking.html

Maps of walks of different lengths are available at the Mugdock shop (~20p each).

- To the Gowk Stone
- Carbeth & Back
- The Water Way
- Mugdock Park Map (Trails- see below)

Trails

www.mugdock-country-park.org.uk/historytrail.html

Tree Trail

Tree identification fun for all the family! Based around the Visitor Centre and Gallowhill area of the Country Park, this easy access Tree Trail guides you around 10 of Mugdock's common tree species using a map and clues. Summer and winter trails available to borrow.

History Trail

Why not try the park's 2-mile circular history trail starting and finishing at the visitor centre. A history trail leaflet can be purchased for 20p at the park office or Stables Gift shop every day of the week.

Easy Access Orienteering

The Easy Access Orienteering Course provides a fun way to find your way around the countryside. Borrow one of the orienteering packs, which include crayons and paper, and take wax rubbings at each of the orienteering posts.

Scavenger Hunt

Fun for younger members of the family, the Scavenger Hunt can be borrowed for use anywhere within the Country Park. Keep your eyes peeled and search for the objects on the list ranging from fuzzy things to things that make a noise.

The only limit is your imagination!

4. Geocaching

Geocaching is an outdoor treasure-hunting game in which you (Geocachers) use a Global Positioning System (GPS) receiver or other navigational techniques to hide and seek containers (called "geocaches" or "caches") anywhere in the world. The locations for these caches are listed on several internet sites.

Once you get to within a few feet of a hidden cache you start looking for it. A typical cache is a small waterproof container containing a logbook and "treasure," usually toys or trinkets of little value. When you find it, you can note in the logbook who you are and when you found it and leave it in the same position for the next person to find!

All you need to do is go the website below:

www.geocaching.com

Enter your post code in to the search box and you can identify the geocaching in your local area and start your treasure hunt! There are routes in the East Dunbartonshire Area which you can access through this service.

It's a fun day out for the family!

Tips for increasing your physical activity

- Keep your Activity Goals in view
- Plan for longer activity at the weekends
- Take a longer dog walking route than normal
- Walk more briskly
- Replace sedentary behaviours e.g. TV watching, with something active e.g. an active game

Can you think of 2 more tips that will help you be physically active?

-
-

18

What can you do if….?

- You are busy
- You feel tired
- It is raining

Problems reaching your targets?

Think of the reason or reasons why it was difficult to be active

Think of a way to overcome this problem and still be active

19

Stars for Stars!!!

It's great to be active so you should have a reward.

You will find star stickers in your pack. Stick 1 star on the activity chart for each day you, your child and your dog are active together!

Count up the number of stars at the end of the week and enjoy the rewards!

Chose your rewards and write them in the Rewards Ladder below.
e.g. if you get 3 stars in one week, your child can chose the dog walking route or which games to play the following week

If you get 7 stars in one week- that's fantastic- your reward should be something special!

You decide!

Reward Ladder

7 or more stars

4-6 stars

3 stars

CPET Goal Setting Sheet

Pack for Children, Parents and Pets Exercising Together.

In 2 weeks;

•
•
•

In 6 weeks;

•
•
•

In 10 weeks;

•
•
•

We agree to carry out the following physical activity plan from ____________ to ____________

Signed: ______________________________ and ______________________________

Researcher: ______________________________ It's great to be active

21

Keep your memories

Pictures, drawings etc..........

22

Keep your memories

Pictures, drawings etc..........

23

Thank you for taking part

Contact details

If you have any questions about the study or the material in this folder please do not hesitate to contact us:

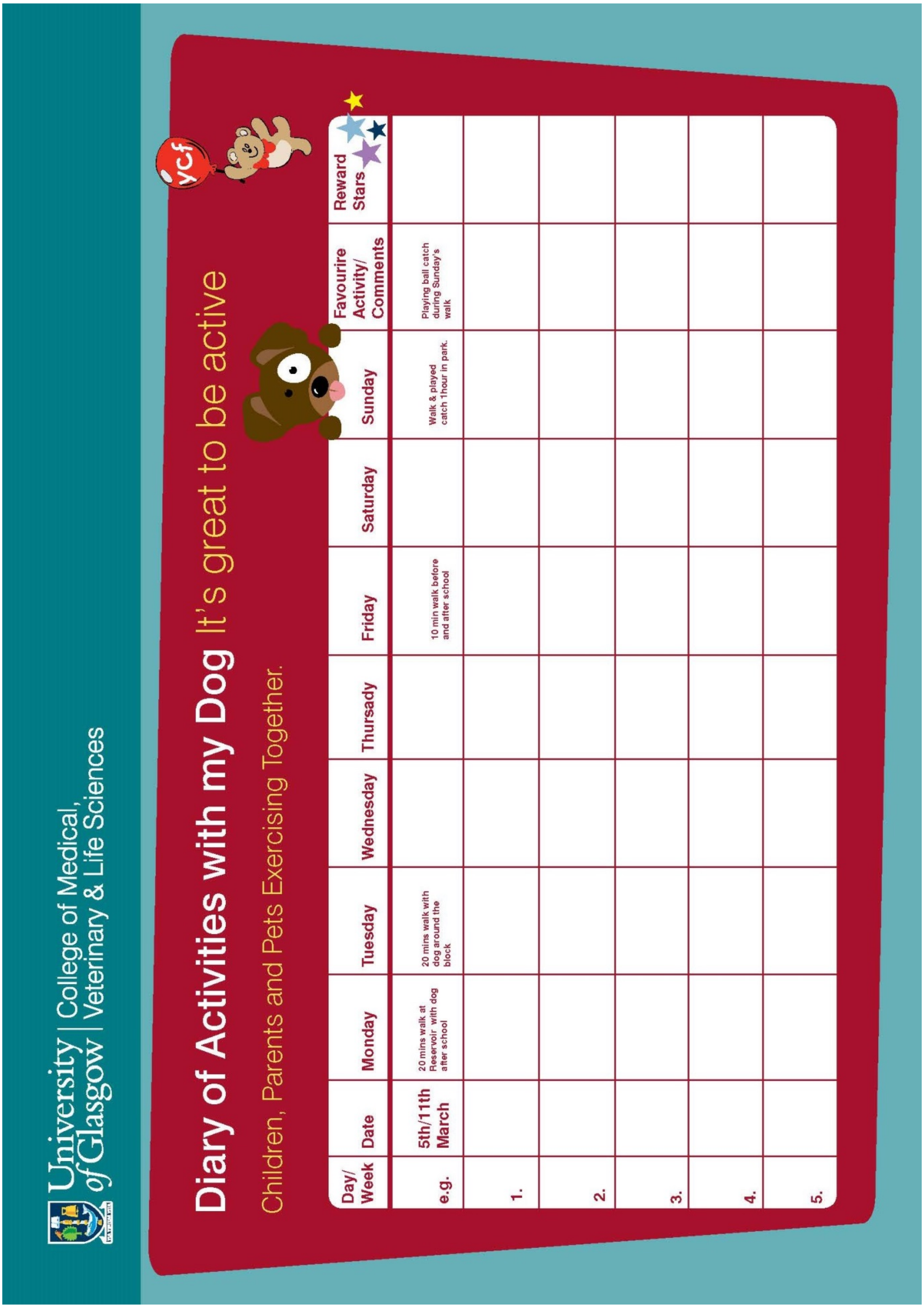
Queries about physical activity or accelerometers:

Viki Penpraze
Telephone: 0141 330 2456 (w) or 07900 811 734 (m)
Email: Victoria.Penpraze@glasgow.ac.uk

Queries about dog behaviour and interactions:

Pippa Hutchison
Telephone: 07764 616 122
Email: positiveimprint@aol.com

Appendix G: Reward chart used in CPET study (Chapter 6)



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Diary of Activities with my Dog It's great to be active

Children, Parents and Pets Exercising Together.

Day/ Week	Date	Monday	Tuesday	Wednesday	Thursady	Friday	Saturday	Sunday	Favourire Activity/ Comments	Reward Stars
e.g.	5th/11th March	20 mins walk at Reservoir with dog after school	20 mins walk with dog around the block			10 min walk before and after school		Walk & played catch 1hour in park.	Playing ball catch during Sunday's walk	
6.										
7.										
8.										
9.										
10.										

Appendix H: Study exit questionnaire used in CPET study (Chapter 6)

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CPET Children Parents and Pets Exercising Together

Study exit questionnaire

Dear CPET participant,

We would be very grateful if you could complete this questionnaire, which should take between 5 and 10 minutes. We hope to design a larger study based on the CPET study you have been participating in and need your feedback on your experiences during CPET. The questionnaire should be filled out by you, the parent but with the help of your son/daughter as appropriate and all answers will be treated anonymously with the strictest confidence.

We would also like to take this opportunity to thank you for taking part in the study and for completing this questionnaire.

Kind Regards,

CPET research team

Please circle the number that corresponds most closely to your desired response

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
1. The verbal advice given to you during the visit by Pippa Hutchison was sufficient to allow you and your child to:					
a) take part in the CPET programme in a safe manner	1	2	3	4	5
b) use any equipment given to you properly	1	2	3	4	5
2. The verbal advice and written content given to you during visits by the Viki Penpraze was sufficient to:					
a) raise your awareness of current physical activity levels among children and adults	1	2	3	4	5
b) motivate you to increase the amount of dog walking you did previously	1	2	3	4	5
c) motivate your child to increase the amount of dog walking they did previously	1	2	3	4	5
d) motivate you to increase the amount of time you spent playing with your dog either inside or outside the home (e.g. garden)	1	2	3	4	5
e) motivate you to increase the amount of time your child spent playing with your dog either inside or outside the home (e.g. garden)	1	2	3	4	5
3. The single home visit by Pippa Hutchison allowed sufficient time to train you and your child on aspects of safety and physical activity interactions between you and your dog	1	2	3	4	5
4. The number of home visits by Viki Penpraze were sufficient to allow you and your child to understand the content of the CPET programme	1	2	3	4	5

5. The number of telephone calls and emails/texts you received were sufficient to:	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
a) review your progress	1	2	3	4	5
b) provide positive encouragement during the CPET programme	1	2	3	4	5
6. During the last 10 weeks you and your child were restricted from taking part in the CPET programme through:					
a) lack of information	1	2	3	4	5
b) lack of motivation	1	2	3	4	5
c) lack of enjoyment	1	2	3	4	5
d) lack of training	1	2	3	4	5
e) feeling of embarrassment	1	2	3	4	5
f) injury or illness	1	2	3	4	5
g) lack of support from family as a whole	1	2	3	4	5
h) lack of accessibility to places for exercise	1	2	3	4	5
i) lack of safe outdoor environment	1	2	3	4	5
j) lack of time	1	2	3	4	5
k) If there are any other reasons, please explain in the space provided					
7. During the last 10 weeks you and your child were encouraged to take part in the CPET programme through:					
a) being provided with enough information about your physical activity levels	1	2	3	4	5
b) receiving enough motivation from the researchers	1	2	3	4	5
c) receiving training regarding how to properly handle your dog during walks/games	1	2	3	4	5
d) the implementation of enjoyable activities with your dog	1	2	3	4	5
e) being able to confidently engage in exercise with your dog	1	2	3	4	5
f) support from your family as a whole	1	2	3	4	5
g) the flexibility of the CPET programme (i.e. ability to fit walks/games round busy schedule)	1	2	3	4	5
h) accessibility to safe places for physical activity	1	2	3	4	5

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
i) access to information regarding tips and hints on how to increase physical activity (maps, goal setting etc)	1	2	3	4	5

j) If there are any other reasons, please explain in the space provided

8. You were asked to do too much during the CPET programme (i.e. physical activity)	1	2	3	4	5
9. You were asked to do too much before and after the CPET programme (i.e. wear accelerometer, dxa scans, have height and weight measured etc)	1	2	3	4	5
10. The CPET programme booklet:					
a) had the right amount of information	1	2	3	4	5
b) was easy to use and understand	1	2	3	4	5
11. The colour scheme and layout of the CPET programme booklet and wall chart were:					
a) friendly	1	2	3	4	5
b) vibrant	1	2	3	4	5
c) energetic	1	2	3	4	5

12. Is there anything about the dog behaviour/training aspects of the CPET programme that could have been done better? Please explain

13. Is there anything about the physical activity aspects of the CPET programme that could have been done better? Please explain

14. Is there anything about the measurements (accelerometry, dxa scans, height/weight measurements etc) that could have been done better? Please explain

Appendix I: Diary for recording when accelerometer was removed from participants of the CPET study (Chapter 6)

All participants in the CPET study were asked to complete a diary (see next page), recording any periods that the accelerometer was removed, the reason, and when it was reattached. Any such periods were then removed from analysis.

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Yorkhill Children's Foundation

CPET Children Parents and Pets Exercising Together

Activity Diary ____________________

Day	Time on 	Time taken off 	Reason/ Comments 

Appendix J: Chapter 6 Post-hoc power calculation

Minitab 16.1.1 (Minitab Inc, USA) was used to perform a power calculation to estimate sample sizes required to show a statistically significant difference in child total volume of PA (mean accelerometer cpm) using the data collected in Chapter 6. The power calculation requires the following input:

- the value of the difference in change between intervention and control groups. The difference in child total volume of PA in this study was 30 cpm.

- the required power value, which was set at 80%

- an estimate of the standard deviation. For this sample size estimation using the square root of the mean square error is appropriate. The mean square error was 24336, meaning the square root was 156.

Inputting this data into the power and sample size calculation feature of Minitab gives the following power curve:

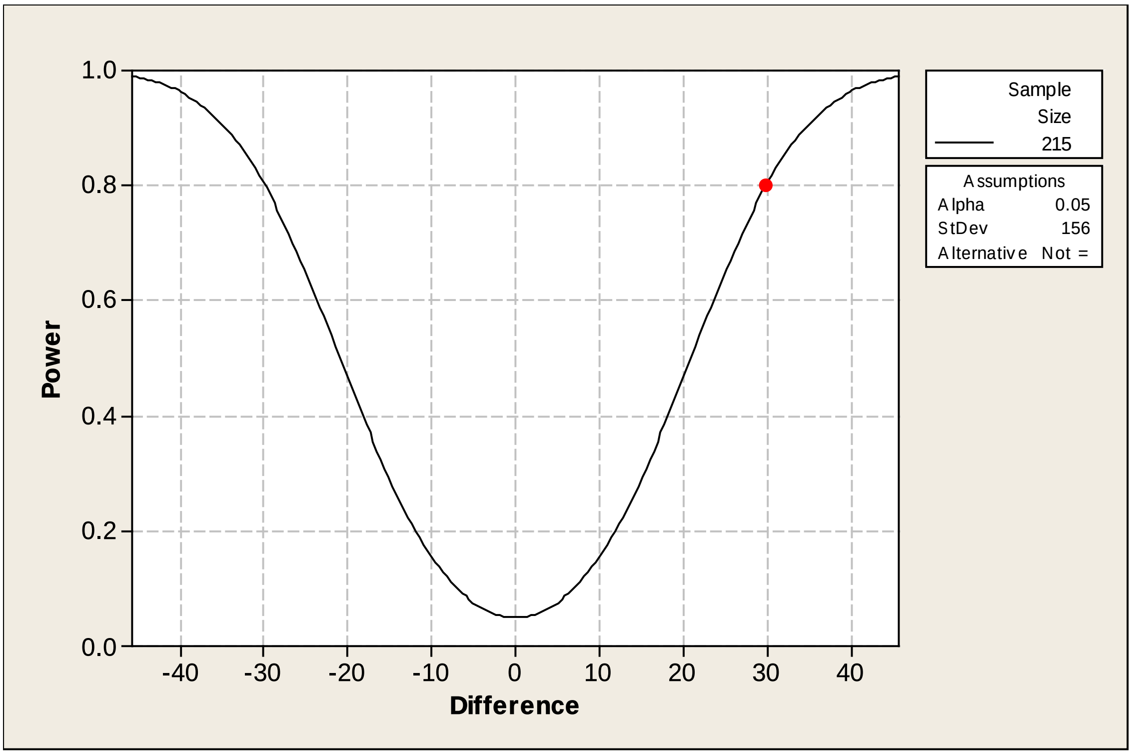

Figure A.J.1 Power curve showing sample size required to detect a statistically significant difference in child total volume of PA (mean accelerometer count per minute) in CPET study.

The power curve shows that a sample size of 215 children per group would be required to detect a difference of 30 cpm between intervention and control group children, meaning a total sample of 430 children would be required.