MSc Thesis

The effect of meditation on the parameters of running economy

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1. Introduction

Investigation into the characteristics of elite performers and the factors associated with elite performance provide valuable information for athlete and coach. Identification of methods of improving performance also make a valuable contribution to the field. Much research has linked specific psychological frameworks to elite performance (Morgan, 1974). It is clear that the effects of changes in psychology can and do influence performance. The question remains, is there a link between these psychological changes and the autonomic physiological control of the body. If so where and how does it manifest itself?

At present there is limited information on the psychological techniques leading to improved running economy. Ideally a simple psychological technique has appeal and may offer a method for improved running economy leading to enhanced performance.

The economy of running has demonstrated an association with performance in distance running events in groups of homogenous subjects (Conley and Krahenbuhl, 1980; Daniels, and Daniels, 1992). A preferential running economy indicates the need for less oxygen at a particular speed. Research has attempted to investigate the variability in running economy with external factors (Frederick *et al.*, 1980; Morgan *et al.*, 1989a), very few studies, at present have examined the effects of a psychological intervention on running economy (Ashley *et al.*, 1995).

When applied to competitive running, it is of interest to establish if a psychological technique can lead to changes in running economy, the cost of ventilation, or alter the perception of effort resulting in a greater work output, during a race or in hard training situations.

A large body of research has described the effects of meditation practice on physiological (Benson *et al.*, 1978; Ashley, 1995; Wallace, 1970; Morgan *et al.*, 1983) and psychological (Gaylord *et al.*, 1989; Baharke and Morgan 1978) parameters. In a sporting context research has been scarce. Only Reddy *et al.* (1976), and Ashley *et al.* (1995), have investigated the effects of meditation on running, and associated physiological variables. The majority of research in the area has been on resting subjects, or at very light intensities (Benson *et al.*, 1978; Wallace, 1970). Both Ashley's and Reddy's groups suggested improvements in physiological, psychological, and performance variables due to meditational techniques, possibly through either arousal reduction or attentional focus. Ashley and colleagues noted an improved running economy in their subjects.

1.1 Aim/ purpose of research

The purpose of the study is:

I. To investigate the effects of a psychological intervention (Meditation practice-The mindfulness of breathing) during running, on physiological variables at a training pace and a competitive 10km pace.

II. To investigate the effect of a psychological intervention during running, on subjective measures of perception of effort, tension, anxiety and mood during running, at a training pace and a competitive 10km pace.

III. To identify any associations found between psychological and physiological variables during running at two different paces.

2 Literature Review

2.1 Physiology

2.1.1 Introduction

The Science of Sport and Exercise Physiology has long been concerned with the measurement of acute and chronic responses of the human systems to an exercise stress. This branch of Physiological Science has continued to develop, constantly striving to catch those historical sciences in knowledge and regard. Major developments in the Science of Sport and Exercise Physiology have included examination of the acute physiological demands of many exercise sessions and athletic events (MacDougall *et al.*, 1991). The physiological characteristics of a multitude of populations, from sedentary to elite performers, have been outlined.

Elite running performance has long been an important area of research (Costill, 1967). Physiologically, a high level of performance is dependent on the ability to develop and sustain a high rate of metabolism, to release and convert stored chemical energy into external physical work efficiently, and to maintain the constancy of the body's *milieu intérieur* in the face of what may be an extreme metabolic challenge. (Shephard, 1992).

The basis for the initiation of physical activity is anaerobic energy production. Stored Adenosine Triphosphate (ATP) and Creatine Phosphate (PCr) are used to cycle the cross bridges of actin and myosin molecules within the muscle fibre. The intramuscular stores of ATP and PCr are very small, lasting only 6-8 seconds in intense exercise (Åstrand and Rodahl, 1986, McArdle *et al.*, 1991). For exercise to continue, the high energy bonds must be regenerated by anaerobic metabolism (oxygen independent breakdown of intramuscular glycogen stores and blood glucose) and/ or aerobic metabolism (oxygen dependent breakdown of intramuscular carbohydrate and fat in addition to blood-borne carbohydrate, free fatty acids and amino acids).

High intensity activities lasting less than approximately two minutes are heavily dependent on anaerobic metabolism for regeneration of high energy phosphates (Åstrand and Rodahl, 1986). Moderate intensity physical work of prolonged duration requires a predomination of aerobic metabolism. However, beyond a certain exercise intensity (individually ascribed), the rate of aerobic energy production is insufficient to meet demand and anaerobic processes will increase their supplementation of the aerobic contribution.

Performance of moderate to long distance running (for example 3000m to ultra marathon) rely predominantly on the provision of energy from aerobic sources. Estimations of the relative contribution of the oxidative processes to the total energy requirement range from 90% in 5000m, to nearly 100% in the marathon (Davies and Thompson, 1979; Åstrand and Rodahl, 1986). Anaerobic capacity, estimated by measures such as, peak exercise blood lactate concentration and accumulated oxygen deficit (Medbø, 1988) do not correlate well with performance in events of 5000m plus (Conley and Krahnebuhl, 1980; Bulbulian *et al.*, 1986; Saltin *et al.*, 1995). Therefore the measurement of aerobic capability is essential in the assessment of performance capability for the moderate to long distance runner.

Determinants of distance running performance include, maximal aerobic power ($\dot{V}_{O_2max}$) (Boileau *et al.* 1982; Saltin and Astrand, 1967) fractional utilisation of $\dot{V}_{O_2max}$ (Conley *et al.*, 1981, 1984; Costill *et al.*, 1973; Leger *et al.* 1986; Sjodin and Svendenhag, 1985), Lactate threshold (Allen *et al.*, 1985; Farrell *et al.*, 1979; Heck *et al.*, 1985; Jacobs, 1986; Sjodin and Jacobs, 1981), muscle respiratory capacity and skeletal muscle fibre type (Costill *et al.*, 1973; Ivy *et al.*, 1980), relative leanness (Pollock *et al.*, 1977; Wilmore *et al.*, 1977), fuel supply (Bergstrom *et al.*, 1967; Lamb, 1988), and running economy (Daniels and Daniels, 1992; Morgan, 1992). To appraise these physiological phenomenon, both laboratory and field tests have been developed.

2.1.2 $\dot{V}_{O_2max}$ Aerobic power

2.1.2.1 Association with performance

Aerobic power has been shown to be highly correlated with, and predict performance of, middle to long distance running (Costill, 1967, Costill *et al.*, 1973, Foster *et al.*, 1978, Farrell *et al.*, 1979). The majority of these studies have observed groups heterogeneous in aerobic power. Alternatively $\dot{V}_{O_2max}$ has not been able to distinguish the performance of somewhat homogenous groups (similar performance times) of trained competitive runners (Conley and Krahenbuhl, 1980).

The limitations of aerobic power measurement have initiated a further search for physiological determinants of performance. This has lead scientists to the development of invasive measurements of muscle and blood metabolites.

2.1.3 Invasive measurements

Attention has recently focused on the capability of athletes to maintain work at certain "Threshold" points.

Invasive measures of lactate, a precursor of fatigue in some situations, has been at the forefront of this dialogue.

Assessments of "Anaerobic Threshold" (in it's widest sense) such as, lactate threshold, onset of blood lactate accumulation (OBLA), ventilatory thresholds and lactate minimum (Tetgbur *et al.*, 1993; Wasserman *et al.*, 1973; Weltman, 1995; Yoshida *et al.*, 1987) have given physiologists a component associated with and able to predict athletic performance in numerous sporting events. These measurements have been the charge of physiologists over the past decade. The use of threshold measures has been thought to indicate areas of exercise negotiating the boundary of steady state and non steady state exercise. A thorough discussion of "Threshold" measures is beyond the scope of this thesis. For further information, the reader is directed to Weltman (1995).

2.1.4 Steady state

Much of moderate to long distance running success is produced at a intensity sustained for a period of time, at a proportion of an athlete's maximal aerobic power. The dependence of the anaerobic contribution is related to the distance of the run, the velocity, and the individuals own capability. Disparate performance distances require varying proportions of aerobic and anaerobic energy contributions. Dependent on this, performance can be attained in either relative steady state, or non-steady state conditions, or flux between the two.

2.1.4.1 Definition

As early as the mid 1920's, Hill and Lupton (1922, cited by Åstrand and Rodahl, 1986) differentiated between $\dot{V}_{O_2}$ "steady state" and $\dot{V}_{O_2}$ while not at a steady state, the later requiring the runner to go into "oxygen debt". A steady state condition connotes a work situation where oxygen uptake equals the oxygen requirement of the tissues without an accumulation of lactic acid in the body. Heart rate, cardiac output, and pulmonary ventilation also attain fairly constant levels (Åstrand and Rodahl, 1986).

2.1.4.2 Steady state in trained athletes

The well-trained individual can maintain "steady state" at a higher relative work rate and reach steady state quicker than sedentary individuals (Hickson *et al.*, 1978). This indicates a more efficient oxygen transport system, and oxygen and substrate utilisation in his/ her active muscles. Elite cross country skiers can exercise at 85% of their maximal aerobic power for at least 1 hour, oxygen uptake being 4.5 litres.min^{-1} or even higher

(Åstrand *et al.*, 1963). Well-trained athletes, can exercise for hours with an oxygen uptake around 70 to 80% of their maximum with little or no increase in blood lactate concentration (Costill, 1970).

The finding that athletes can compete with diverse oxygen cost at similar speeds, across a range of distances has spawned new interests for the physiologist. Running economy has extended the physiologist's discourse of steady state into new areas.

2.1.4.3 O_2 kinetics

At the onset of exercise a slow increase in the oxygen uptake is seen before meeting the oxygen demand. This is explained by the sluggish adjustment of respiration and circulation (the oxygen transport system) and intrinsic delays of the activation of oxidative reactions (Connett, 1986). The first 2-3 mins of exercise therefore creates an oxygen deficit. There is general agreement that oxygen kinetics are faster for a given work rate in the fitter individual (Åstrand, 1986; Hickson, 1978; Wasserman, 1994) and therefore these individuals accumulate a lower oxygen deficit.

The importance of oxygen kinetics has implications for the measurement of oxygen consumption. Measurements of oxygen cost must allow time for the physiological kinetics to stabilise, before a true oxygen cost for a running speed can be attained. Research has proposed that a minimum period of three minutes is required for O_2 kinetics to stabilise (Åstrand, 1986). This value is dependent on a number of factors including, work rate, relative intensity, and fitness level of the subject.

2.1.5 Running Economy (RE)

2.1.5.1 Definition.

In elite competitors the influence of running economy has become a substantial entity. Sports science has provided a measurement of oxygen cost at specific speeds, that is both easy and relatively cheap, and can provide an invaluable information on running performance (Daniels, 1985). What has not been achieved by many, is the ability to influence positive changes in running economy by physical or psychological training.

"Efficient" refers to the relationship between work done and energy expended. Minimising or eliminating unwanted or counter-productive muscular movement is a desirable goal for any distance runner. The terms "efficient" and "efficiency" should not, however, be used to relate the energy demands of running to velocity of running, because velocity of running represents only part of the work being performed by the body while it is transported from one point to another. For this reason, running "economy" is more applicable to the description of this relationship between running velocity and energy expenditure (Daniels, 1985).

Morgan *et al.* (1989a) calculated running economy using the steady state $\dot{V}_{O_2}$, expressed with respect to body mass and time, for a standardised submaximal running speed. They stated that it represents the aerobic demand of running, and the generation of energy must derive wholly from cell respiration.

In addition to Morgan, Daniels and Daniels (1992) recommended that economy data be collected up to speeds requiring over 90% $\dot{V}_{O_{2}max}$. Running Economy was defined as the relationship between oxygen consumption ($\dot{V}_{O_2}$) and velocity (v) of running, or as the aerobic demands of running throughout these speeds. Daniels and Daniels have thereby indicated that running economy should be a measure encompassing several speeds, and including both steady state and non-steady state conditions, although they have not clarified how they would disentangle the aerobic and anaerobic components of this analysis.

2.1.5.2 Running Economy as a performance predictor

Compelling evidence exists to indicate that running economy be used, either alone or in combination with other variables, to predict/ differentiate performance over a wide range of running events (Bransford and Howley, 1977; Conley and Krahenbuhl, 1980; Conley *et al.*, 1981; Daniels, 1985; Daniels *et al.*, 1977, 1978; Krahenbuhl *et al.*, 1989; Morgan *et al.*, 1989b). For running economy to exhibit this predictive power, subjects must be encompassed within a relatively homogeneous aerobic power subset.

Conley and Krahenbuhl (1980) investigated the relationship between running economy and distance running performance (10 km) in highly trained (n = 12), experienced runners of comparable ability. The investigators measured maximal aerobic power ($\dot{V}_{O_{2max}}$), and oxygen uptake ($\dot{V}_{O_2}$) during steady state exercise at three velocities 14.5, 16.1, and 17.7 $km.h^{-1}$.

Subjects averaged 32.1 min for the 10 km run. The relationship between $\dot{V}_{O_{2max}}$ and 10 km performance was poor r = -0.12. The correlations between performance and steady state $\dot{V}_{O_2}$ at 241, 268, and 295 $m.min^{-1}$ were r = 0.83, 0.82, and 0.79 respectively. The investigators concluded that among highly trained experienced runners of comparable ability and similar $\dot{V}_{O_{2max}}$, running economy accounted for a large (65.4%) and significant proportion of the variation observed in 10 km race performance. This research provides very clear evidence that running economy is a useful performance predictor in certain populations.

Figure 1 shows the possible variation in two subjects of equivalent $\dot{V}_{O_2max}$ but disparate running economy. Subject 2 displays a superior running economy. This in turn allows this subject to run at a quicker pace for any given % of $\dot{V}_{O_2max}$ in this measured range.

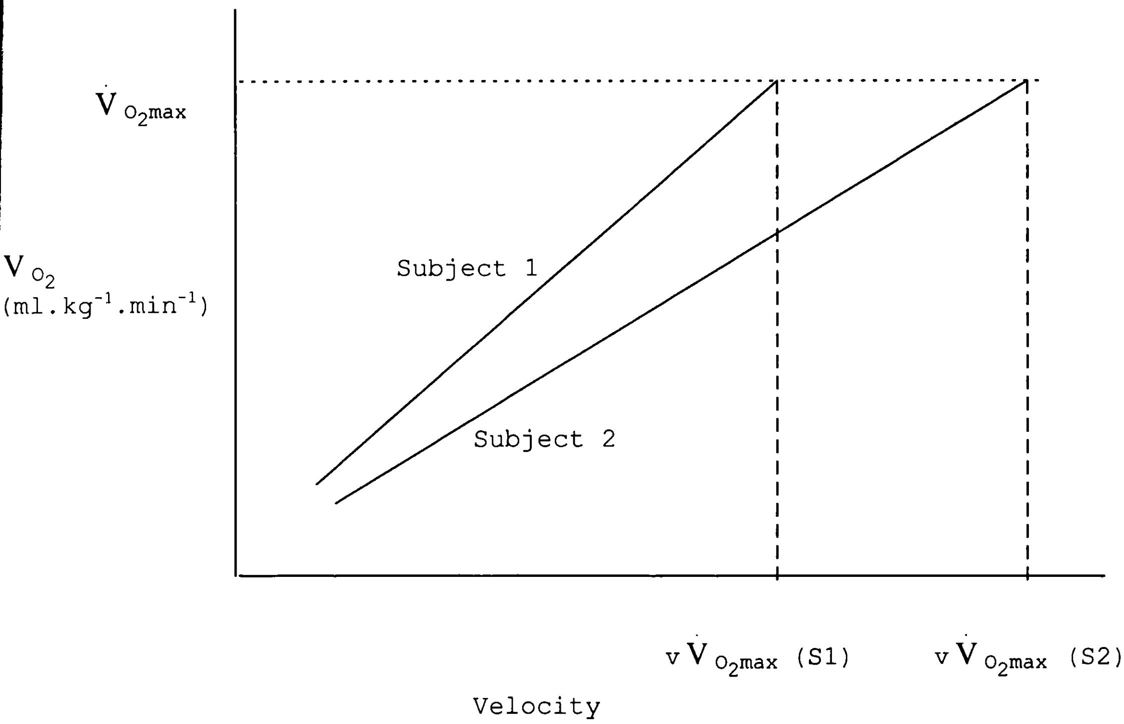


Figure 1. Diagram displaying $v\dot{V}_{O_2max}$ (see section 2.1.6) of two subjects with equivalent $\dot{V}_{O_2max}$ and varying running economy.

Conley and Krahenbuhl stated that it could not be argued from their data that $\dot{V}_{O_2max}$ was unimportant, for all the subjects exhibited high values. The data suggested that a high $\dot{V}_{O_2max}$ helped each subject gain membership to an elite performance cluster, but did not ultimately discriminate success in a 10 km race within the group.

Running economy has been shown to vary among individuals who represent a variety of performance levels, therefore economy can be found **not** to correlate well with performance. However, within a more homogenous group of runners (relative to performance), running economy has the potential of being a very important characteristic in the determination of running success (Daniels, 1985).

2.1.5.3 Variability in Running Economy

Research has indicated the extent of variability in running economy. Morgan and colleagues (1989a) reviewed the running economy literature and found that those studies which reported an intraindivdual variability, reported a 2-11% disparity for a given speed. The majority of this was attributed to "Biological error", indicating that technological and methodological error were negligible, although measurement of this variable was not discussed.

Morgan and colleagues (1994a) attempted to quantify the normal day-to-day variability of the aerobic demand of running over a wide range of speeds (2.83-4.47ms^{-1}) and a moderate time period (28 days). The coefficient of variation (CV) in running economy over these speeds ranged from 1-4% in moderate to well-trained athletes measured over 2, 4, 20, and 28 days. Controlled factors included, time of day, training activity, footwear, and treadmill accommodation/ familiarity. Technological variation, or variability associated with measurement error accounted for less than 10% of the total CV. Other studies have encountered a 15 to 30% difference in interindividual economy (Conley and Krahenbuhl, 1980;

Daniels, 1974; Daniels *et al.*, 1977). These researchers have studied trained, untrained, males, and females.

The accuracy of measurement of running economy is paramount. Documenting intraindividual variation in the aerobic demand of running would aid in determining the number of test sessions required to obtain accurate and stable exercise oxygen consumption measures. This quantification of within subject economy differences in highly trained male and female distance runners would yield important baseline data necessary to evaluate the efficacy of manipulations designed to alter running economy in these cohorts.

A recent study by Morgan *et al.*, (1994a) suggested that if the experimental setting is controlled, with subjects attending the laboratory at the same time of day, with the same footwear, and in the same hydration and nutritional state, a single record of running economy is adequate if comparison of group scores is of interest. Obviously this measurement must be considered an absolute minimum. In thorough scientific analysis a re-evaluation should be considered a preferable option, as both a biological and technological comparison over time.

To date research has been scarce in progressing Morgan's analysis of running economy variation into the area of extrinsic intervention. Recently, Lake and Cavanagh (1996) investigated the effects of a six week training programme on running economy and mechanics in 15 untrained subjects. They found no significant changes in running economy and trends of a worsening running economy in the training group. They concluded from their results that it was feasible that changes in running economy, and running mechanics, with training are speed dependent. With this in mind, it may be beneficial to examine subjects over a range of speeds.

2.1.5.3.1 Gender

Variation between gender and age have also been of interest to physiologists. Morgan, *et al.* (1989a) found no evidence of a gender difference. Although, they acknowledged that the possibility that males may be more economical than females. Their review indicated that pre-pubescent children are less economical than older children or adults, and older adults are less economic when compared to younger counterparts. A recent question has arisen when considering these apparent differences (Winter, 1992). Scaling of oxygen uptake has recently come under scrutiny. This topic will be addressed in section 1.2.1.5.3.2.

In addition to research by Morgan and colleges, Daniels and Daniels (1992) established that males had a higher

$\dot{V}_{O_2max}$ than females and were more economical at common velocities. The combination of greater maximal aerobic power and superior running economy (measured as $v\dot{V}_{O_2max}$-velocity at maximal aerobic power) lead to a total advantage at $v\dot{V}_{O_2max}$, evaluated to be 14%. Although when data were interpreted in terms of O_2 cost per distance travelled ($ml.kg^{-1}.km^{-1}$), it was shown that none of the intensities typically used in races, through to the marathon, produced significant differences between the males and the females in running economy. Discussion on analysis of oxygen consumption in terms of O_2 cost per distance travelled ($ml.kg^{-1}.km^{-1}$) is presently under debate regarding the possible bias' of the analysis.

2.1.5.3.2 Allometric scaling

Conventionally $\dot{V}_{O_2}$ is expressed in ratio with body mass, e.g., peak $\dot{V}_{O_2}$ as $ml.kg^{-1}.min^{-1}$. In this way, division of the physiological variable by body mass is assumed to "normalise" the data, i.e. remove the influence of body mass from subsequent analyses.

The use of the ratio standard, however, has resulted in a distortion of the data with the magnitude of the distortion varying across body mass. As a result, smaller individuals receive an arithmetical advantage, while larger individuals are penalised in terms of magnitude of oxygen consumption. Linear adjustment models have also been used, but have been found to be not entirely satisfactory. A log-linear model (allometric) appears to reduce the error in the other models (Winter, 1992).

According to geometric similarity, as human power output is proportional to L^2 or body mass$^{0.67}$, peak $\dot{V}_{O_2}$ should also be proportional to mass$^{0.67}$. From this knowledge and early animal studies, Welsman *et al.* (1996) recommended that for investigating functional changes in peak $\dot{V}_{O_2}$, the use of $ml.kg^{-0.67}.min^{-1}$ to normalise data should become the criterion standard.

In agreement with Welsman, Bergh *et al.* (1991) concluded from his review, that larger individuals are more economical per unit body mass than smaller individuals when scaled relative to body mass. Bergh went on to suggest scaling of aerobic demand, but did not discriminate between coefficients of 0.75 or 0.66 indicated by analysis of the data of the past research he reviewed. Bergh concluded by indicating that body mass may also correlate with a number of other variables, for example, body surface area and stride frequency, which may affect the energy demand of running.

The considerable interindividual variation shown in running economy (Section 1.2.1.5.2) may to some extent be due to the way in which the oxygen uptake during running is normally expressed (Svedenhag and Sjodin, 1995). This expression may not be appropriate in cross sectional studies or in studies of subjects with changing body weights. In many studies comparing running economy (expressed as $ml.kg^{-1}.min^{-1}$) between the sexes, more economic values have been reported for men than women. Biomechanical gender differences have been put forward as a possible cause of such a difference in running economy. However, this difference may, to a great extent, or perhaps entirely, be explained by body mass differences between the sexes. In particular to differences in the sexes of percentage body fat.

Svedenhag and Sjodin recommend that new reference values, for $\dot{V}_{O_2max}$ and $\dot{V}_{O_2}$submax, using $ml.kg^{-0.75}.min^{-1}$ and $ml.kg^{-0.67}.km^{-1}$ be procured. Debate over the expression of submaximal and maximal oxygen uptake has yet to be resolved.

In conclusion this study, due to the measurement of change over time within an individual, will report oxygen consumption in units of $ml.kg^{-1}.min^{-1}$.

2.1.5.4 Factors influencing Running Economy

2.1.5.4.1 Introduction

Many factors affect running economy; age, training, stride rate and frequency, temperature, wind, and air resistance (including the lower air density found at altitude), (Daniels, 1992). Furthermore, clothing, footwear, and terrain are additional factors that may change the "cost" of running (Brandon, 1995). Pate *et al.* (1992) investigated the importance of selected variables on running economy in a large (n = 188) and diverse sample of male and female, "average to good", runners. They found that the variables that best estimated running economy were, in order of importance, minute ventilation, heart rate, $\dot{V}_{O_{2}max}$ (ml.kg^{-1}.min^{-1}) and body mass see section 1.2.1.5.4.3. The results of this study in an extremely large and diverse population are that minute ventilation may play a crucial role in the parameter of running economy.

The factors which influence running economy will now be discussed in greater detail.

2.1.5.4.2 Body Temperature

Temperature related rises in $\dot{V}_{O_2}$ (Q_{10} effect) have been associated with added peripheral blood flow and sweating demands, increased ventilatory rate, and a decrease in efficiency of oxidative phosphorylation (Morgan *et al.*, 1989a). British Association of Sport Sciences (BASS, 1988) testing guidelines suggest ambient laboratory temperature should be between 18 and 22°C and humidity should not rise above 60%. The American College of Sports Medicine (ACSM, 1995) recommend laboratory temperatures of 21 to 23°C in order to negate this effect.

2.1.5.4.3 Cardiopulmonary and peripheral factors

Interindividual variation in economy has been linked to differences in heart rate and minute ventilation, two indices that, during steady state, reflect oxygen supply to the active musculature (Pate *et al.*, 1989; 1992). Pate and associates revealed better running economy was associated with a lower heart rate ($r = 0.307$) and ventilation ($r = 0.366$) in their heterogeneous population ($n = 188$). They hypothesised that training induced reductions in heart rate and ventilation might produce an overall drop in total body $\dot{V}_{O_2}$, leading to lower aerobic demands. Meaningful reductions in $\dot{V}_{O_2}$ might therefore accrue primarily from a total decrease in ventilatory resistance, and therefore ventilatory cost, resulting from a combination of reduced breathing frequency and an increased tidal volume. Pate et al. (1989) tested all subjects, regardless of ability at a relatively slow pace of 9.7 $km.h^{-1}$. The correlations described are significant, but only suggest that between 9 and 13% of the variation in running economy can be predicted from heart rate and minute ventilation. Statistically the large heterogeneous group allow correlations to become more promenent.

2.1.5.4.4 Muscle fibre type

Oxygen is ultimately processed in the muscle to produce energy. Interindividual variation in running economy may be linked to differences in proportions and recruitment patterns of muscle fibre type between individuals (Saltin, 1995). Conflicting with this hypothesis, Williams and Cavanagh (1987) have found no difference in muscle fibre type in trained male runners who exhibited good, medium, and poor economy.

2.1.5.4.5 Environmental factors

2.1.5.4.5.1 Air and Wind resistance

At low to moderately fast speeds (2.27-4.77ms^{-1}) no difference in economy have been reported between level track and treadmill running. At faster speeds (4.47 and 5.57ms^{-1}) level overground running increased the aerobic demand of running by 7.1% (Morgan *et al.*, 1989a) compared with the energy requirement of level treadmill running. Jones and Doust (1996) have stated that the accurate extrapolation of data generated by physiological assessment of trained runners to conditions of outdoor road running requires that the treadmill be set at a 1% grade. Jones and Doust's statement may consequently be a generalisation, as both surface and speed alter the relationship of treadmill running to outdoor running.

2.1.5.4.6 Training and performance related considerations

2.1.5.4.6.1 Fatigue

Morgan, Martin, Baldini and Krahenbuhl, (1990) studied the effect of a 30 min fatiguing/ exhaustive run on measurements of running economy. The small intraindividual variation in oxygen consumption displayed by the subjects was in agreement with that documented in non fatigued, moderately trained distance runners who performed fixed pace endurance runs and refrained from competitive racing (Morgan *et al.*, 1991; Williams *et al.*, 1991). The day to day stability in oxygen consumption reported suggests that serial measurements of running economy in well trained athletes are relatively unaffected by demanding training and performance regimens (Morgan *et al.*, 1990).

2.1.5.4.6.2 Training programmes

At present there is little consensus regarding the effects of different types of physiological training programmes on running economy (Lake and Cavanagh, 1996). Substantial variation in economy among groups of homogenous distance runners suggests, non physiological training factors may also influence economy, e.g. Genetic predisposition and psychological skills training.

Researchers, by employing different combinations of distance, interval, and uphill training performed over long time spans (14 weeks to 5 years), have described training programmes to have had; no effect, a small decrement, and an improvement in running economy (Morgan *et al.,* 1989a). Reasons given for the above changes have included, biomechanical, metabolic, and neuromuscular adaptations (i.e. better mechanical efficiency, treadmill familiarisation/ habituation, alterations in running style and oxidative energy supply, and optimisation of motor unit recruitment patterns).

Conversely it has been proposed that training exerts only a minor influence on economy and that economical runners are endowed with an anatomical or genetic makeup that produces an economical running style and favours success in long distance running events (Daniels and Daniels, 1992).

2.1.5.4.6.3 Anthropometric and Biomechanical factors

Saltin *et al.,* (1995) investigated the factors discriminating between economy of Scandinavian and Kenyan runners. Consistent with Williams and Cavanagh (1987) above, they indicated that muscle fibre type could not explain differences in economy since Kenyan and Scandinavian runners were similar. They hypothesised that Kenyans had; 1. a high degree of flexibility in the hip joint, and a small range of movement around the ankle, encompassed with an enlarged storage of elastic energy in the Achilles tendon and the triceps surae. 2. Contrasting weight distribution: relatively long slender legs, and long lever arms due to a different arrangement of tendon insertions around the knee joint, as well as differences in the size and shape of the femur and tibia.

2.1.5.4.7 Treadmill Familiarisation

If laboratory forms of exercise are repeated on several occasions, the physiological responses may be modified by three concurrent processes, learning, habituation and training. Learning leads to an increased skill of performance; it may be demonstrated as an improvement of mechanical efficiency with repetition of a task. Habituation is a form of "negative conditioning" leading to a decreased anxiety in the experimental situation. Training leads to an increased exercise tolerance that is independent of anxiety level.

Learning can be shown to be insubstantial if a preliminary practice session is allowed. The habituation process generally occurs from day 1 to day 2. Shephard

(1969) concluded by stating that when measuring the response to a training regime, it would seem important to ensure that subjects either 1. Have no habituation to the proposed test (this is not possible in repeated measures methodology), or 2. Are fully habituated to the test. Shephard did not fully define the terms of full habituation.

The inference from Shephard's work is that subjects should be familiar with treadmill running and apparatus, and in a state of physiological consistency so as to negate or minimise the above effects.

2.1.5.4.8 Stride length/ frequency

Running mechanics have been shown to affect the metabolic energy demand (Martin and Morgan, 1992). The aerobic demand of running at a certain speed tends to increase curvilinearly as stride length is either lengthened or shortened. This results in a U-shaped stride length-economy response (Morgan, 1994a). The specific mechanisms underlying the U-shaped response are unclear. This response may be associated with fundamental muscle force and power generating capabilities (Huxley, 1980), or fibre recruitment (Saltin *et al.*, 1995). Holt *et al.* (1991) considered the possibility that stride length/ frequency optimisation, and thus minimisation of aerobic demand, is directly associated with anthropometric and inertial characteristics of the individuals legs. The majority of research has indicated that athletes tend to unconsciously locate their optimal stride length/ frequency (Morgan *et al.*, 1994a), thereby finding their own most economical gait.

2.1.5.4.8.1 Factors affecting stride length/ frequency

A decline in flexibility could result in a modified gait pattern (e.g. a shorter stride length) that is less economical, or increased muscular effort to produce the same gait pattern, because of increased resistance to motion near the extremities of the range of motion. If future research substantiates this hypothesis, science would again advocate the use of regular flexibility training to optimise running performance, and suggest the use of strict flexibility periods prior to laboratory or field testing. In contrast, recent work has suggested that inflexibility in certain areas of the musculoskeletal system may enhance running economy in sub-elite male runners by increasing storage and return of elastic energy and minimising the need for muscle-stabilising activity (Craib *et al.*, 1996).

2.1.5.4.9 Measurement of running economy

Speeds at which runners are tested may be critical in the measurement of running economy. Middle distance runners

(800/ 1500m) have been shown to be more economic at speeds of greater than marathon race pace, whereas long distance runners are most economical at speeds equal to, and slower than, marathon race pace (Daniels and Daniels, 1992). From this we must question the effects of the anaerobic contribution of these divergent running populations.

Insufficient research has investigated running economy at speeds equivalent to "race pace" for the individuals involved (Daniels and Daniels, 1992). One limitation exists in the attempt to evaluate running economy at "race pace". At competitive running speeds at distances of approximately less than 10K, there is an energy yield from anaerobic glycolysis that cannot be quantified exactly (Saltin *et al.*, 1995). Therefore, the majority of previous research has reflected true aerobic demands falling below the mean relative workload (80-85% $\dot{V}_{O_2max}$) approximately associated with a "Steady state" or a "Threshold" measure in good and elite distance runners (Sjodin and Svendenhag, 1985).

2.1.5.5 Conclusion

In conclusion it appears that the running economy of any individual is at least in part a function of inherent characteristics. These characteristics are, in turn, subject to some degree of alteration as a function of growth, physiological and psychological training, and the environment in which the individual performs.

From a practical standpoint it is feasible to detect small changes in submaximal $\dot{V}_{O_2}$ and demonstrate the effectiveness of a particular intervention aimed at perturbing running economy. The coefficient of variation (CV) in running economy is small (~1 to 2%) among well trained male and female runners, with rest, or following a demanding regimen of training and competitive racing (Morgan *et al.*, 1994a). Frederick (1985) states; If attention is paid to the design of the experiment, collection of data and methodological concerns such as length of treadmill accommodation/ familiarisation, test habituation, time of testing, and footwear, it is practical to use oxygen consumption measurements to find significant differences between treatments as small as 1-2%.

Within physiological research, running economy has been found to be both extremely easy to measure and very acceptable as a performance predictor in very similar groups (Conley & Krahenbuhl, 1980; Daniels, 1985). Despite the recognition that in groups with homogeneous aerobic power running economy accounts for a large and significant proportion of variation in distance running performance, relatively little is known regarding the numerous physiological, biomechanical, environmental, structural and psychological factors potentially associated with change in the aerobic demand of running.

Importantly, inter and intra-individual differences can and do exist resulting in questions for future research.

1. What type of physiological and psychological training is most effective in bringing about changes in running economy?
2. How much change in economy can be expected with optimal physiological and psychological training?
3. What physiological and psychological parameters either cause, or are associated with these changes in running economy?

2.1.6 Velocity at Maximal Aerobic Power ($v\dot{V}_{O_{2}max}$)

More recently a combination of $\dot{V}_{O_{2}max}$ and running economy has been used to differentiate performance. Several definitions of the velocity at $\dot{V}_{O_{2}max}$ exist (Billat *et al.*, 1994; Daniels, 1985; Lacour *et al.*, 1990; Noakes *et al.*, 1990). All definitions of $v\dot{V}_{O_{2}max}$ have been reported to be good indicators of performance in distance running events from 800m (Gough, 1996 Unpublished), and 1500m (Lacour *et al.*, 1990; Craig *et al.* 1995) through to

5000m, 10km, and, 21.1km and 42.2km road races (Morgan *et al.*, 1989b; Noakes *et al.*, 1990; Tanaka *et al.*, 1984).

The evidence presented clarifies the multitude of predictive uses for running economy testing in both homogeneous and heterogeneous groups (Hill and Rowell, 1996). Running economy therefore serves as an extremely useful variable in the prediction of running performance and as a measure of change within individuals.

2.1.7 Cardiorespiratory parameters

2.1.7.1 Minute Ventilation ($\dot{V}_E$), Tidal volume (V_T), Respiratory frequency (f).

During strenuous exercise, the breathing frequency (f) of healthy young adults reaches 35-45 breaths per minute. Tidal volume can increase to approximately 2.0-2.5 litres and ventilation can reach 100 $l.min^{-1}$, up to 17 times the resting value. Endurance athletes can reach exercise minute ventilations of 160-200 $l.min^{-1}$ (Åstrand and Rodahl, 1986; McArdle, Katch and Katch, 1991). Respiratory frequency in 20-25 year olds have been reported to be as high as 40-45.min^{-1} (Åstrand and Rodahl, 1986) and in well trained athletes with high aerobic power, respiratory frequencies of about 60.min^{-1} are not unusual (Clark *et al.*, 1983).

The increase in tidal volume apparent in exercise, is brought about through the utilisation of both the inspiratory and expiratory reserve volume. Inspiration and expiration become more equal in both time and pattern with increments in exercise intensity. Studies have indicated that an individual spontaneously balances the depth of respiration and respiratory frequency in such a way that ventilation takes place at optimal efficiency, that is, with the utilisation of a minimum of energy by the respiratory muscles. The greater the pulmonary ventilation, the narrower the range of respiratory frequencies appear to be, yielding minimal energy expenditure (Otis, 1964), with any increase causing an increased resistance to breathing.

In athletic performances, applying the research of Otis above, it may be advisable to allow the athlete to assume the respiratory pattern which feels natural. This appears to slightly contrast research in entrained breathing (Bernasconi, 1995), which indicates that the use of the impact in running in assisting the diaphragm to reduce the intercostal space during exhalation, can possibly reduce ventilatory cost. Bernasconi noted that athletes adopted a spontaneous tendency to co-ordinate leg and respiratory movements possibly improving ventilatory efficiency.

Bernasconi also noted that endurance-trained triathletes maintained a high degree of co-ordination between running and breathing during both aerobic and anaerobic exercise. In contrast, sprinters and untrained subjects co-ordination only occurred at lower workloads. There is therefore an indication from Bernasconi's research that a conscious factor is involved in the co-ordination of breathing and running rhythm.

The interpretation is that physiological control mechanisms are presumed to optimally choose the most efficient method of ventilation, but Bernasconi has indicated that external factors may alter this optimal control. The inference may be that autonomic physiological control can be affected by adapting consciously to external factors.

2.1.7.2 Control of ventilation

In the past, it has been suggested that the ventilatory response observed during steady-state exercise is controlled primarily by the additive combination of signals originating from the higher motor centres and the exercising limbs (the initial neural response), and of signals from the central and peripheral chemoreceptors (the slow humoral response), so termed as the neuro-humoral theory (Dejours, 1964; cited by Wolff, 1992). Additional factors, have since been found to influence a portion of the ventilation response: Stimuli from metabaroreceptors, and the influence of catecholamines.

Research has suggested that the contribution of the peripheral chemoreceptors to the control of ventilation could be enhanced by increases in the amplitude of oscillations in the partial pressure of CO_2 and/ or increases in plasma potassium (K^+), adenosine, and osmolarity (Wolff, 1992). It is possible that exercise sensitises the peripheral chemoreceptors. The most likely mechanism is that there are a number of small changes in humoral stimuli. These combine to provide a sufficient signal to the central and peripheral chemoreceptors, accordingly, the chemoreflex feedback mechanism controls ventilation to keep pulmonary gas exchange matched as closely as possible to metabolic rate (Mateika *et al.*, 1995).

2.1.7.3 Energy cost of breathing

At rest and in light exercise the O_2 requirement of breathing is approx. 1.9-3 ml of O_2 per litre of air or about 2% of the total energy requirement. This increases to 4ml and may rise to 9ml of O_2 per litre of air when $\dot{V}_E$ exceeds 100 $l.min^{-1}$. Aaron and colleagues (1992) estimated the cost of $\dot{V}_E$ increased during exercise from 1.8 ml O_2/l at 70% $\dot{V}_{O_2max}$ (4.6% of the total $\dot{V}_{O_2}$) to 2.9 ml O_2/l at

100% $\dot{V}_{O_2max}$ (a mean of 10.1% of the total $\dot{V}_{O_2}$, and was as high as 15% in one subject).

2.1.7.3.1 Adaptations in breathing with training

After training it has been demonstrated that ventilation increases in maximal exercise. In submaximal exercise, after four weeks of training a considerable reduction in the ventilatory equivalent has been displayed. That is, a lower ventilation is required at a particular rate of submaximal oxygen requirement. This leads to a reduction in the percentage of the total oxygen cost of exercise attributed to breathing. Which in turn leads to; 1. a decrease in fatiguing effects of exercise on ventilatory musculature and 2. a decrease in O_2 requirement by the respiratory muscles meaning a greater availability of oxygen to the exercising muscles.

The mechanism for training changes in ventilation in submaximal exercise are unknown. In general, V_T increases, f is reduced, decreasing the dead space, and air remains in the lungs for a longer period of time between breaths. This results in an increase in the amount of oxygen extracted from the inspired air. The content of exhaled air is altered, since expired air of trained athletes can contain as little as 14-15% O_2, whereas untrained individuals exhibit O_2 content of approximately 18% at the same relative work level. It is possible that the ventilatory adjustments to training results from local neural and chemical adaptations in the specific muscles trained through exercise.

2.1.7.3.2 $\dot{V}_E/\dot{V}_{O_2}$-Ventilatory equivalent/ coefficient

The ventilatory coefficient or the ventilatory equivalent for oxygen, is an index of submaximal ventilatory efficiency. The value represents the volume of air required to extract one litre of oxygen. Therefore, the lower the $\dot{V}_E/\dot{V}_{O_2}$ the greater the efficiency of the ventilation.

2.1.7.3.3 Ventilation and performance

Martin *et al.,* (1979) revealed that the majority of endurance athletes are endowed with low ventilatory responses to chemical stimuli. The implications are unclear, but non-athletes were shown to have a greater exercise ventilation per unit metabolic rate ($\dot{V}_{O_2}$ or $\dot{V}_{CO_2}$). The low exercise ventilation may be the link between low ventilatory chemosensitivity and outstanding endurance athletic performance. Martin did not go on to question if an intervention strategy could lower exercise ventilation still further.

Low exercise ventilation may also enhance endurance performance through an influence on the perceived effort of exercise (see section 1.7.3) Several studies have found a close correlation of ventilation with the sensed effort of work.

2.1.7.4. $\dot{V}_E$ - Steady state conditions

In steady state conditions (see section 1.1.4) minute ventilation increases linearly with oxygen consumption and CO_2 production up to about 55% of the maximal O_2 uptake. Ventilation averages between 20-25 litres of air for each litre of O_2 consumed (Wasserman, 1994). The 20-25 to 1 ratio applies in submaximal exercise and will vary both inter and intra individually. The possibility of change in the ventilatory equivalent is measurable, and an effect on this variable by an intervention can indicate improvements in the efficiency of the respiratory system for transporting oxygen.

2.1.7.5 Respiratory Exchange Ratio (RER)

As oxygen is consumed in the mitochondria during the process of catabolising a particular substrate, the oxygen consumption is associated with a certain production of carbon dioxide. Each type of substrate (fat, carbohydrate, and protein) when broken down, gives a particular ratio of the volume of CO_2 produced to O_2

consumed. This ratio, $\dot{V}_{CO_2}/\dot{V}_{O_2}$ is known as the Respiratory Quotient at the cellular respiratory level and the Respiratory Exchange Ratio for volumes exchanged between body and atmosphere.

Precautions must be taken in the interpretation of RER. Any factor which influences the production of CO_2 or the consumption of O_2, but which is not directly related to the combustion of food, may result in a RER that is misleading. During unstable, heavy exercise the RER may be greater than 1, and in recovery may be less than 0.7. Possible explanations exist to account for high RER values. 1. Lactic acid production during heavy exercise may a) Lead to a decreased pH, stimulating the breakdown of carbonic acid in the blood, to excess carbon dioxide and water, buffering the effect of the lactic acid. b) The decrease in pH stimulates the brain to increase ventilation, and leads to excessive exhalation of CO_2. 2. Hyperventilation by an anxious subject may cause the exhalation of excess CO_2, artificially increasing the RER. Following heavy exercise the body retains CO_2 to replenish the stores of bicarbonate used to buffer the lactic acid.

2.1.7.6 Heart Rate

Heart rate displays a linear relationship with workload and O_2 consumption to near maximum (Åstrand and Rodahl, 1986). Due to this relationship, and the ease of heart rate monitoring, the use of heart rate for training purposes has become almost the "norm" throughout the athletic world.

The heart is controlled by neural, humoral, and intrinsic factors. Of these, the heart rate is predominantly influenced by the nervous system. The neural supply to the heart is from both sympathetic and parasympathetic divisions of the autonomic nervous system. The firing of these two neural divisions is primarily from the nerve centres in the medulla. These cardiac control centres can be stimulated by emotional excitement, nerve reflexes sensitive to changes in muscle chemistry, blood pressure, and arterial pH, and also many other factors, which may include psychogenic elements.

The parasympathetic and sympathetic neurones have an interactive effect on the heart that cannot be explained in a simple additive manner. The effect that vagal stimulation has in the heart depends on the degree of existing sympathetic activity. If there is pre-existing sympathetic activity, the inhibitory effect of vagal activity will be augmented. This is known as accentuated antagonism. It seems to be due to acetylcholine released from the parasympathetic vagal neurones, causing a decrease in the rate of noradrealine release from adjacent sympathetic nerve terminals. Theoretically this could be an important way of keeping the heart rate low, and therefore maximising cardiac filling time during exercise. Only at maximal exercise is vagal tone completely lost. However at present there is no direct evidence that accentuated antagonism operates during exercise.

2.2 Psychology

2.2.1 Introduction

Sports, and Exercise Psychology have been the interest of both the general population and researchers for many years. Since the dawn of sport the intervention of the mind over the body, in performance, has been recognised. Today common terms, such as, motivation, attention and focus, are used by athletes, coaches and audiences at sporting events, and exercise also coexists with terminology relating to the application of psychology. Exercise psychology has also become a branch of psychology with great influence in public health, with the reasons for adoption, maintenance, adherence and addiction to exercise are well researched (See Dishman, 1994).

Sports Psychology is a science in which the principles of psychology are applied in a sports setting. A sports psychologist is interested in helping every sport participant reach his or her potential as an athlete. Sports psychology is a subject dedicated to the enhancement of both athletic performance and the social-psychological aspects of human enrichment.

2.2.2 Brief history

The modern view of Sport psychology is that it educates athletes in a way that enables them to enhance their performance. However, in the early 70's the image of athletes was of good mental health, therefore the focus was upon inducing an optimal prestart condition and readiness to perform by means of therapeutic or clinical intervention, or through counselling.

The 1970's saw the importance of psychological processes and skills in regulating sporting activity and achieving high performance recognised. Although, systematic enhancement by means of psychological training was neglected because psychological skills were either thought to be innate, or capable of being developed through physical practice. However, Rodionow (cited in Seiler, 1992) explained that the higher level of performance, the more specialised the psychological functions that regulate the action. It would take too long for spontaneous development to occur, therefore special training methods are needed.

Sport psychology then took on the role of guidance, and teaching, training, and refining skills to optimise performance. Orlick (1980) stated that self-control is the central skill a sport psychologist must impress.

Stock (1990, cited in Seiler, 1992) found 88 psychological techniques that had been applied or might be used in sport. Mahoney *et al.*, (1987) asked athletes and sports psychologists which psychological skills had the potential importance in sport skill level differentiation: They found that concentration, anxiety control, self-confidence, mental preparation, and motivation were selected. Vealey (1988), reviewed performance skills as: optimal physical arousal, optimal mental arousal, and optimal attention. Morris and Bull (1991) ascribed four skills to be important in distinguishing successful and less successful athletes as: controlling anxiety, focusing, being confident, and using imagery. The skills mentioned above are obviously important to athletes, but each will have different influences within a specific sport, in specific situations in the sport, and within the individual involved in that sport.

Hardy and Jones (1994) conferred with 37 British and international sports psychologists to categorise seven domains of sport psychology that were considered to be priorities for research over the next 5-10 years. These were: motivational issues in performance; aspects of skill acquisition and motor control that might influence the attainment of excellence; stress and performance; interpersonal issues and group dynamics; the implications for well being of the pursuit of excellence; psychological skills training; and the role of the sports psychologist.

2.2.2.1 Where does relaxation fit in?

Relaxation has not been indicated in its own right as a major psychological skill, although the use of imagery, mental preparation, and control/ optimisation of arousal and anxiety among others, do imply the use of a relaxation technique. Much of the research has investigated the preparatory stages of performance with little work focusing entirely on psychological strategies during performance.

2.2.3 Psychological parameters and Running

2.2.3.1 Introduction

The combination of interest in running and the associations of psychological parameters with performance has produced a large volume of literature. Research has covered the importance of psychological parameters on performance, and the associations between psychological factors and performance. A number of theories linked to each psychological factor have grown to investigate the mechanisms of the visible effects of psychological parameters.

2.2.3.2 Arousal

Arousal is synonymous with the notion of alertness. The state of readiness can be represented as a continuum from deep sleep to extreme excitement.

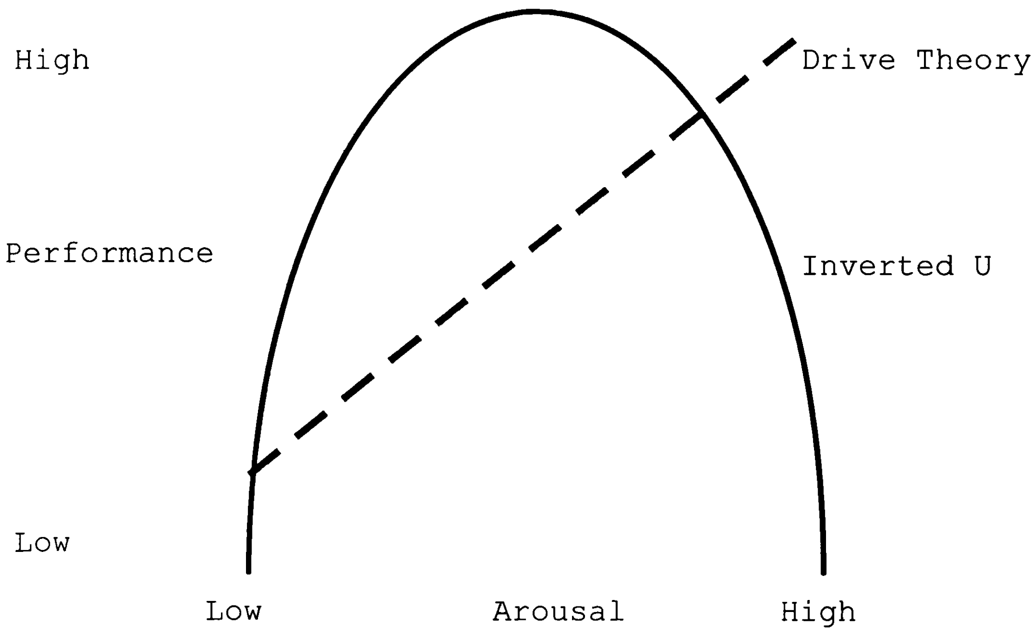
The basis of arousal is within the autonomic nervous systems' two divisions. The activation division, the sympathetic, and the deactivation, the parasympathetic. A stimulus causes excitation of the two divisions leading to a physiological response along the arousal continuum.

2.2.3.2.1 Arousal and performance

Two basic theories of the performance-arousal relationship exist. The first is the drive theory (see figure 2). A multidimensional theory of performance and learning. The drive theory proposes a positive linear relationship between arousal and performance.

The second theory is the inverted U. Which proposes a quadratic relationship between arousal and performance (see figure 2).

Figure 2. Diagram of two theories of the relationship between arousal and performance.



2.2.3.2.1.1 Drive theory

The drive theory appears to explain the relationship between learning and arousal, as well as between performance and arousal. The theory states that 1. an increased arousal (drive) will elicit the dominant response. 2. The response associated with the strongest reaction potential is the dominant response. 3. Early in learning or for complex tasks, the dominant response is the incorrect response. 4. Late in learning or for simple tasks, the dominant response is the correct response.

From the above tenets it can be noted that, heightened arousal should benefit the skilled performer but hamper the beginner. A complex task will require a lower level of arousal. Conversely a very simple task would benefit from increased arousal.

In response to criticisms of a theoretical ever increasing performance with increased arousal, adaptations of the drive theory have made it more compatible with research supporting the inverted U theory. Stroms (1961, cited by Cox, 1992) indicated a possible ceiling effect associated with a deterioration in performance with further increases in arousal.

2.2.3.2.1.2 Inverted U theory

Yeakes and Dodson (1908; cited in Cox, 1990) were the forefathers of the inverted U theory. Their work on mice has since been applied in sporting settings very successfully. The basic observation is that a quadratic relationship exists between arousal and performance suggesting that too low, or too high and arousal leads to a detriment in performance. Their work can be taken further, by showing that as the complexity of a skill increases, the amount of arousal needed for optimal performance decreases but still remains in the same quadratic format. Therefore each sport skill has its own theoretical optimal arousal for best performance. The theory also applies in that the optimal level of arousal for a beginner should be lower than the optimal level of arousal for an expert performing the same task.

Research has supported the inverted U theory, linking pencil and paper tests of arousal/ anxiety to performance in basketball (Sonstrem and Bernado, 1982, cited by Cox, 1992) and swimming (Burton, 1988) among many others.

2.2.3.2.1.3 Easterbrook's cue utilisation theory.

Easterbrook (1959; cited in Cox, 1990) attempted to link performance changes due to arousal, to attentional alterations. Easterbrook stated that as arousal increases, attention narrows. The narrowing of attention results in some cues being gated out, first irrelevant ones, then relevant cues. It is clear that this theory can be directly linked to the inverted U theory. When arousal is low, the attentional band is wide and both irrelevant and relevant cues are available. The presence of irrelevant cues is distracting and causes a decrement in performance. At a moderate or optimal level of arousal, only the irrelevant cues are eliminated, and therefore performance is high. Finally, when arousal is high, attentional focus is narrow and both relevant and irrelevant cues are gated out. Thereby resulting in a performance decrement. Easterbrook's theory can be considered to be very similar to the information processing theory.

2.2.3.3 Attentional strategies [Dissociation/ Association]

The association of arousal and attentional focus can be linked to running. Research on elite and non elite distance runners has suggested differences in attentional focus (Morgan *et al.*, 1992). Elite distance runners have exhibited a narrow internal focus on Nideffers attentional focus scaling (Nideffer, 1976), or are sometimes known as associators. Associators are athletes who attend to their bodies' signals during performance. In contrast to this Morgan noted that sub elite runners tended to reveal a dissociative strategy during performance, consciously distracting their own mind from their bodies' cues. If allied to Easterbrook's interpretation of the inverted U theory, it would be expected that associators would perform better than dissociators.

Evidence indicates that effective use of association may be linked to the use of relaxation (Morgan, *et al.*, 1992). The lower oxygen consumption of elite marathoners, at marathon pace, compared to elite middle distance runners, may be the result of a conscious focus on relaxation. Therefore attentional strategies that focus on awareness of muscular tension may benefit runners performance (Crews, 1992; Morgan, 1991).

Research instigated by Smith *et al.* (1995) compared the attentional strategies of the most and least economical runners in a population of 36 experienced distance runners. They also investigated whether the least economical runners (n = 12) could improve their running economy with the use of an active associative (progressive muscular relaxation) attentional strategy. Results indicated that the most economical and least economical runners did not differ significantly in associative style use. The most economical runners, however, reported less dissociation use and more use of relaxation, although other factors cannot be disregarded. No physiological or psychological changes were associated with any of three attentional strategy conditions; control, passive associative, and active associative. Unfortunately only a 20 minute pre-run learning phase for the intervention strategy was incorporated into the study.

Possible explanations for the lack of change in both physiological and psychological variables with attentional strategy may be;

1. The subjects did not adhere to the attentional instructions.
2. Subjects may have found it difficult to create relaxation upon the identification of tension

(Progressive Muscular Relaxation-PMR), many subjects have claimed difficulty in producing a relaxation effect during treadmill running (Also found by Ashley, Personal communication).

3. A tension/ anxiety and TMD floor effect occurred, as evidenced by the mean values on the scales. A floor effect would temper the oxygen consumption reduction that results from relaxation induction.

Exercise research has focused on the effect of dissociative strategies on running performance and perception of exertion. Dissociation has been shown to be a useful coping mechanism and significantly improve performance, measured as time to fatigue (Morgan *et al.*, 1983). The hypothesis is that dissociative strategies provide a relief from fatigue by occupying limited channels which would otherwise bring internal sensory cues to the focal awareness, thus supporting the parallel-processing model (Rejeski, 1985). It would appear that what is available in perception can be blocked from consciousness by flooding the lines of communication with distracting stimuli.

Research using subjects who were unpractised in an endurance task (Gill and Stom, 1985) indicate that dissociative strategies may result in better performances than associative. In contrast work by Morgan and Craig

(1992) has revealed that associative strategies are more frequently used by elite athletes, are related to better performances, and that experience may mediate the use of associative strategies. Morgan ascertained that elite runners tend to be associators to internal cues, non elite runners were more likely dissociators; and from a group of less elite runners asked to use associative or dissociative strategies, and control, dissociators performed best. The authors suggest that the elite runners may attend to the internal cues with psychological strategies.

Morgan (1985) investigated the oxygen cost of elite associators and non-elite dissociators. The associators consumed less oxygen at both 16 $km.h^{-1}$ (56 to 51 $ml.kg^{-1}.min^{-1}$) and 19 $km.h^{-1}$ (68 to 65 $ml.kg^{-1}.min^{-1}$). At the faster of the two speeds differences of 2-3 $ml.kg^{-1}.min^{-1}$ were noted, and although not statistically significant, may be of practical significance to a distance runner if extended across a 10 km or marathon (Tanaka *et al.*, 1984). These differences in oxygen consumption could theoretically enable the elite performer to tolerate the physiological stresses associated with vigorous exercise for a longer period of time, or they could tolerate greater physiological stresses for a fixed period of time. The elite runners performance was clearly superior, and may have been dependent in part on the type of coping strategy employed during prolonged exercise. Morgan's study, although suggestive of differences between associators and dissociators, does not consider the innate differences between elite and subelite runners or that the relative workload is greater for the sub-elite runners leading to the possibility that the subelite runners become fatigued at the faster pace and have to recruit larger muscle fibres, costing more oxygen.

2.2.3.3.1 Entrained breathing

Rohe (1974) suggested that entrained breathing is a form of meditation, he also stated that "being aware of the details of your running gives you economy of energy", although definitions of "being aware" and "economy of energy" were not available. We could presume that Rohe is indicating the application of either an associative strategy, placing the conscious on a bodily sensation, or a dissociative strategy, taking the thoughts away from the remainder of the body by focusing on one particular section.

Dempsey *et al.* (1979) discussed the effect of higher central processes influencing ventilation, while performing at intensities associated with athletic competition. The control of ventilatory activity may reduce any unnecessary effort and therefore increase economy. Dempsey suggested that individuals can exert an appreciable amount of voluntary control over ventilation. Efficient control of exercise hyperpnea seems to hold practical significance as Loke *et al.* (1982) reported that an endurance run can result in temporary decreases in respiratory muscle strength and endurance.

2.2.3.4 Previous research

In 1992, Crews reviewed the literature on Psychological state and running economy. She found only six studies which included measures of Oxygen consumption at a given workload (i.e. economy) and used running as the mode of exercise.

The general finding was that increased tension was associated with increased oxygen cost; and that tension reduction, using stress management techniques prior to running, improved running economy. Research appears to show that cognition (i.e. mental strategy, coping, and biofeedback) elicits changes in the physiological and behavioural responses to exercise. Although no changes in oxygen consumption have been observed in these studies.

Crews noted that the psychological state in the studies reviewed, refers to a particular cognitive or emotional condition of the mind. Categories that could affect running economy are: perception and cognition. Studies have used hypnosis to alter affect perception, others have used various cognitive strategies; association/ dissociation, relaxation, stress management, to alter exercise metabolism.

2.2.3.4.1 Perception.

Perception involves the use of all the senses, awareness and comprehension to understand objects and qualities in the environment. During exercise Morgan *et al.* (1973) have demonstrated that hypnotic suggestion of heavy or light exercise, and suggestions of a hill during a cycle ride, produces alterations in various physiological responses (e.g., oxygen debt, RPE, HR, CO_2). However, Morgan concluded that it is difficult to alter oxygen cost of exercise using hypnosis and suggested that specific cognitive strategies may be more effective to alter the cost of exercise.

2.2.3.4.2 Affect

Affect refers to an emotion or feeling related to an idea or object. Many terms have been used interchangeably to describe affect (i.e. mood, emotion, feeling). Ketai (1975) stated that there may be a difference in the time course and intensity between mood and affect. Mood represents feelings of longer duration and lower intensity while affect refers to shorter duration and higher intensity emotions. From this it could be discussed that the Profile of mood states (POMS) may measure mood and affect depending on the associated request from the researcher. It may also be considered that the incredibly short POMS (ISP) (Whelan, Personal communication) may measure affect rather than mood.

At rest the influence of psychological state (i.e. anxiety, excitement, and happiness) on oxygen consumption has been established (Whitehorn *et al.*, 1930). During exercise, changes have been noted in the physiological response to both positive and negative affect. The effect of Mood state on running economy has been documented by Williams *et al.*, (1991). Mood changes have long been associated with running. Athletes and the general population have experienced the euphoric effect during running. Clinical populations have also been shown to respond to exercise with an increase in positive mood.

Williams investigated a small subject cohort of moderately trained male runners (n = 10). They completed 5 fairly slow runs per week for four weeks at three treadmill speeds (2.68, 3.13, and 3.58 $m.s^{-1}$) that approximated 50, 60, and 70% of the maximal oxygen consumption. On the last day of each week, prior to their run, subjects completed the POMS scale to determine their mood state over the previous week.

The group correlation for oxygen consumption and Total Mood Disturbance (TMD-as measured by POMS) was non significant. However, the within subject variation showed a positive linear trend for five of the six subscales and for TMD ranging from 0.70 to 0.99. The positive correlation indicated that, when the focus of attention was within-subject variation, weeks featuring more economical values were associated with more positive health profiles. The correlation for TMD and RE was strong ($r = 0.88$), indicating that less negative affect was associated with lower oxygen consumption for a given workload.

The subscale illustrating the strongest relationship with RE was tension ($r = 0.81$), and the subscale unrelated to RE was fatigue ($r = 0.18$). The study indicates that less negative emotion (e.g. anxiety) is associated with greater economy. However, since both positive and negative emotions alter physiological responses to exercise, it cannot be assumed that more positive emotion (e.g. excitement) produces greater economy, due to possibilities of overarousal (see section on arousal).

Though Williams study did not manipulate psychogenic factors, the changes observed in oxygen consumption were in the same direction as those reported in experiments where $\dot{V}_{O_2}$ served as a dependent variable, and mood shifts were assumed under conditions such as rest, hypnotisation, suggestions of mood state, and relaxation response.

Mood changes in runners have long been thought to be linked to the discovery of an increase, in the blood, of endogenous peptides with morphine like effects (endorphins). Sceptics have iterated that problems exist with endorphins crossing the blood-brain barrier. In conjunction with the blood-brain barrier sceptics, Markoff *et al.* (1984), found, through the use of naloxone (a narcotic antagonist, which competes with opiates for receptor sites and reverses opiate and endorphin effects), increases in mood state due to running were not altered, although this could be due to the lack of transfer from blood to brain of the naloxone itself.

2.2.3.4.3 Personality.

Personality could potentially alter the cost of exercise. Rejeski's (1985) parallel processing model suggests, as stated earlier (section 1.2.3.4.1) that perception is an active rather than passive process, and that sensory cues may be altered by psychological state at a subconscious level prior to reaching the conscious level at the cerebral cortex. If the information interpreted at the conscious level of the cortex has been influenced by affect, perception, and cognition, autonomic control of various physiological responses to exercise (i.e. HR, SBP, DBP, $\dot{V}_{O_2}$, CO_2, ventilation) may differ among individuals.

None of the studies on perceptual effects of economy have used running or walking as the mode of exercise. It may be easier to modify perception during a run/ walk exercise bout since this is the most common form of exercise/ activity for most people. Both running and walking are virtually automatic and thus allow cognition and affect freedom to vary and to influence perception. It may also be necessary for the subject to be actively involved in the treatment to change physiological parameters.

2.2.3.4.4 Cognition.

Memory, judgements, and perceptions are integrated to form cognition, or the process of knowing. Three categories that may influence RE through cognition, are mental strategies, coping strategies, and biofeedback. Mental strategies include associative and dissociative techniques, coping strategies include relaxation and stress management techniques, and biofeedback refers to the control of physiological responses that are normally governed by autonomic mechanisms in the body.

2.2.3.4.4.1 Mental strategies.

Mental strategies are defined as conscious thoughts devised specifically to modify behaviour. Morgan (1985) and Smith *et al.* (1995) have investigated the effects of associative and disociative strategies in running (see section 2.2.3.3).

2.2.3.4.4.2 Coping strategies.

Techniques used to counteract the effects of exercise stress are termed coping strategies. Benson's relaxation technique was used by Benson *et al.* (1978) to reduce anxiety while subjects exercised at a fixed work intensity (Heart rate 95-100 beats.min^{-1}) on a cycle ergometer. Subjects were able to lower their oxygen cost by 4% during the relaxation phase.

2.2.3.4.4.3 Biofeedback.

Information provided to individuals representing their own physiological responses have shown no changes in running economy defined as energy cost, although changes in HR, blood pressure, and ventilatory efficiency/ economy have occurred.

2.2.3.4.5 Research Summary.

Of six studies reviewed by Crews (1992) which investigated the effect of psychological state on running economy, only two indicate that psychological state may influence RE. Both studies showed that reduced tension was associated with improved economy. Several factors need to be considered when examining psychological state and RE. Possible moderating psychological factors include aerobic fitness level of the subject, intensity and duration of the exercise bout, and the interaction of psychological state with both acute and chronic exercise.

Because of possible accommodating effects that can occur in the cardiovascular, respiratory and extraction phases of exercise metabolism, it will be necessary to use multiple physiological measures for determining the means by which psychological state influences economy. Crews states it may be that changes in economy only occur with extended training regimens. This has been disputed in recent unpublished work by Ashley *et al.*, displaying a reduction in running economy produced after only a two week relaxation training programme.

Martin *et al.* (1995) have since explored the relationships of anxiety and self-attenuation to running economy in 18 subjects with a mean 10km time of 34.17 min. The investigators used the psychological measurement tools, Sport competition anxiety test (SCAT), Trait anxiety inventory (TAI), and Private self-consciousness subscale of SCSR (PSC); This scale examines self-focus, described as a measure of self-attention or the degree to which people habitually direct attention inwards.

Individuals high in PSC score are particularly aware of their thoughts, feelings, bodily sensations, behaviour patterns and goals. These individuals are able to self-regulate their behaviour more effectively than people lower in PSC, because they have "access" to information used to self-regulate behaviour. Running economy was measured as the $\dot{V}_{O_2}$ at 4.13 ms^{-1}. In contrast to Crews assessment of the relationship between tension and running economy, no relationship between SCAT/ TAI and RE was observed. However, PSC and RE were related, suggesting that runners who habitually used a mental strategy directing there focus inwards were most economical.

Martin and colleagues noted that the use of trait measures of anxiety did not ensure that subject reports of tension/ anxiety reflected a similar, or the same, time period as the running economy data, and suggested the future use of state measures.

Martins hypothesis for the PSC-RE relationship was that runners high in PSC were sensitive to muscle tension and employed relaxation techniques. The reduced muscle activity resulted in a reduced oxygen demand and a greater economy. It was also hypothesised that runners high in PSC were likely to have to engage in cognitive techniques aimed at promoting economy such as, positive self talk, and associative strategies.

Research by Hatfield *et al.* (1986) has also indicated that self-focus is related to running economy. They found that ventilatory efficiency was increased in well-trained male runners when they were provided with ventilatory equivalent feedback. The hypothesis was that the biofeedback prompted self-focus, suggesting that an internal focus on the breathing improves running economy. But because biofeedback is difficult to use during racing, Hatfield suggested that more practical psychological means need to be developed for use by runners to improve performance.

Hatfield *et al.* (1992) later investigated the effect of biofeedback on cardiorespiratory variables in twelve trained subjects. Exercise was at a higher intensity than pervious studies (just below V_{Thresh} 71% $\dot{V}_{O_2max}$, HR 168). They found reductions in ventilation, respiratory rate, and $\dot{V}_E/\dot{V}_{O_2}$ in the intervention group as compared to the distraction and control group. RPE was found to decrease in both distraction and intervention group as compared with control.

It appears that attention to physical effort during exercise can promote a diminished $\dot{V}_E/\dot{V}_{O_2}$. As such, Hatfield *et al.*, suggested that well trained runners engaging in an associative cognitive strategy can exert control over ventilation, thereby supporting a notion that an associative strategy may play a role in ventilatory efficiency.

It seems that there is some plasticity in the relationship between imposed workloads and physiological cost, such that the latter may be influenced (elevated or depressed) to some degree by psychogenic factors.

2.2.4 Relaxation

2.2.4.1 Introduction

The basic technique of relaxation in it's many forms (meditation, imagery based relaxation, biofeedback training, autogenic training, PMR) has been the focus of research over much of the last decade. However, relatively little is known about the mechanism that underlies this technique, or about the influence upon disparate performance related variables. There is relatively little literature that shows a direct effect of relaxation upon sports performance, although considerable literature exists demonstrating the anxiety reducing properties of relaxation (for reviews, see

Davidson and Schwartz, 1976; Greenspan and Feltz, 1989) and the efficacy of cognitive behavioural strategies involving relaxation (for reviews, see Burton, 1990; Mace, 1990). It is also widely accepted that relaxation enhances imagery (Suinn, 1984), and that imagery can be used to induce relaxation.

Relaxation can be regarded as one of the fundamental techniques that is involved in more complex skills such as anxiety and attentional control, although the mechanism by which relaxation exerts its influence on these factors is not fully understood. The notion of relaxation is usually undefined, and denotes implicit, unspecified states of psychophysical easing of tension or resting (Kokoszka, 1992).

Syer (1992, cited by Cox, 1992) indicates the key points of relaxation use:

- appropriate levels vary from individual to individual and occasion to occasion.
- Complete relaxation regenerates and allows recognition of resources, patterns of behaviour and environment
- momentary relaxation increases speed of reaction, restores balance and gives awareness of kinaesthetic sense.

Syer suggested use of relaxation:

- before warming up
- when learning a new skill or tactic
- as part of a warm down
- before practising a form of visualisation

2.2.4.2 Relaxation and economy

Cadarette *et al.* (1982) found no change in oxygen cost for 40 minutes of cycle ergometry at 50 Watts in "relaxers" compared with controls, but did find reduced respiratory frequency, tidal volume and therefore minute ventilation. Both Benson and Cadarette's groups used exercise of very low absolute and relative intensities.

Morgan *et al.* (1980) investigated subjects walking on a treadmill at 80% $\dot{V}_{O_2max}$ to exhaustion. There was no difference in the cost of exercise even though the 14 relaxation subjects walked significantly longer than the 13 controls.

The effects of two stress management techniques on cardiorespiratory efficiency during treadmill running has been described by Ziegler *et al.* (1982). The subjects ran on a treadmill for 20 min at 50% of maximal aerobic power, and the mean oxygen uptakes were reported to be 36.7 $ml.kg^{-1}.min^{-1}$ in the controls and 33.7 and 32.1 $ml.kg^{-1}.min^{-1}$, significantly lower, in the two stress management groups. Heart rate was also substantially lower in the experimental groups by 13-16 bpm. While the investigation seems to suggest that the economy of running can be improved by means of stress inoculation and management, the results may only be applied to workloads in this light-moderate area.

The work by Ziegler and colleagues must be assessed carefully. No baseline measurements were taken, no familiarisation procedure is described, and innate differences between "relaxers" and controls are not accounted for.

An explanation for alterations in oxygen consumption during fixed exercise has been offered by Benson *et al.* (1978). These investigators have suggested that a portion of the oxygen requirements at a given exercise intensity is determined by the "emergency reaction" and its associated sympathetic activity. The amount of oxygen used in connection with this reaction would represent an excess above that required by the actual work. Furthermore, elicitation of a relaxation response, which is known to reduce arousal, would then provoke a reduction in oxygen consumption. This hypothesis certainly appears tenable and offers support for the view that cognition can mediate physiological responses during exercise. What may be problematic, is the effects of working at higher relative intensities than Benson and colleagues have investigated, reducing the excess consumption closer to the actual requirement, and working with trained athletic populations who may have achieved optimal arousal, and therefore reduced their own excess consumption to near zero.

Changes in oxygen consumption during light work (100 Watts) was indicated by Benson *et al.* (1978) in 4 of their 8 subjects. The 4% decrease in oxygen consumption during the relaxation response occurred while "RQ" and HR were unchanged. Benson suggested that the substantial decrease in O_2 consumption (8% in four of the subjects) and the absence of change in others could be related to the inability of some subjects to continue the mental technique while exercising, or it may be related to individual differences in capacity to elicit the relaxation response.

Research into the effects of pranayama (a controlled yogic breathing practice) on variables of submaximal and maximal exercise was carried out by Raju *et al.* (1994) over a 2 year period. The main finding was in conjunction with earlier work by Benson *et al.* (1978), indicating that there was a reduction in oxygen consumption per unit work in the experimental group, on an individual basis.

2.2.5 Meditation Studies.

2.2.5.1 Definition

Mahesh Yogi (1969, cited by Smith *et al.*, 1995) defined Transcendental meditation as "turning the attention inwards towards the subtler state and arrives at the source of the thought".

Smith *et al.* (1995) stated that the meditation refers to a family of mental exercises that generally involve calmly limiting thought and attention. The mindfulness of breathing technique concentrates the inward attention on the subjects breathing with the subject to achieve a relaxed state. Thereby, the mindfulness of breathing can be hypothesised to manipulate both the arousal and the attentional focus of an individual, in an attempt to reduce and internally associate respectively. A possibility also exists that for some individuals the mindfulness of breathing could cause a dissociative focus, leading to individuals distracted, or not processing, cues from other internal sources.

Meditation contains many different systems. These include Yoga, Zen and TM, each utilise different devices. These devices include techniques such as; concentration on breathing, visualising an object, imagining a sound or mantra, working on a paradoxical riddle, or "just sitting". Most meditation techniques are approached sitting cross legged, preferably in the lotus position. However, meditation can be done sitting on a chair, standing, walking, or running. As far as the technique is concerned, all stress the importance of an erect posture permitting deep and easy breathing, and all state the meditation position should be a relaxed one. All seek to develop awareness of the present, with a lack of concern for the past and future, and all provide training in concentration of attention. Meditation is seen as a means to increasing awareness, eliminating illusory thinking, stilling the mind, stabilising the emotions, and making more energy available for activity. These factors appear to have an inherent positive aspect if applied to a performance situation.

2.2.5.2 Brief history & research

Forms of Meditation have been used as relaxation techniques in cultures around the world for centuries. In the western world a small number of forms of meditation have become the most widely used techniques of relaxation. Transcendental meditation has been the most studied of the meditative techniques due to its ease and non-cultic background.

The process of meditation is still not fully understood. Kokaszka (1992) regarded meditation as a form of relaxation which includes the reduction of internal and external stimuli, in conjunction with a "thoughtlessness state" resulting from a diminishment of the goal-oriented activity of imagination. Other researchers (Crews, 1992; Davidson and Schwartz, 1976; Martin *et al.*, 1995) have suggested that meditation causes; 1. the focus of attention to turn inward or internal (association); 2. the focus of attention to turn outward or external (dissociation); 3. the reduction of somatic and cognitive anxiety and arousal; or a combination of the above. The precise definition of the mechanistic effects of meditative techniques is very unclear and may vary from individual to individual and situation to situation.

2.2.5.3 Investigations in Meditation:

2.2.5.3.1 Physiology

The physiological effects of various forms of meditation have been thoroughly researched in the resting situation. Very little work has extended this into exercise or sport where physiological systems are stressed. The majority of work that has been done has utilised the technique of Transcendental Meditation (TM). Among the most common physiological effects are sectioned below.

2.2.5.3.1.1 Autonomic nervous system (ANS)

The majority of work investigating the effect of meditation on the ANS has ascertained an increase in autonomic stability, or a reduced hyper-arousal of the sympathetic division of the autonomic nervous system and activation of the energy restoring parasympathetic division. A decrease in sympathetic activation, decreased concentration of noradrenaline, and a slight vasodilation has resulted. In apparent contrast, Lang *et al.* (1979, cited by Lang *et al.* 1980) attempted to stimulate the response of the sympathetic nervous system by inducing light exercise in meditators. Their overall conclusion was that meditation enhances sympathetic activity. Lang and colleagues asked experienced and less experienced meditators to undergo a period of light exercise (100 Watts) post meditation, comparing this to post reading. They found that advanced meditators reduced heart rate due to an increased vagal tone or decreased sympathetic activity, during meditation (by 9%) and this remained lower during the 3 minute exercise bout. But Lang also noted urinal collection indicated an increased catecholamine release and therefore an increased sympathoadrenal activity.

In conclusion Lang *et al.* stated it was their hypothesis that during meditation there is a simultaneous excitation of both autonomic systems, the sympathetic and the parasympathetic, which may be associated with changes in the lateral nuclei of the hypothalamus. This may also link to findings of Bujatti *et al.* (1976) regarding the hormone serotonin.

In agreement with Lang (1979, cited by Lang *et al.*, 1980), Telles and Desiraju (1993) suggested from a study in yogic meditation at rest that the use of some autonomic and respiratory variables may reveal group effects of meditation, whereas other variables can alter in an individualistic way, sometimes with both a relaxation and activation consequence. Hence, a single model of meditation producing either overall relaxation or overall activation is probably inadequate.

2.2.5.3.1.2 Metabolism/ Oxygen consumption

One of the first findings in meditation research was by Wallace (1970), who described a lowered metabolism and named this meditative response as a "Wakeful hypometabolic state". This work stemmed from findings by Wallace in 1970. Wallace found respiratory changes due to meditation to consist of a decreased O_2 consumption (by 17%), CO_2 elimination, respiratory rate, and minute ventilation, with no change in respiratory quotient in a resting situation. Arterial blood pH and base excess were found to decrease slightly, and blood lactate also decreased. Demonstration of several changes in respiration occurring during Transcendental meditation (TM) were also shown by Orme-Johnson (1973). These included decreases in respiratory rate, minute ventilation, O_2 consumption and CO_2 elimination with no change in respiratory quotient or arterial PO_2 and PCO_2.

More recently Wilson *et al.* (1987) discussed the effects of TM on metabolism. It was noted that during TM, forearm oxygen consumption acutely decreases about 30%, while production of carbon dioxide "virtually ceases". The implication to physiological systems warrants caution to the above findings, as CO_2 production is a normal product of metabolism.

Use of meditation during exercise has been sparse. Benson *et al.*,(1978) found that at a fixed work intensity on a cycle ergometer (Heart rate approx. 95-100 beats.min^{-1}), subjects with at least 6 months experience in relaxation training had a reduced oxygen consumption during the phase involving incorporation of the meditative relaxation response. It must be noted that subjects performed the exercise at very low workloads, and were very skilled in the relaxation technique. What may also be questioned, is the effect of learning of the exercise test.

During hypnotic suggestion of heavy work, Morgan *et al.* (1973) noted an increase in oxygen uptake of 3ml.kg^{-1}.min^{-1}, in the fifth minute of exercise, at 100 Watts on a cycle ergometer. It was also noted that a steady state was not achieved with this suggestion. The reverse scenario of a hypnotic suggestion of light work actually produced similar results of an increased oxygen uptake and no achievement of steady state. Heart rate increased by 10-15 bpm in the suggestion of heavy work, along with increases in CO_2 production, RER, and minute ventilation (15 $l.min^{-1}$). The rating of perceived exertion (RPE) changed from 11 to 9 in light suggestion, and to 14 in heavy suggestion, indicating that RPE is governed by both the physiological cost and the subjects cognitive-perceptual appraisal, a gestalt measure. In Morgans study RPE was significantly correlated with measures of anxiety (STAI) at higher workloads (150-250W). HR after 5 mins correlated with trait anxiety.

To summarise the metabolic findings meditation may be regarded as a hypometabolic state, associated with reduced basal metabolic rate, O_2 consumption, and CO_2 production. Again these findings are applicable to subjects in a resting condition, and further extrapolation to increased metabolic states cannot be made without extreme caution.

2.2.5.3.1.3 Heart rate

In his initial study into meditation effects on the physiology of the body, Wallace (1970) also noted a decrease, during meditation, in heart rate by a mean of 5 beats.min^{-1}. General findings since have been in congruity with Wallace. Mechanisms of this heart rate reduction have again centred on the ANS, with increases in vagal tone and, or decreases in sympathetic activity, slowing the heart rate and possibly allowing a greater time for cardiac filling (Green, 1990). Problems do occur if attempts to extrapolate this to higher exercise intensities. Vagal tone tends to decrease as exercise stress increases, although it is not fully diminished until maximal exercise.

2.2.5.3.1.4 Ventilation/ Respiration

Overall, as indicated in the section concerning metabolism, minute ventilation has tended to decrease with the use of meditation techniques. Some investigators have observed periods of respiratory suspension during meditation. Quantitative reductions in minute ventilation have been recorded in the order of 1 liter.min^{-1} (Wallace ,1970). Respiratory suspension periods during TM are different from those seen during sleep apnea as they are not followed by periods of compensatory hyperventilation (Badawi *et al.*, 1984)

Corey (1977, cited by Badwai *et al.* 1984) found that as well as a reduction in respiratory rate, meditation produced a significant increase in specific airway conductance, and research has indicated improvements in asthmatic conditions (Honsberger *et al.*, 1973, cited by Reddy *et al.* 1976; Wilson *et al.*, 1975). The investigators suggested that TM was a useful adjunct in treating asthma based on: reduction in symptom severity-duration index; improvement of pulmonary function abnormalities, particularly airway resistance; and subject and physician evaluation. The exact mechanism(s) underlying the effects of TM upon asthma are speculative. Inclusion of a reduction in physical stress, a reduction of bronchomotor tone, via reflex or chemical factors, and a reduction in minute ventilation, i.e., decreased need for oxygen delivery and carbon dioxide elimination, should be considered in future investigations (Wilson *et al.*, 1975).

Wolkove *et al.*,(1984) found that in experienced meditators, at rest, ventilation decreased significantly. They stated that the change in ventilation resulted from a shortened inspiratory time (T_I). The mean inspiratory flow rate (V_T/T_I), which has been shown to be an index of neural inspiratory drive, was unaffected. The findings indicate that during meditation there is an alteration in central neural control mechanisms, such that an earlier switch occurs from inspiration to expiration. Linking this to findings of respiratory suspension, it is possible that meditation temporarily interferes with the central respiratory drive, and may influence the sensitivity of central chemoreceptors to hypercapnia. Meditation was also associated with a decreased response to progressive hypercapnia.

2.2.5.3.1.5 Blood pressure:

Volunteers with mild hypertension were taught TM, clinical recordings showed significant decreases in systolic and diastolic blood pressure (Blackwell *et al.*, 1975, cited by Benson *et al.* 1978). The authors suggested that TM can produce additional significant benefit in patients with moderate hypertension, which may be mediated through a reduction in anxiety. Problems are evident, with experimental attention focused on the clinical group and no control group to compare findings. This makes the results interesting but only suggestive in nature. Studies in normotensive subjects have maintained that systolic, diastolic, and mean arterial blood pressure remained unchanged with meditation.

2.2.5.3.1.6 Galvanic skin response:

A common physiological response test is that of galvanic skin resistance. The resistance of the skin to an electrical current is thought to reflect the level of "anxiety". A decrease in the resistance represents a greater anxiety, a rise in resistance, greater relaxation (Wallace and Benson, 1972). Research has displayed increases during meditation techniques at rest, in some cases more than four-fold, of galvanic skin resistance (Wallace and Benson, 1972; Wallace, 1970).

2.2.5.3.1.7 Blood flow

In association with changes in the ANS, blood flow has been noted to alter. Both a vasodilation and a redistribution of blood flow has been shown. Increases in blood flow to skeletal muscle (Levander *et al.*, 1972, cited by Joseph *et al.* 1981) were concluded to be due to a decreased arteriolar sympathetic adrenergic activity.

Various reports have been published indicating the wide individual variation in the effects of meditation. Rieckert (1967; cited by Wallace and Benson, 1972) detailed a 300% increase in blood flow to skeletal muscle, attributed to increased parasympathetic activation, acetylcholine release, and vasodilation. Whereas Wallace and Benson (1972) documented a 32% increase in non renal and non hepatic blood flow.

2.2.5.3.1.8 Temperature

McDonagh and Egenes (1971; cited by Joseph *et al.*, 1981) found a rapid recovery of temperature to baseline after exercise, with the use of a meditation technique. Again, this may be due to ANS alterations involving skin and muscle blood flow.

2.2.5.3.1.9 Motor tasks

Motor tasks are generally associated with a level of alertness. Appelle and Oswald (1974) found regular meditators had 10% quicker simple reaction times than other populations and that a 20 min period of meditation did not affect acutely reaction time. The investigators also noted that in contrast to other groups, meditators showed no significant learning effect throughout 100 trials. The authors concluded by intimating that it is conceivable for meditators to have chronically reduced the latency in neurotransmission, although they did not investigate or discuss the possible mechanism(s) for this.

Proponents of meditation techniques state that an increase in the index of skill development though learning occurs. This development is characterised by a smoother and more integrated behaviour. Extraneous movements are omitted, and the performance is executed with fewer errors and increased speed and accuracy. This efficiency requires good co-ordination between mind and body (Blasdell ,1971, cited in Appelle and Oswald, 1974). Results indicate that individuals practising meditation performed faster and more accurately on a Mirror-Star tracing test. Investigators proposed that meditation could provide both physiological (reduced tension, greater neural adaptability) and psychological (decreased anxiety and extroversion) factors which could reduce impediments to motor performance (Blasdell ,1971, cited by Appelle and Oswald, 1974).

In opposition to improvements in motor task with meditation, results from Williams (1978) presented no support that TM facilitates learning and performance of a complex, fine motor skill. In contrast to Appelle, and in accord with Williams, Wood (1986) found no significant difference in the performance of either a fine or gross motor task between meditators and non-meditators asked to relax. Care must be taken with these results as groups exhibited significant differences in some variables at the pre-test phase possibly indicating innate differences between meditation groups and the general population.

2.2.5.3.1.10 Other

Other generally reported effects of TM include: changes in endocrine, immune, and brain wave activity (Jevning and Davidson, 1978; Solberg *et al.* 1995; Herbert and Lehmann, 1977); benefits on physical and mental health, biologic ageing, and pyschophysiologic performance. TM also decreases the distress associated with the experience of acute experimental pain (Mills and Farrow, 1981).

2.2.6 Difference to Hypnosis, autosuggestion, and deep sleep:

2.2.6.1 Hypnosis

Research has indicated no changes in HR, blood pressure, respiration, and Galvanic skin resistance (GSR) during hypnotic suggestion of relaxation. Hypnotic sleep following the suggestion of relaxation has also produced no change in O_2 consumption. Hypnotic suggestions do tend to reflect physiological changes associated with the suggested emotional state, although EEG sychronicity is not shown to occur as in meditation.

2.2.6.2 Sleep

Oxygen consumption only decreases appreciably after several hours rather than 5-10 mins as in meditation. Skin resistance commonly increases in sleep, but again over an extended period of time. EEG patterns differ to meditation (for a full review the reader is directed to Banquet, 1973. Unlike meditation there are no acute changes in hormones such as plasma cortisol, and plasma phenylalanine. (Jevning *et al.*, 1977).

2.2.6.3 Biofeedback

Meditation differs in some important ways from biofeedback. Meditation is independent of the stimulus and feedback of a reinforcer, and produces not a single specific response, but a complex of responses that marks a highly relaxed state.

In a letter to the American Psychologist, Dillbeck and Orme-Johnson (1976) highlighted the differences between transcendental meditation and rest with a meta analysis of somatic arousal variables in 31 studies. They indicated that larger effect sizes were associated with meditation than eyes closed rest in basal skin resistance, respiration rate, and plasma lactate. They also stated that somatic arousal does not capture the full range of physiological effects reported in meditation studies, such as, electroencephalogram (EEG) coherence, hemispheric EEG lateralisation, increased plasma arginine vasopressin, and improved reflex responses, a number of which suggest increased alertness.

One major area discussed in the research into measurements of changes and comparisons in these varying states of consciousness was touched upon. That of a "floor effect" or the "law of initial values". In which the ability to decrease levels of physiological variables is mitigated by low initial values. The possibility of floor effects may also be greater in extreme populations such as athletes.

2.2.7 Psychology

2.2.7.1 General Psychology

The psychological research on the effects of meditation shows improved academic performance, increased productivity, improved reaction time, improved concentration, sensitivity to internal cues, and sensory discrimination. Personality differences have also been noted.

2.2.7.2 Anxiety

Ferguson and colleagues (1976) showed the effects of learning meditation on anxiety. Six and a half weeks of TM instruction lead to a significant decrease in anxiety compared to controls as measured by Speilbergers anxiety inventory (SAI). A study investigating the difference between anxiety changes of sitting quietly and meditation was conducted by Dillbeck (1977). Findings indicated that meditation is associated with an anxiety reducing effect which is not attributable to merely sitting in quiet relaxation. Dillbeck does clarify this by admitting that subjects expectations of meditation may have influenced the completion of Speilbergers state-trait anxiety inventory.

Bahrke and Morgan (1981) considered the differences in anxiety reduction between exercise, meditation and quiet rest. The investigators noted that all three interventions led to a decrease in anxiety as measured by Speilbergers STAI X-1. They concluded by questioning the issue of causality in anxiety reduction, suggesting that future research should look toward exploration of the causal/ associative nature.

Schwarz *et al.* (1978) investigated the differences in anxiety mode between exercisers and meditators. They found that exercisers displayed lower somatic anxiety, but greater cognitive anxiety than meditators. The investigators noted that their study did not rule out the possibility of pre-dispositional (including expectation) contributions to their observations. The implication for athletes, may be the optimisation of both somatic and cognitive anxiety, prior to, and during performance.

There is, however, some considerable overlap in anxiety changes associated with meditation. A number of distinctly somatic effects of meditation have been noted (see section 2.2.5.3.1), therefore the clear delineation of meditation as a cognitive effector cannot be maintained, and an understanding of the close association of somatic and cognitive anxiety must be used to investigate meditative techniques.

2.2.7.3 Self-Actualisation/ Inner control

Seeman *et al.*, (1976) utilised the Personal Orientation Inventory (POI of Shostrom, 1966) to investigate the nature of a change in personality due to meditation. The investigators discovered that meditation had a salutary influence on a subjects psychological state as measured by the POI. Inner directedness appeared augmented, capacity for intimate contact, self-regard and acceptance of aggression, and spontaneity were all positively affected. An increased ability to focus attention, and stabilise an internal frame of reference was also indicated by the questionnaires. Further measures of direction of focus through the Locus of Control scale may be appropriate for athletic populations.

Gaylord *et al.* (1989) indicated that TM offered a greater reduction in neuroticism than Progressive muscular relaxation (PMR). Further work by Hjelle (1974) investigated the psychological health of long term meditators and those wishing to begin meditation. Hjelle measured locus of control (Rotter, 1966), anxiety (Bendig, 1956; cited by Hjelle, 1974) and personality orientation (Shostrem, 1966). He encountered differences between the two groups which were indicative of a more positive psychological health (internal, less anxious, and greater self-actualisation) in the long term meditators.

Ferguson and Gowan (1976) concluded that six weeks of TM "appears" to reduce anxiety, depression, and neurotic levels, and to increase self-actualisation in an interested volunteer group.

2.2.8 In Sport

What does meditation have to offer the athlete?
There is very little well designed research to provide the answer. However, the attitude implicit in meditation suggests application to sport, along with reports of personal experience, this must induce further steps to answer the performance question. Meditation can be offered as a focus. Concentrating on the here and now, not past mistakes or future obstacles, and as a method of arousal reduction in those who are hyperaroused.

Reddy *et al.* (1976) conducted a careful and objective measure of a meditation programme. 30 male athletes wishing to learn meditation were randomly assigned to one of two groups. Athletic performance tests, physiological tests, and an intelligence test were administered pre and post six weeks of meditation instruction. The results showed the meditating group improved significantly better than controls in the 50 metre dash, agility test, standing broad jump, and reaction time and co-ordination test. Meditators also improved more than controls in shot putt and strength test, but the differences were not significant. Physiologically meditators improved significantly better on cardiovascular efficiency (step test), respiratory efficiency as indicated by vital capacity, systolic blood pressure, diastolic blood pressure, and haemoglobin changes. Meditators also showed greater increase in intelligence. The investigators concluded that the meditation programme helped the athletes to develop a broad range of qualities essential to his performance: agility, speed, endurance, fast reactions, and mind-body co-ordination. Questions remain regarding the significance of improvements found by Reddy *et al.* (1976).

Appropriate control of this research appears to have been neglected. All subjects had high expectations of the positive effects of meditation, as shown by their volunteering for the study after being shown a promotional video on the effects of meditation. Half were then informed that they were to be controls, while 15 subjects began learning the technique over a six week period. Therefore problems with expectations, Hawthorne effect, and the negative psychological aspect of those placed in the control group could have artificially affected results. Nevertheless the results are an initiation into the effects of meditation on athletic performance. One notable aspect of these results is the athletes' improvement in a wide variety of performance, physiological, and psychological measures.

Ashley *et al.* (1996), investigated the effect of two relaxation techniques on running economy. The techniques, progressive muscular relaxation and a meditation practice, were instigated 20 mins prior to treadmill running with a prior two week learning period in a cross over design. The researchers found that the meditation technique, even with only a two week learning phase, reduced oxygen cost of the slower of two runs (approx 6 miles.hour^{-1}). No control group was available for comparison, no familiarisation detailed, and no indication as to the time point in the protocol at which running economy changes occurred was given.

The combination of long, slow running and meditation has been used effectively as an adjunct to psychotherapy (Solomon and Bumpus, 1981, cited by Ashley, 1996). Elicitation of an altered state of consciousness or peak experience can be achieved through either method, but a combination of the two appears to be of benefit in clinical therapy. Patients are asked to run non competitively, for approximately an hour at a slow pace, in conjunction with this they are directed to relax and concentrate on their breathing. The hypothesis is that both techniques are forms of autohypnosis and subjective benefits appear enormous. This work is one of the few published studies which combines the use of running and meditation, in this case as a clinical therapy.

In a review of research concerning meditation and sports performance, Layman (1980) concluded that it appeared there was enough preliminary evidence to indicate meditation may be beneficial to athletic performance to make it worth while trying. However, she clarified this by stating that the preliminary evidence must be translated into hypothesis which can be thoroughly tested in sporting situations, with planned research with pre-post design, suitable comparison groups, and larger numbers.

The proponents of meditation claim rejuvenation and normalisation of the functions of the nervous system, elimination of mental stress, promotion of clear thinking and comprehension, and enrichment of perception. The possible effects to transfer to athletic ability are: athletes may feel better, learn faster, be more relaxed and have more energy. Meditation may be particularly beneficial to athletes in calming the mind and reducing hyper-arousal. Orme-Johnson (1973) has demonstrated meditation provides greater autonomic stability and greater physiological efficiency at rest. If application can be transferred to sporting performance, benefits may complement physical and psychological training enormously.

2.2.9 Research problems

A major problem with the majority of research into meditation and its effects has been one of selection bias. It seems likely that the people who practise TM are not a random selection from the population at large. It may be that studies comparing meditators and non-meditators are flawed due to the two populations not being comparable. At the very least, meditators, by their decision to learn meditation, demonstrate some motivation for self-improvement.

It is also possible that the sample of those who volunteer to participate in meditation research are perhaps not representative of the whole population of those who have learned to meditate. In the more rigorous studies, where random assignment of subjects to control and intervention groups, with testing prior to and post treatment, the problem of expectation still arises. Although the use of this expectation may in itself be beneficial to athletic populations.

It is clear that controlled longitudinal studies and ideographic research may go further to settle these issues. Future short term research should use randomly selected populations, teach them the meditation technique and observe differences between control and intervention groups, attempting to negate any expectational or experimenter bias.

2.2.10 In Conclusion

Evidence exists that metabolism at rest and during exercise, is affected by somatic, cognitive, affective, and perceptual factors. These thoughts, feelings, and sensations, can operate independently, or in concert with variables of a physiological nature to influence metabolism (Morgan, 1985).

Hypnotic suggestions have been a key focus of research. Changes in metabolism at rest (oxygen cost and ventilation) through suggestions of varying exercise intensity, have indicated that the perception of intensity plays a role in one's metabolic response. Suggestion during exercise has indicated that exercise metabolism is also governed to a substantial degree by one's perception of the exercise cost (Morgan, 1985).

Meditation has been shown to affect the energy cost at rest and during light exercise (Wallace, 1970). Mechanisms for this displayed reduced cost are unclear, although reduction in arousal, and changes in attentional focus may be associated either exclusively or in conjunction. Individuals may also benefit with disparate outcomes through different mechanisms.

2.2.11 Measurement instruments of psychological parameters.

The development of tools to measure psychological parameters is a continuous process. Measurement mediums have been utilised from general psychology and adapted for exercise and sports populations.

Questionnaire based assessment is the most common strategy, allowing a valid and reproducible measure to be analysed objectively. The use of interviews has also been applied, this can permit a greater individual understanding and in depth information, but must be analysed in a subjective manner. Self report diaries have become another option open to the sport psychologist. This method has problems and can suffer from adjusted responses and subjective analysis.

State and trait anxiety (cognitive and somatic), stress, mood, tension, self-confidence, personality, attention, arousal, aggression, attributions, and motivations are indicative of the common measures of sport psychologists. These parameters are used sometimes individually, sometimes as a gestalt, in order to assess an athlete either in generality (trait), or in a certain time specific situation (state).

2.2.11.1 Mood (Incredibly Short Profile of mood states-ISP)

The profile of mood states (POMS) was developed by McNair, Lorr and Droppleman in 1971 to measure mood states and mood changes. The development was of a questionnaire measuring six identifiable mood or affective states: Tension-Anxiety; Depression-Dejection; Anger-Hostility; Vigour-Activity; Fatigue-Inertia; and Confusion-Bewilderment. The POMS has been validated and applied in disparate populations (See McNair et al., 1971). Further development of the POMS has led to the Bipolar POMS (POMS-BI) (McNair *et al.*, 1971). The POMS-BI represent both positive and negative aspects of mood characterised as: Composed-Anxious; Agreeable-Hostile; Elated-Depressed; Confident-Unsure; Energetic-Tired; Clearheaded-Confused. The uses of the Bipolar POMS and the POMS are similar, for example;

a) To identify and assess mood and feelings in normal subjects;

b) To assess relevant mood states in individual psychiatric outpatients in order to determine their clinical status and need for therapy;

c) To evaluate the relative effectiveness of various psychotropic drug treatments for reducing states such as anxiety, depression, hostile feeling, and confusion in outpatients;

d) To experimentally assess in groups the influence of various drugs and emotion-inducing films of other experimental manipulations;

e) To assess mood change resulting from such techniques as relaxation therapy, meditative treatment, and brief and long-term psychotherapies;

f) To compare the various Personality Disorders described in DSM-II, as to characteristic mood profile.

g) To identify and assess moods and feelings in athletic populations.

The POMS-BI allows the addition of categorising two higher-order dimensions: negative and positive aspects of mood, or affect.

The Profile of mood states has been used in many situations but has been found to take extended periods of time to complete. From this observation some researchers have attempted to identify fewer adjectives which can be applied to subjects with identical outcomes. The development of the Incredibly Short POMS (ISP) (Whelan, unpublished) has condensed the POMS to its bare minimum (See appendix 2). The use of the ISP allows for rapid retrospective assessment of mood immediately after a bout of exercise or training, not allowing any effect of time to dilute the subjects mood.

Mood has been shown to affect performance (Williams *et al.*, 1991) Athletic success appears to coincide with a particular mood profile (Morgan, 1979). The "iceberg profile" shows lower than "norm" tension, depression, anger and confusion, and higher vigour. Total mood appears to be better in athletes than the general population. Changes in mood may be extremely dynamic, therefore measurement of mood during running may elicit further information as to the effect on running performance. It may also be of interest to investigate if a relaxation intervention can alter mood positively, over the short period during a run. For further information on the POMS see appendix 2.

2.2.11.2 Tension (Body Tension Index- BTI)

The Tension mannequin was initially developed by Webster *et al.* (1984) as an aid to the busy clinician. Webster and colleagues attempted to validate the scale following relaxation training and in suffers of tension headaches. Ashley *et al.* (1995) investigated the use of a modified version of Websters Tension mannequin (1984) in runners post relaxation. The questionnaire allows a rapid retrospective assessment of tension during an activity. For further information see appendix 2. Previous research has indicated a link between tension (as measured by POMS) and running economy (Crews, 1992). It is therefore of interest to measure changes in tension over the intervention of a relaxation technique, and to associate changes in tension and running economy due to such a psychological intervention.

2.2.11.3 Exertion (Rating of Perceived Exertion-RPE)

The cultivation of the Rating of perceived exertion scale (RPE) began in 1970 by Borg. The scale, containing 15 grades from 6-20, allows a subject to rate the degree of exertion during an activity. Borg stated that the values of the RPE-scale grow fairly linearly with the workload and that correlations between RPE and heart rate were around r = 0.8. The indication was, as a rough approximation, that heart rate for "middle aged people at workloads of medium intensity" should be fairly close to 10-times the RPE values. Borg went on to indicate that RPE should be used as a complement to pulse counting, and that people during exercise normally rely on their subjective feeling of effort and fatigue to regulate the work intensity. The significant thrust of Borg's work suggested that an organism's perceptual response to exercise is influenced by extraneous psychological and physiological variables. The key factor being that perception of effort contains information from all inputs into cognition, indicating that RPE must be considered a gestalt measure, and thereby more useful than any single variable in measuring effort.

RPE is now extremely widely used. A number of factors are known to influence it's use, although the majority of research has advanced the physiological explanations. Rejeski (1985) emphasised the importance of cognition, motivation, emotion, learning, and environmental and task variables on perceived exertion, but clarified the effects of psychogenic factors in relation to the exercise stimulus. He indicated that the strength of the exercise stress may lead sensory cues to dominate perception.

The work of Rejeski has enhanced the understanding of RPE as an active process. He expounds that empirical data supports the position that sensory cues can be manipulated psychologically prior to reaching the cortex. In other words, similar peripheral physiological changes in two individuals do not necessarily result in identical percepts.

It is therefore of interest to investigate the changes in RPE associated with a relaxation intervention during running. Questions remain regarding the effect of the intervention reducing the percpt of exertion, possibly allowing an athlete to continue at a greater intensity for longer. This may be a strong influence as perception of effort and the cognition of this perception must be a major contributing factor to a reduction in exercise intensity.

2.2.11.4 Anxiety (State-Trait Anxiety Inventory-STAI)

Measurements of anxiety are common place in psychology. A abundance of self-report based assessments are available for use (see Cox, 1990). The State-Trait Anxiety Inventory (STAI) (Speielberger, 1983) has been utilised in research and clinical practice. It comprises separate scales for measuring state and trait anxiety each containing twenty statements. The S-Anxiety scale has been found to be a sensitive indicator of changes in transitory anxiety experienced by clients and patients in counselling, psychotherapy, and behaviour-modification programmes (Speilberger, 1983).

Anxiety is an important component of athletic performance. The links between sub-components of anxiety, and arousal with effects on performance are clear (see section on arousal). An optimal level of anxiety is required for an individual to perform his or her best. Investigations into the effects of psychological interventions in optimising anxiety during running are of interest to athletic performers.

3 Method

3.1 Subjects

Thirty nine subjects initially volunteered to take part in the study. From this population eleven subjects failed to complete the protocol due to injury or illness. The remaining twenty eight subjects completed the study randomly assigned to intervention and control groups. All were healthy and physically active, partaking in at least 3 exercise sessions per week adhering to ACSM guidelines (1991). The cohort contained 7 females and 21 males, table 1 shows anthropometric data for all subjects and by group.

Table 1. Table showing mean data for anthropometric variables of all subjects, and by group.

	All Subjects	**Intervention**	**Control**
Antropometric variable	**Mean ± s.d.**	**Mean ± s.d.**	**Mean ± s.d.**
Age (years)	24.4 ± 4.8	22.3 ± 4.8	26.5 ± 3.8
Body mass (kg):			
Visit 1	65.7 ± 7.3	65.8 ± 7.7	65.6 ± 7.2
Visit 2	66.6 ± 8.6	67.4 ± 9.8	65.8 ± 7.5
Visit 3	66.2 ± 8.8	66.9 ± 10.2	65.6 ± 7.6
Visit 4	66.2 ± 8.5	66.9 ± 9.7	65.7 ± 7.5
Height (cm)	174.6 ± 6.3	175.5 ± 6.7	173.7 ± 5.9
Sum of 4 skinfolds (mm)	27.6 ± 6.0	27.6 ± 4.8	27.7 ± 7.3

Of the 28 subjects 22 were familiar with laboratory testing. The remaining 6 were habituised to laboratory and equipment prior to commencement of testing. Skinfold measurements, (Durnin and Wormsley, 1974), were taken prior to exercise testing to avoid possible dehydration effects on composition (ACSM, 1995). No conversion was made to % body fat as this was felt inappropriate and unnecessary.

The study was approved by the University of Glasgow ethical committee. Subjects completed consent and medical forms prior to testing.

3.2 Apparatus

SensorMedics S2900Z on line metabolic cart (SensorMedics Corp., Yorba Linda CA)

Powerjog EG30 (Powerjog)

Hans rudolph 2900 valve (Hans Rudolph,)

Less than 1m large bore tubing (SensorMedics Corp., Yorba Linda CA)

Heart rate monitor PE 3000 (Polar, Finland)

Fan

Stadiometer (Holtain, Dyfed Wales)

Scales (Holtain, Dyfed Wales)

Harpendon Skinfold callipers (Holtain, Dyfed Wales)

3.3 Regulated factors

Subjects reported to the laboratory on 4 occasions. Instructions regarding prior exercise and dietary regime (see appendix 1, ACSM, 1995) were given to subjects in advance of their first test. On each visit subjects wore the same running shoes and lightweight clothing. They performed an identical self selected warm up and flexibility procedure before each test. To minimise anxiety, the test environment was quiet and private. Laboratory temperature was maintained at 21 to 23°C (70 to 74°F) (ACSM, 1995), relative humidity remained less than 60% throughout testing (BASS, 1988). Training status was recorded through training diaries.

3.4 Protocol

3.4.1 Protocol summary

Subjects attended the laboratory on 4 occasions. Each visit consisted of 2 identical runs at 2 paces, the second faster than the first. Each run lasted 10 mins, with a 10 minute recovery between runs. The intervention group attempted to use a learned intervention technique, with assistance on visit 3 and without assistance on visit 4.

3.4.2 Outline (see figure 3)

Subjects were randomly assigned to one of two groups, control or intervention.

Subjects attended the laboratory on four occasions and performed two runs on each visit at 0.5 $min.mile^{-1}$ slower than 10km pace, and 10km pace. Three to seven days was given between each visit (exactly 7 days between visit 2 and visit 3). The control group maintained an identical protocol (protocol A) throughout testing. The intervention group completed an identical protocol for the first two visits (pre-intervention phase) as baseline data.

On completion of visit 2 the intervention group were given an audio cassette and instructions pertaining to the intervention (see appendix 3). For the first three days between visit 2 and 3 the intervention group were asked to listen to the introduction and short practice (section A) of the audio cassette. For the following 3 days they were asked to listen to the full practice (section B), and at least once while running.

On visit 3 the intervention group were asked to listen to section B of the audio cassette during each of their two runs. On visit 4 the intervention group were asked to use the learned intervention technique (Appendix 3) during their runs without external assistance.

Figure 3. Protocol Outline

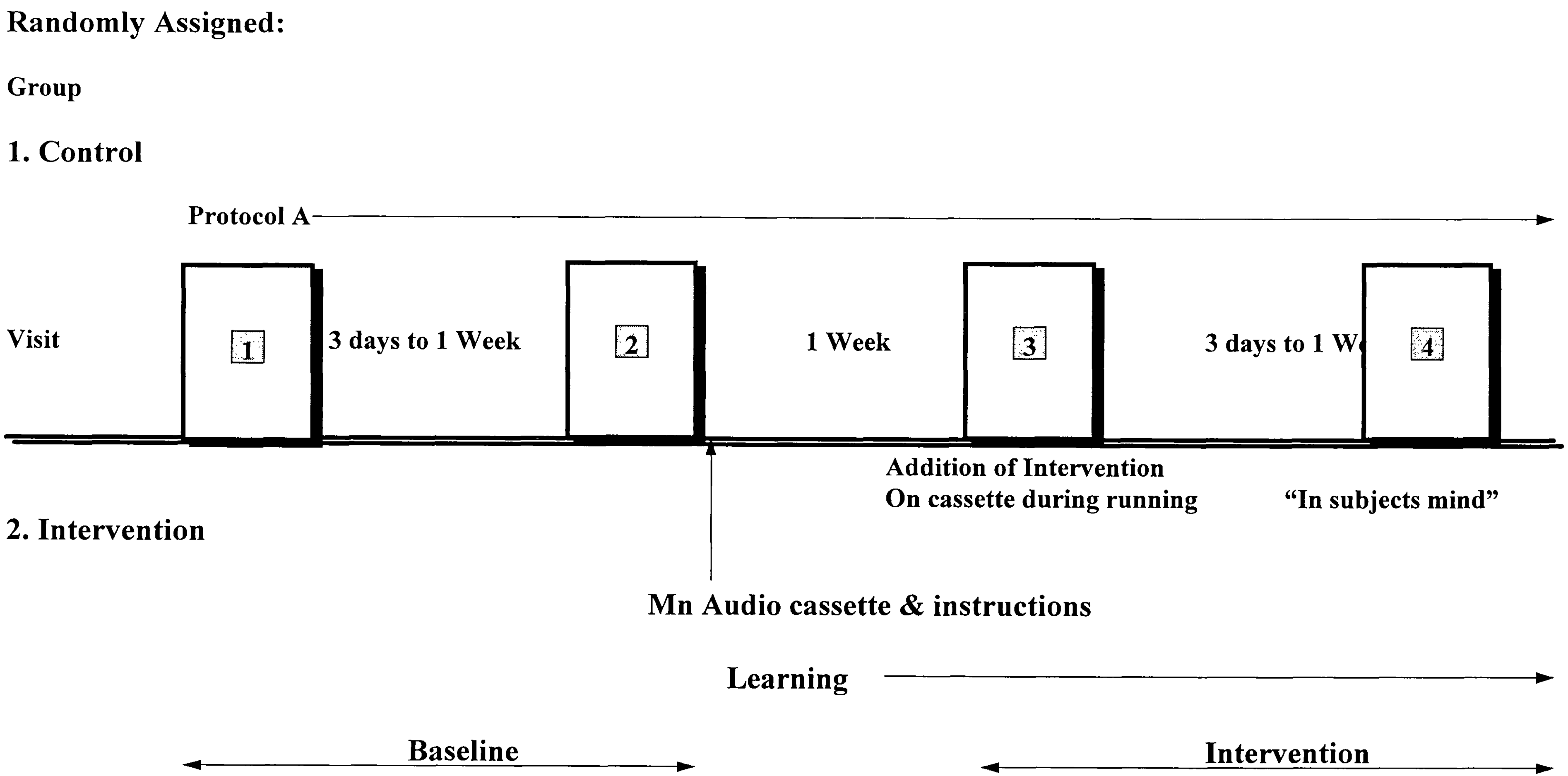
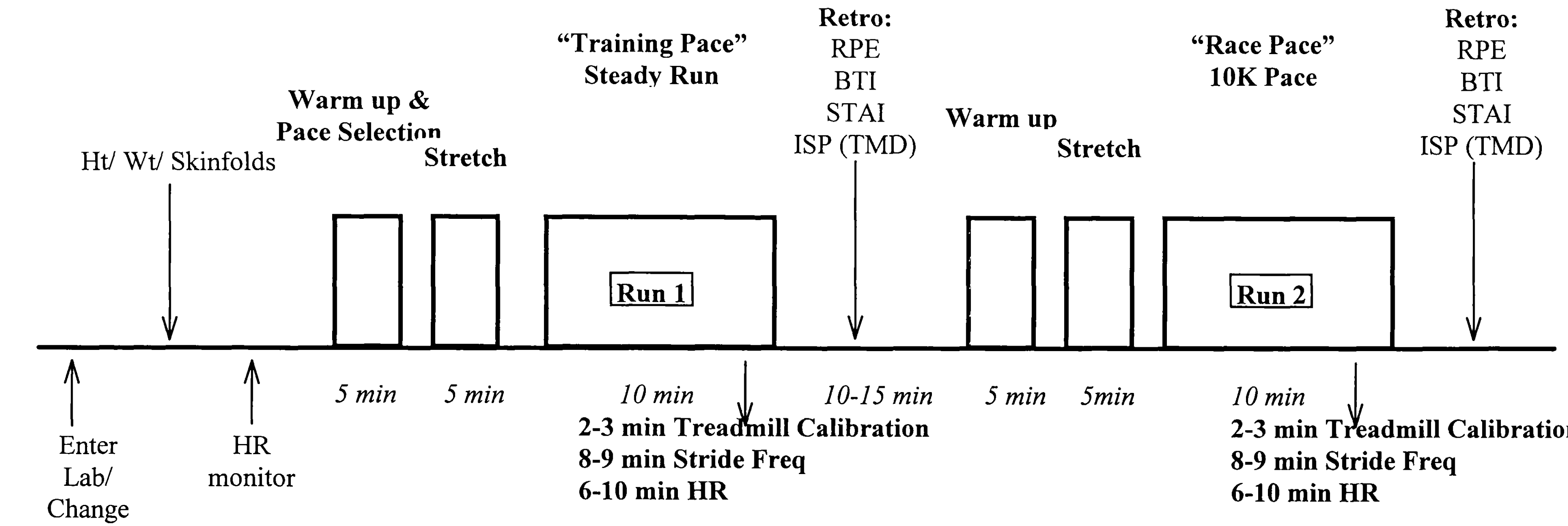


Figure 4. Protocol A



Measurements:

1 and 2:
Continuous Gas analysis
2-3 Treadmill Calibration
HR mins 7,8,9,10
Stride Frequency
RPE 30s post 10 min (Retrospective)

Physiological
VO_2, VCO_2, VE, RER, VE/VO_2

Heart Rate
Stride Frequency and Length

Psychological
Body Tension Index (BTI)
STAI
ISP (TMD)
RPE
Open ended "thoughts" question

During study. Training Diaries on adherence to intervention and Training

3.5 Basic protocol (Protocol A)

(See figure 4)

3.5.1 Visit 1

Anthropometric data were taken prior to exercise testing. Subjects selected a 5 min warm up pace which remained consistent throughout subsequent test visits. Subjects selected a 5 min flexibility routine, which remained constant throughout testing.

Discussion with each subject lead to an estimated pace at which 10 Km would be run. From this, paces for a "training pace steady run" 0.5 $min.mile^{-1}$ slower, and 10 Km "race pace" were selected as run 1 and run 2 paces respectively.

Each subject placed the mouthpiece (Hans Rudolph 2900, low resistance valve) and nose clip in position. The mouthpiece was supported by headgear (Hans Rudolph) and connected via less than 1 metre of wide bore tubing to the metabolic cart (Sensor medic 2900). The treadmill (Powerjog EG30) was set at run 1 pace. Subjects remained still for approximately one minute to allow expired gas to enter the mixing chamber of the metabolic analysis equipment (Sensor medic 2900). Subjects lowered themselves onto the moving treadmill and the expired gas analysis began. Each run lasted 10 mins in order to achieve stability in the measured physiological variables and to allow the implementation of the intervention during running on a later visit (Åstrand and Rodahl, 1986; Benson, 1978; Hickson, 1978).

After run 1 subjects were allowed to warm down and they completed a set of questionnaires. The instruction was to "complete the questionnaires as to how you felt toward then end of the 10 min period". Questionnaires consisted of the Rating of perceived exertion scale (RPE), the body tension index (BTI), the incredibly short profile of mood states (ISP), the state-trait anxiety inventory form Y (STAI), and an open ended question on their thoughts during the run. The questionnaires were presented in the above order.

Subjects were allowed a 10 min recovery period (inclusive of questionnaire completion) before the same sequence of warm up, flexibility, run 2, and questionnaires began again.

3.5.2 Visit 2

Visit 2 consisted of an identical protocol to visit 1 for each subject and for both control and intervention groups.

3.5.3 Visit 3 and 4

The control group continued the protocol outlined in visits 1 and 2 above. One change occurred with the intervention group. On visit three instructions regarding the intervention technique were played to the subject during both run 1 and run 2, with a audio cassette player, volume remained constant for all subjects. Instructions were taped, lasted 10 mins, and comprised section B of the audio cassette given to them on completion of visit 2.

On visit 4 the intervention group was asked to use the intervention technique learned using all or part of the cassette instructions, but without the external assistance of the audio cassette.

3.6 Calibration

3.6.1 Height

The stadiometer was calibrated using a height stick set to 1 metre before each subject.

3.6.2 Body mass

Scales were calibrated prior to the study, using electronically measured weights.

3.6.3 Skinfold callipers

Harpendon callipers were checked using a micrometer and standard calculation techniques.

3.6.4 Metabolic cart (Sensor medic 2900)

The metabolic cart was calibrated according to makers specifications before and after each test. Flow probe calibration was achieved using a 3 litre syringe (Sensor medic) at varying flow rates. Instructions require 4 manoeuvres to set the flow probe, followed by 4 verification manoeuvres. Expired gas analysis was calibrated using unchanged reference gas tanks (Sensor medic). A two point calibration was achieved using tanks containing 16% O_2, 4% CO_2, balance nitrogen, and 26% O_2, balance nitrogen.

3.6.5 Powerjog EG30

Prior to and after all testing, treadmill angle was calibrated using an inclinometer in both y (running in line with treadmill belt) and z (running across the treadmill belt) planes. The treadmill was found to be at 0.3° in the y plane and 0.1° in the z plane. This was deemed to be an acceptable level of error, and remained consistent throughout testing.

Calibration of treadmill belt speed was attained in two steps. Preceding testing the treadmill belt speed was set at 5 speeds and calibrated against the placement of a Trumeter (Radcliffe, England) to count the number of meters travelled in 1 minute. Belt speed was also calibrated against the count of a line on the treadmill (belt length 3 metres). These two procedures were then repeated during pilot testing with six different subjects mounted on the treadmill on two different occasions. Results indicated that belt count and trumeter analysis provided identical values for treadmill speed, both gave values slightly lower than the treadmill display. All results are given by belt count analysis.

3.7 Measurements

Ventilation, respiratory frequency, tidal volume, oxygen consumption, carbon dioxide elimination, and ventilatory equivalent for oxygen were all analysed by the Sensormedic 2900 through a thermal flow probe and within a mixing chamber. Data were processed as 20 second intervals and the average of three points combined to form a minute sample. Data were analysed by taking the mean of the last 2 minutes of expired gas (Morgan *et al.*, 1989a; Benson *et al.*, 1978; Armstrong and Costill, 1985).

Heart rate recording (PE 3000) was set at 5 second intervals, and heart rate was taken as the mean of the last two minutes.

During the 2nd minute of each run the treadmill speed was calculated using belt count. From minute 8 to 9 stride frequency was counted (Schieb, 1986).

Psychological measurements were calculated using appropriate manuals where provided. Scores were recorded for each run separately. Open ended question on the thoughts of the subject during the run were analysed by two independent reviewers for associational and dissociational attentional focus characteristics.

Training diaries were kept by each subject throughout the testing period. Subjective analysis of changes in training during the study were observed.

The first 2 visits consisted of baseline results for all subjects. The final two visits allowed comparison of the changes that occur in control and intervention groups and comparison of baseline against intervention for the intervention group.

3.8 Statistical analysis

Anthropometric data was analysed for group differences using two sample t-tests.

Analysis of the changes across visits for each variable was obtained:

Physiological measured variables; Ventilation ($\dot{V}_E$), respiratory frequency (RR), tidal volume ($\dot{V}_T$), oxygen consumption ($\dot{V}_{O_2}$), carbon dioxide elimination ($\dot{V}_{CO_2}$), respiratory exchange ratio (RER), and ventilatory equivalent ($\dot{V}EO_2$). Results for Oxygen consumption are reported in $ml.kg^{-1}.min^{-1}$ and $ml.kg^{-1}.km^{-1}$ (Daniels and Daniels, 1992).

Psychological measured variables; Rating of perceived exertion (RPE), Body tension index (BTI), Mood (ISP), Anxiety (STAI), and attentional focus (Open ended question).

Analysis of the main study data was split into two sections.

The first analysis questioned if the profiles of the two groups had changed over the four visits. The profile of the physiological variables contains the raw data from each subject at each visit and observes how the raw data may change from visit to visit. A repeated measures analysis of variance, with 1 between group factor (treatment) and 1 repeated measures factor (visits) was modelled. The interaction of group and visits was the area of interest.

Regression analysis of visit x against visit y of both groups, and general linear models of separate groups regression analysis were conducted where significance was observed in the repeated measures ANOVA, in order to locate any change found between the group profiles.

The plots of variable visit 2 against 1, 3 against 2, and 4 against 3, were executed with the line of identity plotted in order to locate trends in changes over visits.

Analysis of data to display stability in measured physiological variables was executed. Plots of all variables across time and analysis of variance over the mean of last 3 mins (Morgan, 1994a) and regression analysis over the last 5 mins were performed. Null hypothesis maintains that no change occurs in variables over final period of the 10 min run (i.e. stability).

4 Results

4.1 Anthropometric data

95% confidence intervals are given on the differences between control and intervention groups in anthropometric variables are shown in table 2. The only significant difference was for age, with the control group, on average 0.8 to 7.6 years older than the intervention group.

Table 2. 95% confidence intervals of difference between control and intervention for anthropometric variables.

Anthropometric Variable	Difference between Intervention and Control groups; 95% Confidence intervals
Height (cm)	-6.7, 3.1
Body mass (kg)	-6.1, 5.8
Sum of four skinfolds (mm)	-5.0, 5.1
Age (years)	0.8, 7.6*

* significant difference; $p < 0.05$;

($t = 2.58$, $p = 0.016$)

4.2 Stability analysis (see also appendix 6)

In order to assess the stability of the physiological measures over the exercise period (Morgan, 1994), one way analysis of variance on the changes between the last 3 mins of the 10 min run (i.e. min 8 - min 9, 8 - 10, 9 - 10) was obtained on all variables for each run, and for each group. The only significant differences were found for the control group for the following variables;

visit 2, run 1, VE/VO_2;

visit 4, run 1, VCO_2;

visit 1, run 2, VT, VCO_2;

visit 4, run 2, VO_2, VCO_2;

and in the intervention group for the following variables;

visit 4, run 1, VEO_2.

These data indicate that the majority of physiological variables do not differ significantly over the last 3 mins, suggesting stability in this period for the physiological variables measured.

Regression analysis was also completed on the last 5 mins (min 5-6 to min 9-10) of data for each subject, for each variable, for each visit, and for each run. The last 5 mins were chosen to give enough data points to allow analysis. Lake and Cavanagh (1996) averaged physiological measurements over the last 6 mins of a 10 min run. Investigation comprised testing if the gradient of the regression fit was significantly different to zero. The null hypothesis is that the gradient of the regression equation is equal to zero and therefore the data points over the last 5 mins lie on a stable line. It is felt that plots of these data (see appendix 4) are important to visually assess stability, and changes across visits.

A number of variables were found to have significantly different gradients from zero. This may indicate that certain variables were not achieving stability, or that the power of the testing leads to type I errors. Closer analysis suggests that the actual quantity of the gradient may be considered physiologically negligible in most cases. For example a representative regression equation for Ve [visit 2] = 86.1 + 0.7 min, indicates that the change in ventilation per min, over the last 5 minutes is only 0.7l.

4.3 Graphical indications

4.3.1 Stability

Plots of the last 5 mins of data for each run, each variable, and each subject (see appendix 4) indicate that generally, stability has occurred over the last 5 mins of the 10 min exercise period. Values of RER in some subjects are higher than 1.00.

4.4 General impression of data

Oxygen consumptions for the given paces concur with ACSM guidelines (1991) for level treadmill running. Variability in the measurements of oxygen consumption from visit 1 to visit 2 (r = 0.94) are in agreement with previous research on day to day variability by Morgan (1994b) and Lake and Cavanagh (1996), with correlations approaching 0.95. These correlations indicate that no "learning effect" has altered results.

Table 2. Mean of the last 2 mins data $\pm$ standard deviation (s.d.) of all variables for run 1, both intervention and control groups.

Group	**Intervention**				**Control**			
Variable	**Mean $\pm$ s.d.**				**Mean $\pm$ s.d.**			
Visit	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Speed (ms^{-1})	13.6 $\pm$ 1.8	13.7 $\pm$ 1.8	13.7 $\pm$ 1.8	13.7 $\pm$ 1.8	12.9 $\pm$ 1.7	12.9 $\pm$ 1.6	12.9 $\pm$ 1.6	12.9 $\pm$ 1.6
HR ($b.min^{-1}$)	170 $\pm$ 16	168 $\pm$ 13	163 $\pm$ 15	164 $\pm$ 15	169 $\pm$ 19	167 $\pm$ 18	166 $\pm$ 17	163 $\pm$ 18
Ve ($l.min^{-1}$)	86.0 $\pm$ 16.7	89.5 $\pm$ 14.6	81.9 $\pm$ 16.8	82.4 $\pm$ 15.6	88.3 $\pm$ 15.6	85.0 $\pm$ 12.3	86.0 $\pm$ 14.5	90.8 $\pm$ 15.3
f ($brth.min^{-1}$)	39 $\pm$ 7	40 $\pm$ 7	35 $\pm$ 9	37 $\pm$ 8	38 $\pm$ 5	38 $\pm$ 4	38 $\pm$ 5	40 $\pm$ 6
VT ($l.min^{-1}$)	2.23 $\pm$ 0.35	2.31 $\pm$ 0.42	2.38 $\pm$ 0.50	2.29 $\pm$ 0.38	2.30 $\pm$ 0.38	2.27 $\pm$ 0.33	2.28 $\pm$ 0.41	2.29 $\pm$ 0.44
VO_2 ($ml.kg^{-1}.min^{-1}$)	49.62 $\pm$ 6.60	51.55 $\pm$ 6.74	49.65 $\pm$ 7.06	49.68 $\pm$ 5.57	48.41 $\pm$ 5.01	46.01 $\pm$ 5.46	47.23 $\pm$ 5.73	47.82 $\pm$ 4.55
VCO_2 ($ml.min^{-1}$)	3245 $\pm$ 620	3314 $\pm$ 491	3154 $\pm$ 584	3116 $\pm$ 538	3187 $\pm$ 657	3041 $\pm$ 583	3067 $\pm$ 629	3151 $\pm$ 655
RER	0.98 $\pm$ 0.06	0.98 $\pm$ 0.02	0.97 $\pm$ 0.03	0.96 $\pm$ 0.04	0.97 $\pm$ 0.07	0.97 $\pm$ 0.05	0.96 $\pm$ 0.05	0.98 $\pm$ 0.07
VEO_2	26 $\pm$ 3	27 $\pm$ 3	25 $\pm$ 3	25 $\pm$ 3	28 $\pm$ 4	28 $\pm$ 3	27 $\pm$ 3	28 $\pm$ 4
Strides (min^{-1})	169 $\pm$ 8	168 $\pm$ 8	168 $\pm$ 7	167 $\pm$ 7	166 $\pm$ 10	163 $\pm$ 8	161 $\pm$ 8	163 $\pm$ 8
RPE	12.2 $\pm$ 1.4	11.5 $\pm$ 1.9	11.7 $\pm$ 1.7	11.3 $\pm$ 1.2	12.7 $\pm$ 1.7	12.0 $\pm$ 1.6	11.8 $\pm$ 1.3	12.1 $\pm$ 1.7
BTI	-2.3 $\pm$ 6.7	-3.5 $\pm$ 6.0	-5.2 $\pm$ 6.4	-5.5 $\pm$ 6.9	-2.5 $\pm$ 4.9	-4.8 $\pm$ 5.4	-5.6 $\pm$ 6.8	-5.1 $\pm$ 5.5
ISP	4.6 $\pm$ 1.7	3.5 $\pm$ 4.0	4.1 $\pm$ 3.9	2.4 $\pm$ 2.3	4.3 $\pm$ 2.0	2.8 $\pm$ 1.2	3.3 $\pm$ 2.9	3.8 $\pm$ 3.0
STAI	32.6 $\pm$ 6.9	31.2 $\pm$ 11.1	33.3 $\pm$ 13.7	30.7 $\pm$ 12.6	32.2 $\pm$ 6.0	31.9 $\pm$ 7.3	32.7 $\pm$ 10.3	32.1 $\pm$ 9.3

Table 3. Mean of the last 2 mins data ± standard deviation (s.d.) of all variables for run 2, both intervention and control groups.

Group	Intervention				Control			
Variable	Mean ± s.d.				Mean ± s.d.			
Visit	1	2	3	4	1	2	3	4
Speed (ms^{-1})	14.7 ± 2.0	14.9 ± 2.0	14.9 ± 2.1	14.9 ± 2.0	13.9 ± 1.9	13.9 ± 1.8	13.9 ± 1.7	14.0 ± 1.8
HR ($b.min^{-1}$)	180 ± 13	176 ± 15	174 ± 13	173 ± 13	178 ± 19	176 ± 16	177 ± 16	173 ± 16
Ve ($l.min^{-1}$)	102.1 ± 20.5	99.9 ± 17.6	96.7 ± 19.0	98.2 ± 17.9	103.7 ± 20.9	101.5 ± 17.6	103.1 ± 18.7	107.9 ± 21.3
f ($brth.min^{-1}$)	43 ± 7	41 ± 6	39 ± 7	40 ± 7	43 ± 7	43 ± 6	42 ± 6	44 ± 6
VT ($l.min^{-1}$)	2.40 ± 0.41	2.46 ± 0.52	2.47 ± 0.40	2.46 ± 0.35	2.42 ± 0.41	2.40 ± 0.43	2.47 ± 0.47	2.45 ± 0.49
VO_2 ($ml.kg^{-1}.min^{-1}$)	55.02 ± 8.25	53.63 ± 8.84	54.46 ± 8.06	54.46 ± 6.87	52.41 ± 6.18	50.96 ± 7.03	51.73 ± 6.57	52.81 ± 5.53
VCO_2 ($ml.min^{-1}$)	3670 ± 771	3676 ± 673	3558 ± 751	3513 ± 690	3527 ± 757	3468 ± 753	3491 ± 749	3590 ± 820
RER	1.01 ± 0.05	1.00 ± 0.04	0.99 ± 0.05	0.99 ± 0.05	1.00 ± 0.07	1.00 ± 0.06	1.00 ± 0.07	1.01 ± 0.08
VEO_2	28 ± 3	28 ± 2	27 ± 2	27 ± 4	28 ± 5	30 ± 5	30 ± 4	31 ± 5
Strides (min^{-1})	172 ± 10	172 ± 10	172 ± 9	170 ± 8	166 ± 9	165 ± 9	165 ± 8	165 ± 8
RPE	13.5 ± 2.1	13.8 ± 1.8	13.4 ± 1.3	12.5 ± 1.5	14.3 ± 1.9	13.6 ± 1.5	13.7 ± 1.5	13.6 ± 2.1
BTI	-0.8 ± 6.4	-2.5 ± 7.0	-3.8 ± 6.8	-4.1 ± 7.1	-0.7 ± 5.4	-3.6 ± 6.3	-4.7 ± 7.4	-4.4 ± 6.4
ISP	4.5 ± 2.4	3.9 ± 2.3	4.3 ± 4.9	2.9 ± 2.3	4.5 ± 2.7	3.4 ± 1.4	4.3 ± 2.8	4.6 ± 3.6
STAI	33.6 ± 6.7	31.9 ± 8.8	35.6 ± 14.3	31.3 ± 12.3	31.9 ± 7.3	31.8 ± 7.5	32.9 ± 9.2	33.6 ± 12.3

As can be seen from tables 2 and 3, the changes in the physiological and psychological variables, in both run 1 and run 2, from visit 1 through to visit 4 are negligible. These data initially indicate that no change has occurred due to the intervention. Further investigation indicates non-significant trends associated with the implementation of the intervention. Across the four visits (run 1) mean heart rate, and ventilation show a downward trend in the intervention group. In run 2, mean heart rate still shows a downward trend across visits.

4.5 Graphical presentation

Plots of each variable in the format of; Visit 2 against Visit 1; Visit 3 against Visit 2; and Visit 4 against Visit 3 (Representative figures 3 to 6), allow comparisons among these visits to be made for particular groups.

There are no significant changes at any visit point, although some trends are indicated. In run 1 ventilation from visit 2 to visit 3 does suggest that the majority of the intervention group (10 of 14) required less minute ventilation on visit 3 when compared to visit 2. VO_2 also indicates the same trend at the same visit point and run. 11 of the 14 intervention group subjects consumed less oxygen on visit 3 than visit 2. These results are not significant but the trends are suggestive of change across visits. The fairly even spread of visit 4 on visit 3 (figures 3 to 6) around the y = x line, indicates that the trend from visit 2 to visit 3 is continued into the 2nd intervention period (Visit 4), i.e. values are stable between visits 3 and 4, therefore the movement in the variables, from visit 2 to visit 3, is maintained through to visit 4.

The faster, run 2, show no trends across visits in any physiological variable.

Figure 5. Plots of Ventilation ($l.min^{-1}$) against ventilation ($l.min^{-1}$), visit against visit, noting line of equality - Run 1.

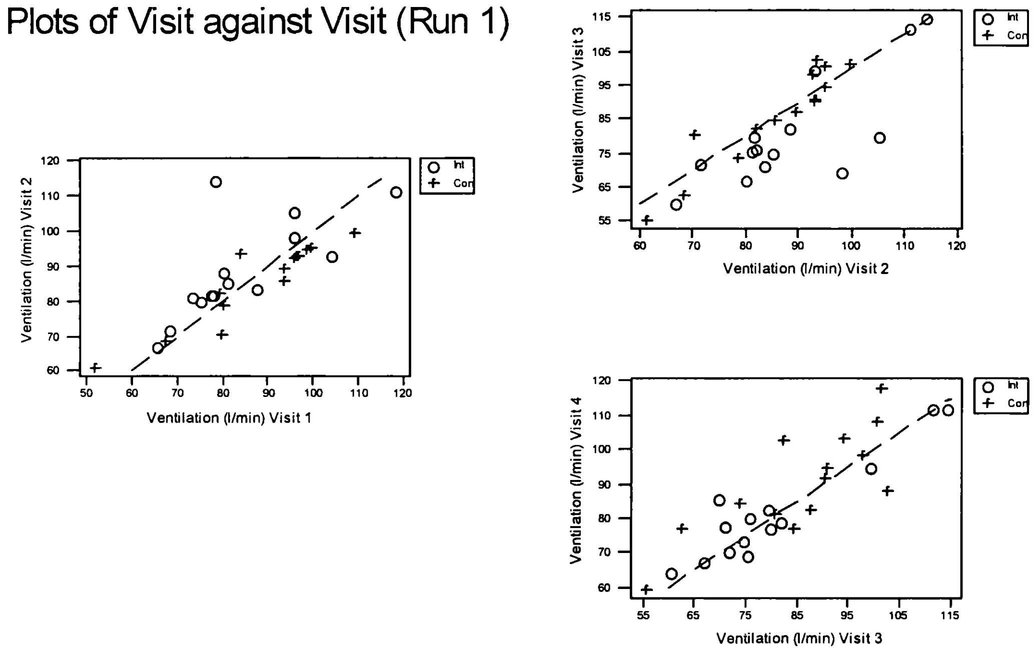


Figure 6. Oxygen consumption ($ml.kg^{-1}.min^{-1}$) against oxygen consumption ($ml.kg^{-1}.min^{-1}$), visit against visit, noting line of equality - Run 1

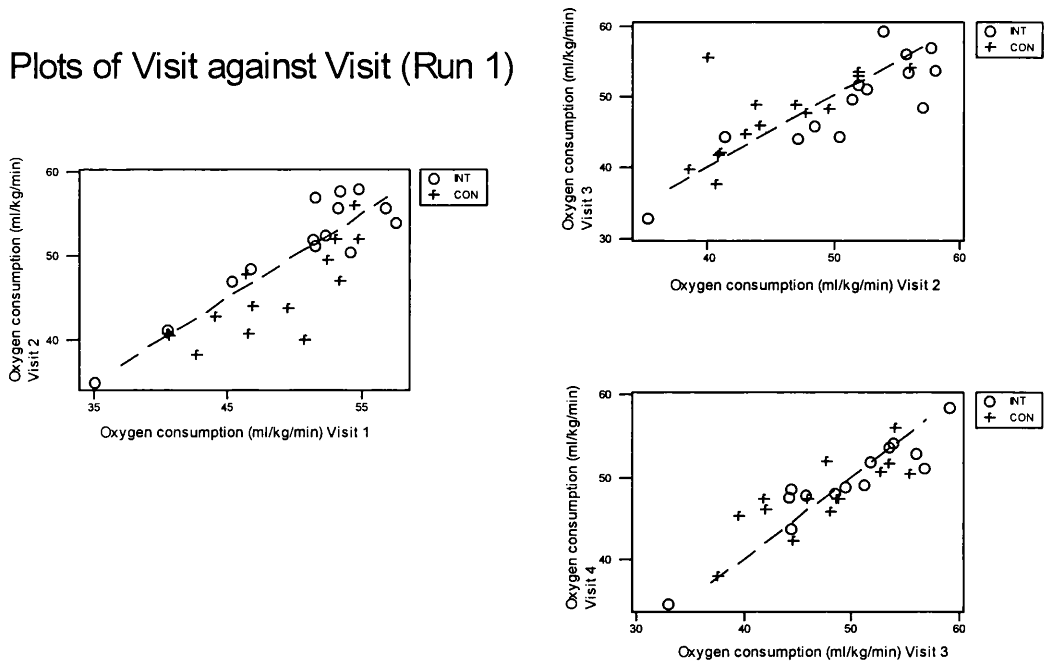


Figure 7. Ventilation ($l.min^{-1}$) against ventilation ($l.min^{-1}$), visit against visit, noting line of equality - Run 2

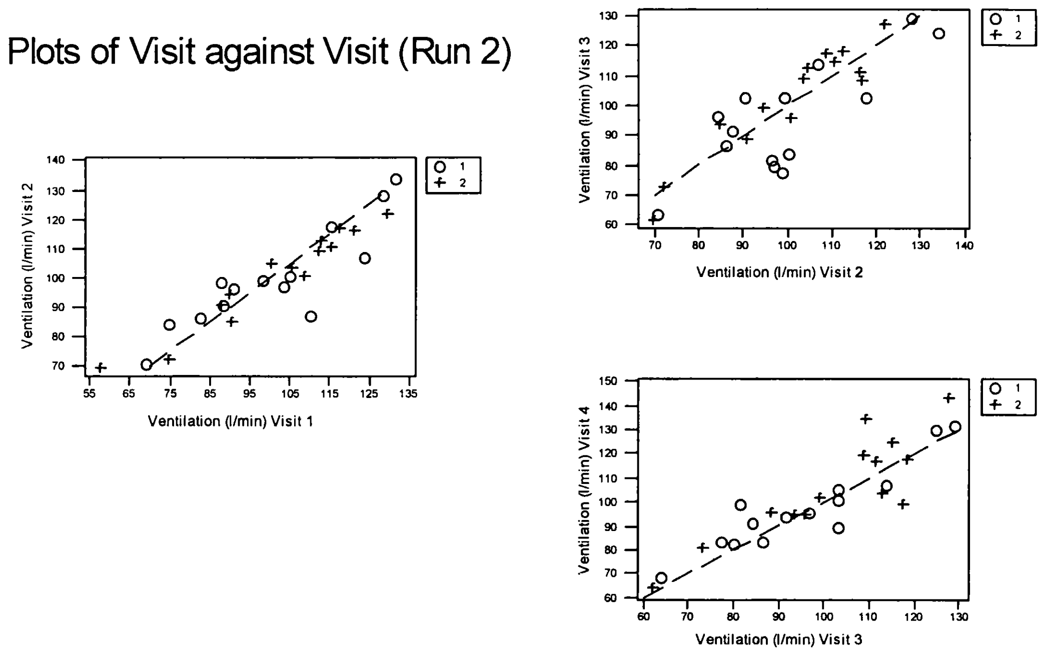
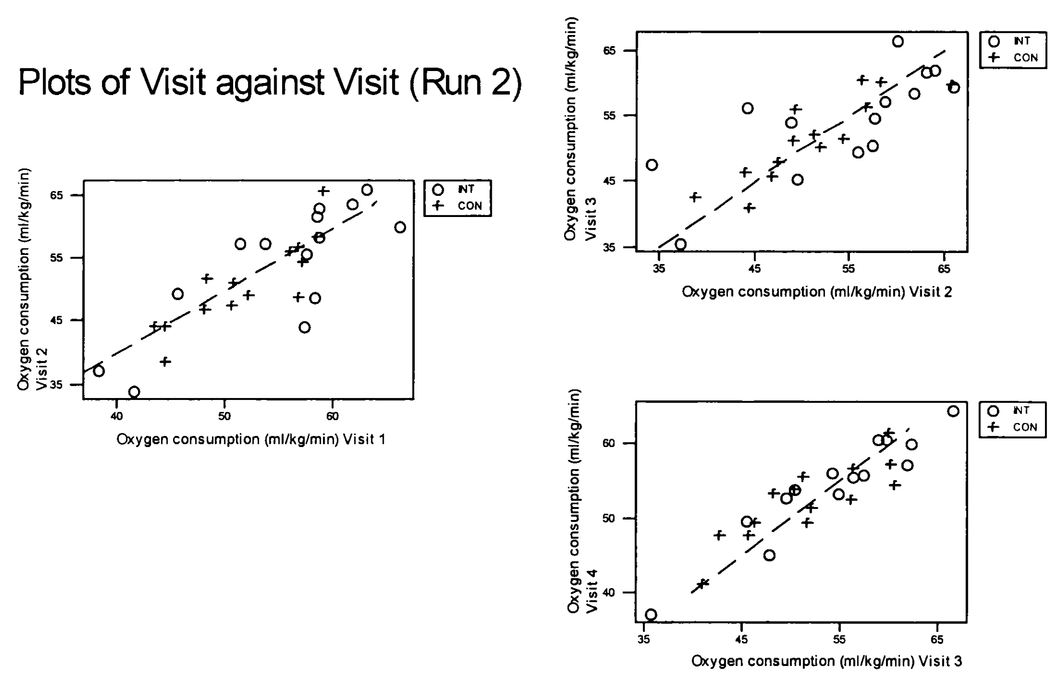
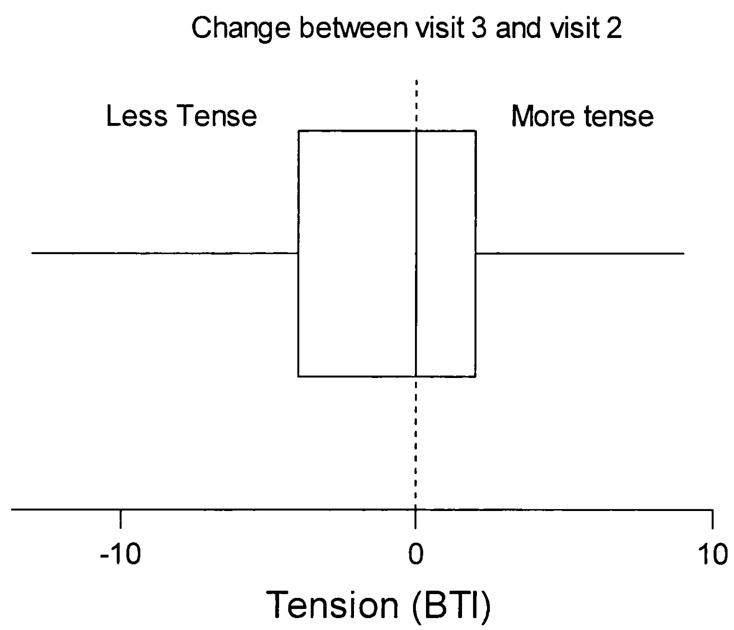


Figure 8. Oxygen consumption ($ml.kg^{-1}.min^{-1}$) against oxygen consumption ($ml.kg^{-1}.min^{-1}$), visit against visit, noting line of equality - Run 2



Figures 9 and 10, below, show the trends in the changes of the intervention group, in heart rate and body tension variables, between visits 2 and 3 (Intervention stage) in an alternative form. Indications are that HR and tension may be reduced slightly in both run 1 (training pace) and run 2 (race pace) and Ventilation reduced in run 1. As stated earlier reductions are non-significant.

Figure 9. Boxplots of changes in variables from visit 3 to visit 2 in run 1 for tension as measured by BTI and Heart rate.



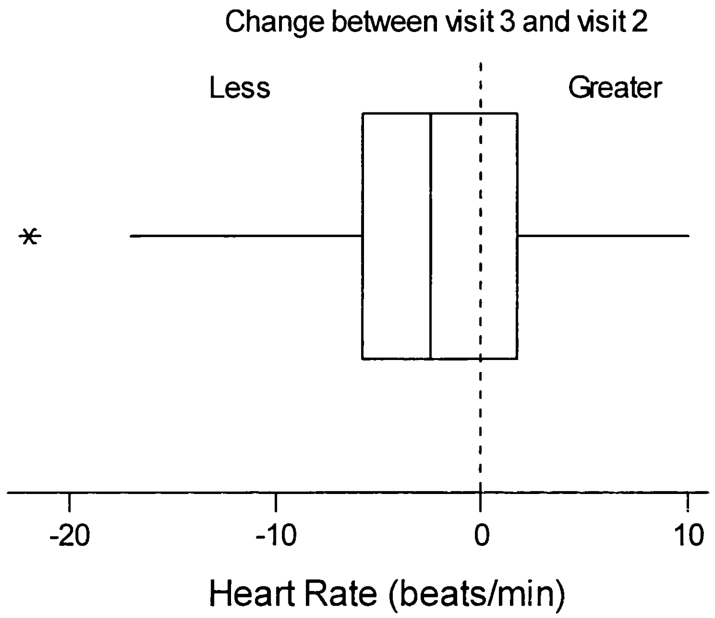
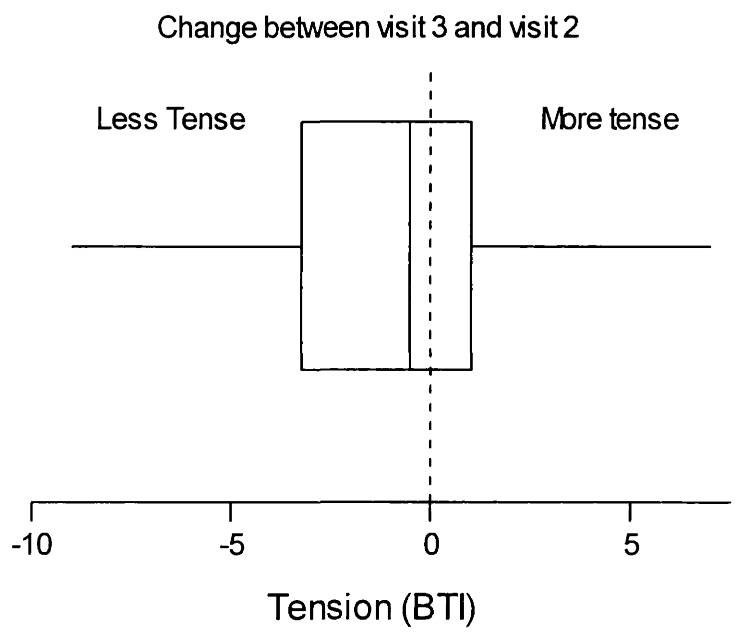
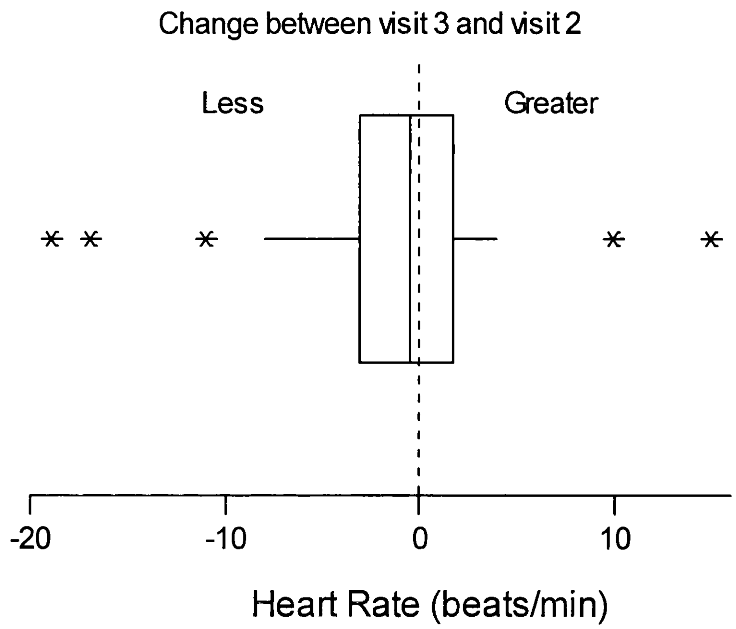

Change between visit 3 and visit 2
Less
Greater
-20
-10
0
10
Heart Rate (beats/min)

Figure 10. Boxplots of changes in variables from visit 3 to visit 2 in run 2 for tension as measured by BTI and Heart rate.





4.6 Statistical analysis

Analysis of the interaction between group and visit displayed that only one physiological variable (VO_2 - $ml.kg^{-1}.km^{-1}$) significantly changed due to the effect of the intervention over the visits. The null hypothesis, that the relaxation technique does not alter physiological variables associated with the cost of running, could not be rejected, there being no significant difference for any physiological variable.

4.6.1 Analysis of VO_2 ($ml.kg^{-1}.km^{-1}$)

The profile of VO_2 as measured in $ml.kg^{-1}.km^{-1}$ was found to be significantly different at the group by visit interaction ($F = 4.12$, $p < 0.05$). The data were subsequently analysed by comparing the regression of all data for visit 2 on visit 1, visit 3 on visit 2, and visit 4 on visit 3, against a general linear model of individual groups. The location of the change was detected at the visit 2 on visit 1 stage, indicating that the change discovered in this variable occurred between visit 1 and visit 2 in the intervention group. This analysis does not indicate that the intervention stage, (visit 3 on visit 2) is associated with any change in VO_2 as measured in $ml.kg^{-1}.km^{-1}$.

4.7 Psychological variables

4.7.1 General impression of data

General findings of the psychological data from tables 2 and 3, are that no significant change was found in the psychological variables measured. Trends indicate that changes in tension, as measured by the mean BTI, occurred across the four visits in the intervention group (see figures 7 and 8). These trends are non significant.

4.7.2 Statistical analysis

Analysis of the psychological variables demonstrated no significant interactions between group and visit. This also indicates that there is no evidence to reject the null hypothesis that the relaxation technique does not influence changes in the psychological variables associated with running performance.

4.8 Associations between Physiological and Psychological variables

Analysis of Pearson's correlation coefficient between physiological and psychological variables for each visit, and each run, displays very little evidence associating any variable with another.

Appropriate significant correlations linking physiological and psychological variables are given in table 4. Variables are chosen to indicate the wide variation in correlation, but the lack of consistant associations.

Table 4. Correlations of associations between physiological and psychological variables measured.

Intervention Group	**Control Group**
Visit 2, Run 1	**Visit 3, Run 1**
HR-RPE; r = -0.534	HR-RPE; r = 0.555
	HR-STAI; r = 0.547
	VE-ISP; r = -0.586
Visit 2, Run 2	
VE-RPE; r = 0.518	**Visit 4, Run 1**
	HR-RPE; r = 0.690
Visit 3, Run 2	HR-ISP; r = 0.633
VE-RPE; r = 0.574	HR-STAI; r =0.663
	Visit 1, Run 2
	HR-RPE; r = 0.793
	HR-ISP; r = 0.733
	VE-RPE; r = 0.559
	Visit 2, Run 2
	HR-ISP; r = 0.621

All correlations significant to $p < 0.05$ level.

4.9 Open ended question-Attentional focus

Two separate reviewers analysed the responses to the open ended question regarding thoughts during the run. Analysis comprised categorisation of thoughts into associative, dissociative, both, or none.

4.9.1 Reviewer comparison

Intra-reviewer correlations coefficients of attentional focus statements for run 1 and run 2 were 0.71 and 0.72 respectively. These correlation coefficients show that the two reviewers are identifying the same factors in the responses given to the open ended question.

4.9.2 Findings

No link was found between the thoughts during the run and any physiological or psychological variable under any categorisation of subject grouping.

5 Discussion

5.1 Stability

The importance of stable physiological measures in the interpretation of results of running economy is paramount. To enable analysis of representative physiological variables during running at a constant speed, the variables must be stable over time.

The question of the existence of "steady state" is still unresolved. It may be considered that a situation of exercise stress causes constant flux in the physiological systems. What must be considered important in this study is the element of stability toward the end of the 10 min run. Analysis of change in physiological variables associated with the cost of running, must ensure that the measured variables are of a stable nature on each visit the subject makes to the laboratory, in order to assess representative measures.

The results of the present study are in line with the general principles of exercise physiology describing physiological systems as able to reach stability over a 3 min period of exercise of moderate intensity, but dependent of various factors

(Åstrand and Rodahl, 1986). The results also concur with the steady state definition from Lake and Cavanagh (1996) who described an increase of less than 10 beats.min^{-1} during the last 6 mins of a 10 min run as being indicative of steady state.

5.1 1 RER

A query remains over the data from the present study. The RER values of a number of subjects are above 1.0, although still stable. Physiologically this would suggest that exhalation of excess CO_2 is occurring. This may be due to the production of lactic acid and an increased anaerobic metabolism. But the results show that these RER's are stable over the last few minutes of exercise. The mean results of run 1 are very similar to other research in this field. Lake and Cavanagh (1996) displayed values of 0.95 + 0.04 in there 15 male subjects, but did not discuss the consequences of subjects with RER's above 1.0.

Normal physiological measurements associated with increased production of lactic acid are, increased ventilation, increased VE/VO_2, and increased $\dot{V}CO_2$. Graphical results are shown in appendix 4, none of these variables climb over the last five minutes of the 10 min runs. RER itself is also stable over this period. The present results regarding the high RER suggest that there may be an affect of a pH driven hyperventilation in the higher intensity work, where stability of $\dot{V}_{O_2}$ and $\dot{V}_E$ may exist and the RER can remain in relative stability, or a transitory steady state (Jennet, personal communication), above a value of 1.0. No previous research has indicated this occurrence.

The results provide a paradox. Stability is shown in all variables, but high RER's indicate anaerobic/ non-stable conditions. The majority of previous studies (Morgan, 1989a; Daniels and Daniels, 1992) have attempted to keep all running economy measures within the constraints of RER's less than 1.0, indicating fully aerobic conditions and giving the aerobic energy cost of the run.

Morgan's and Daniels' work has proved invaluable to the exercise physiologist, but the information cannot be extrapolated to runners at "race pace" where anaerobic contributions do exist. The present study has attempted to address this area by testing subjects at two paces, a "race pace" and a pace ½ $min.mile^{-1}$ slower than "race pace" in fully aerobic conditions, to assess mainly aerobic and combined aerobic/ anaerobic conditions. The findings show that the psychological intervention does not affect these paces differently.

5.2 Main Study findings

The general findings of the study shows a non-changing situation over the four separate visits in both groups. The results of the present study show that none of the physiological variables measured during exercise are altered by the meditation technique, when used during the exercise period, after a one week learning period in this population.

Previous research has showed the effects of meditation in resting and exercising subjects on physiological variables (Benson, 1978; Ashley, 1995). The present results do not support these findings.

5.2.1 Why no differences?

The present study has shown no significant differences in running economy variables, at two paces. In contrast to previous work by Ashley *et* *al.*, and Benson, the present study used a control group and worked subjects at intensities appropriate to training and racing. The reproducibility of the test design and equipment was thoroughly checked (see appendix 2;B2), and subjects were fully familiarised with testing and equipment.

The present study compares to previous work in the number of subjects. Unfortunately subjects, although trained, were of a heterogeneous ability range causing data to be spread over a range of values.

Previous research by Ashley *et al.* indicated that a two week learning period was adequate to produce changes in running economy. The present study, due to differences in design, must question whether the psychological technique was appropriate, if it was adhered to, and if enough time was given for it to successfully impact. Some researchers suggest that extended periods of psychological skill development are required for subjects to gain benefit (Crews, 1992).

Further differences do exist between the previous research and the present work. The present study has negated the effect of self selection by randomly assigning subjects unfamiliar with meditation into a control and intervention group. Ashley *et al.* also failed to compare intervention subjects with a control group.

The present study differs from previous research (Wallace, 1970) by using the meditation technique ***during*** exercise of intensities applicable to runners in training, and during race situations. Benson's research (1978) concluded by theorising that an "emergency reaction" exists in the autonomic nervous system of humans. Benson suggested that the relaxation response decreases this reaction, thereby decreasing oxygen consumption. Benson's findings may be applicable in light workloads and inexperienced exercisers, but at higher intensities and with seasoned exercisers the results of the present study may suggest that no such "emergency reaction" is present. It may be that in this population arousal is already at an optimal state for this exercise test.

The general findings of the study show that the mindfulness of breathing meditation technique, does not influence physiological or psychological variables associated with running economy in this population, using this protocol.

5.3 Associations

No associations between any physiological and psychological measured variables show a continued trend over the four visits. These results are in contrast to research by Borg (1970) on RPE and Heart rate in middle age subjects, and in RPE and ventilation.

Several examples of associations between physiological and psychological variables are displayed in the results, but these correlations are not consistent throughout the test period or across runs, indicating that no constant association exists between the physiological and psychological variables measured within the studies constraints.

5.4 Attentional focus

Results showed that attentional focus, analysed through an open-ended question, did not associate with any physiological or psychological variable. Neither association nor dissociation showed any association with improved or better running economy. These results are in contrast to Morgan (1979), who linked an associative focus with elite performers (see introduction section 2.2.3.3).

Smith *et al.* (1995), who investigated if 12 of their least economical runners could improve running economy using a relaxation technique, also showed no changes in physiological or psychological variables to be associated with any of their 3 attentional strategies, control, passive associative, or active associative. These general findings are very similar to the present study. Differences in design again influence the comparison. Smith *et al.* used paces inapplicable to competitive runners, and only initiated the psychological technique twenty minutes prior to testing, although they did attempt to implement them during the running period.

5.5 Trends in the data

Within the results it is appropriate to examine non-significant trends.

5.5.1 Group trends

Trends of mean data for all subjects within the groups were observed in a number of physiological variables. The intervention period (Post visit 2) indicates changes from baseline data (Visits 1 and

2) in ventilation, heart rate, and tension, all decreasing. These findings are in agreement with work on ventilatory and cardiac cost changes in meditation by Aaron *et al.* (1992) who calculated the cost of increased ventilation and heart rate during simulated exercise.

5.5.2 Individual subjects

Although group data have not shown a significant intervention effect, some individual results are encouraging of the intervention techniques. The magnitude of the trends for certain individuals are considerable. In run 1, from visit 2 (control period) to visit 3 (intervention period) oxygen consumptions have changed from approximately 51 $ml.kg^{-1}.min^{-1}$ to 44 $ml.kg^{-1}.min^{-1}$, and from 57 $ml.kg^{-1}.min^{-1}$ to 48 $ml.kg^{-1}.min^{-1}$ in two separate individuals. These data are outwith previously measured variation (Morgan, 1994) due to day to day biological and non biological variation. This would suggest that observed individual changes are due to an external factor(s).

Tanaka *et al.* (1984) calculated the effects of reduced oxygen consumption on 10Km performance and stated that, in their population, a reduction of 2

$ml.kg^{-1}.min^{-1}$ could translate into a 34 second reduction in 10 km time.

The results of the present study lead to the suggestion that the meditation technique may be particularly individualistic in nature. General comments instigated by individuals after testing support this speculation.

5.6 Problems and future research

Problems with past and present research may exist. A brief summary of subject effects is given below.

1. Subjects did not adhere to instructions.

   It is possible that subjects did not adhere either to the psychological technique during the testing, or to the instructions on learning the technique.

2. Subjects found it difficult to create relaxation, possibly due to apparatus.

   It is also possible that subjects may have found it difficult to accomplish a fully relaxed state due to mouthpeice and tubing. It should be noted that two control visits were completed and subjects were familiar with apparatus and treadmill running.

3.A tension/ anxiety floor effect occurred.

Subjects may not have been as anxious or aroused regarding the testing as they would have about a competitive situation.

STAI scores of the present study confirm the possibility of low initial anxiety levels. Previous work with this tool shows that the present scores are comparatively low, indicating initial low anxiety levels. Spielberger (1983) located norms for college students of 38 ± 11 (mean ± s.d.). The present results show anxiety levels ranging from 30 to 33 measured on the STAI form Y-1. It may also be possible that the ISP scores are also low but no comparisons with previous research are available. BTI comparisons are also difficult to achieve. Ashley *et al.* (1995) showed BTI scores of 0.2 ± 1 pre test, and -7.5 ± 1.1 post intervention (mean ± s.e.). In contrast the present results show a baseline tension score lower than Ashley's results, with a wider deviation.

Refinement of population groups is an area of plausible future research. Testing of both elite athletes and recreational runners should be undertaken, as both groups may benefit for different reasons. Elite athletes may gain through improved performance and recreational runners by enjoying exercise through less tension and a decreased perceived exertion. Research should look to focus on control groups. Attention placebo control groups should be available for comparison to an intervention group involving a possible attentional effect. This should enable future research to distinguish any effects of psychological interventions between anxiety/ tension and attentional differences.

5.6.1 Stability

Analysis of RER stability warrants investigation in future running economy research. The present study has indicated an area where temporary stability in RER occurs above the value of 1.0. At present this has not been investigated by exercise physiology researchers. Investigations into the length of this temporary stability and the individualistic nature of RER may be beneficial to future work on running economy and slow component.

5.6.2 Running economy

The need for research into running economy at "race pace" is paramount. The requirement from athletes and coaches, is that scientists achieve a constant, and confident measure of the anaerobic cost of a run, in order for full analysis to take place. Present research into anaerobic oxygen deficit may help clarify (Medbø, 1988).

5.6.3 Meditation

Clear definition of the effect of a meditative technique must be made. The effect must be categorised into either a coping strategy (arousal reduction), or a mental strategy (attentional focus), and if the technique is dissociative or associative.

5.7 Conclusion

The present study does not provide any evidence to reject the null hypothesis. Therefore it cannot be argued that the mindfulness of breathing meditation technique alters any of the measured physiological or psychological variables, in this population, and at these paces.

As a by product, the results themselves provide very good support for the validity and reliability of the Sensor Medic 2900 over time. This is suggested by the consistency of measured variables over the four visit period, even with the addition of an external factor (intervention) for one set of subjects.

Information extracted from the present study suggests that the effect of the mindfulness of breathing meditation technique may be extremely individual in nature. Research by Telles *et al.* (1993) on meditation, suggested that physiological variables alter in an individualistic nature. Telles' research showed both activation and relaxation due to meditation. Hence he stated that a single model of meditation producing either overall relaxation or activation is inadequate. Therefore if used correctly meditation may enable each subject to optimise his/ her own ANS arousal response to a stress. This can be regarded as an "individual situation specific response".

The results do not discount that the autonomic control of physiological systems is in anyway unchangeable, but the individual changes seen cannot be ascribed to the intervention technique as they do not translate into group effect changes.

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7. Appendices

Appendix 1. ACSM guidelines for exercise testing

Appendix 2.

B. Pilot studies

B.1 Psychological parameters

B.1.1 Body Tension Index (BTI)

B1.2 Incredibly Short Profile of mood states. (ISP)

B1.3 Training diaries

B1.4 Meditation tape/ Instructions

B2. Physiological parameters

B2.1 Reproducibility of Running Economy

B2.2 Validity of Sensor Medic 2900

Appendix 3. Meditation script

Appendix 4. Meditation instruction sheet

Appendix 5. Questionnaire sheet

RPE, BTI, ISP, STAI, Open-ended

Appendix 6. Representative graphical display

Appendix 7. Information sheet

Appendix 8. Test protocol

Appendix 1

ACSM's Guidelines for exercise testing and prescription.

Fifth edition (1995).

Pretest instructions

- Wear comfortable, loose fitting clothing
- Drink plenty of fluids over the 24-hour period preceding the test
- Avoid, tobacco, alcohol, and caffeine for 3 hours prior to taking the test
- Avoid exercise or strenuous physical activity the day of the test
- Get an adequate amount of sleep (6-8 hours) the night before the test.

Appendix 2.

B. Pilot studies

B.1 Psychological parameters

B.1.1 Body Tension Index (BTI)

B.1.1.1 Introduction

The Body Tension Index (BTI) is a relatively new self report questionnaire developed through the adaptation of the Tension mannequin (Webster *et al.*, 1984) by Ashley *et al.* (1995). The index comprises eight parts: Seven parts represent muscle groups (see figure B1.1) and the eighth is used for a general assessment of the whole body. Each part is scored on a five point Likert scale from 1 "Very relaxed" to 5 "Very tense". The scores are then normalised, so that an individual component of 3 ("neither relaxed nor tense") equals zero, thus negative scores represent "relaxed" and positive scores "tense". Scores range from -16 to +16.

Little research has been undertaken on the BTI. Ashley *et al.* (1995) examined the relationship between the BTI as a measurement of subject body tension and the Hoffman reflex (h/m ratio) as a physiological measure of motor neurone pool excitability. The study found that the BTI showed significant correlations to the h/m ratio after a ten minute relaxation period ($r = .79$, $P < .001$). This study indicated the validity of the BTI against a physiological measure of relaxation.

As yet the BTI has not been rigorously studied as an acceptable questionnaire. No study has indicated if subject's view the questionnaire as able to indicate their level of tension appropriately. Exploration of the BTI in a non directly inducing relaxation situation; investigation into its reliability with experienced relaxers; and comparison of the measurement post relaxation with other psychological scales, has yet to be undertaken.

B2.1.1.2 Purpose

The purpose of this part of the study was split into four sections.

A. To investigate the viable, practical use of the BTI as a questionnaire.

B. To investigate the comparability of the BTI with the State-Trait Anxiety Inventory (STAI) (Speilberger, 1983) after a relaxation practice.

C. To investigate the possible range of measurement of the BTI, in non-directly relaxation inducing situations, namely, University Exercise sessions.

D. To investigate the reproducibility of the BTI in a group of expert relaxers.

B2.1.1.3 Methods

A. To investigate the viable, practical use, of the BTI as a questionnaire sixty nine subjects (mean age = 22.1 $\pm$ 3.1 years) studying or working at the University of Glasgow were asked to complete the BTI post exercise and then complete a simple 3 question sheet on the use of the BTI. The questions asked if: 1. The BTI was easy to understand and use? 2. The mannequin and circles were helpful? 3. The BTI allowed them to give a good indication of their level of tension? And 4. Any other comments? Again the questions were scored using a Likert scale Yes equal to 1 and No equal to 5.

B. A progressive muscular relaxation practice was initiated with 35 untrained subjects. Subjects were then asked to complete both the BTI questionnaire and Speilbergers STAI form Y-1 measuring state anxiety. Comparison of the two questionnaires in a relaxed state was undertaken to examine if the questionnaires were associated in their measurements.

C. Sixty nine subjects (mean age = 22.1 $\pm$ 3.1 years) involved in four different exercise activities completed the BTI questionnaire post exercise on one occasion. Activities were three types of the University of

Glasgow's, Sport and Recreation Service exercise sessions and other cardiovascular exercise (n = 2). The sessions include cardiovascular exercise to music (Pop-mo, n = 27), cardiovascular/ circuit based exercise (Tune-up, n = 25) and a Step class (n = 15).

D. To investigate the reproducibility of the BTI, 10 subjects (7 male, 3 female; mean age = 37.2 years $\pm$ 4.6 s.d) practised in meditation (mean practice duration = 2.4 years + 0.3) were asked to complete the BTI on two separate occasions after identical directed relaxation procedures, at the same time of day.

B2.1.1.4 Results

A. Of the sixty nine subjects, sixty seven completed question 1. The mean response was 2.2 $\pm$ 1.4 indicating that subjects found the questionnaire easy to understand and use. The 66 replies to question 2 indicated that the mannequin and circles were helpful (mean = 3.1 $\pm$ 1.5), although some comments stated that they were unnecessary as subjects new the position of the muscles. The 62 response to question 3 suggested that the questionnaire allowed individuals a good indication of their level of tension (mean = 2.7 $\pm$ 1.1).

Question	Response Yes =1 No = 5	
	Mean	**s.d**
1. Was the questionnaire easy to understand and use?	2.2	1.4
2. Did you find the mannequin and circles helpful?	3.1	1.5
3. Does the questionnaire allow you to give a good indication of your level of tension?	2.7	1.1

Analysis of variance of each question, showed that no differences exist due to the 4 activity types (Q1, $F = 1.13$, $p = .34$; Q2, $F = .18$, $p = .91$; Q3, $F = .17$, $p = .91$).

B. Correlations of STAI and BTI variables reveal that STAI is significantly associated with the total BTI score and the general overall rating (STAI-BTI total, $r = .498$; STAI-General, $r = .572$). No other individual variables appear associated with state anxiety as measured by STAI in this population.

Although correlations indicated an association between STAI and total BTI score, regression analysis showed that the STAI could only account for 25% of the variance in the total BTI score.

C. Results indicate that a range of scores are evident on use of the BTI. Although care must be taken with this interpretation as quartile scores are clustered closer together.

BTI total score	
Possible Range	-16 to +16
Mean	0.22
Standard deviation	4.92
Range	-12 to +9
Quartile 1 to Quartile 3	-3 to +4

One-Way Analysis of Variance on BTI total score across activity indicated no significant differences between the 4 activities ($F = .44$, $p = .722$)

D. Reproducibility in this population appeared very good. One sampled t-tests of paired data on all variables of the BTI showed only the shoulders and neck to be significantly different over the two trials. Importantly the total BTI score was not significantly different from trial 1 to trial 2 ($t = -.85$, $p = .42$). Correlations of all variables from visit 1 to visit 2 ranged from r =

.597 to .945, with the total BTI r = .899. Regression analysis of BTI trial 1 to BTI trial 2 signified that 81% of the variance in trial one can be explained by trial two, with the regression line of BTI-trial 1 against BTI-trial 2, not significantly different from the line of identity (y = x).

B2.1.1.5 Conclusions

A. Interpretation of subjective responses in questionnaires can be fraught with imponderabilities. By allocating a level of scoring to the questions some measure can be attained, even if individual interpretation cannot be accounted for. The above results appear to indicate that the BTI questionnaire is understandable, easy to use, and can allow the assessment of an individuals level of somatic tension. No previous validation of the accessibility of the BTI has been attempted, and the original developers (Webster *et al.*, 1984) maintained through there own use and logical assessment that the questionnaire was both understandable, quick, and easy to use. But these researchers did not question their respondents.

B. The indication from the above results, is that BTI and STAI do slightly overlap in their measurement parameters, but that the physiological sensation of tension may be a divergent, but not mutually exclusive, entity from psychological anxiety. Obviously anxiety has been found to be multi-modal containing aspects of somatic, cognitive and self-confidence within an individual. It may be that the BTI measures solely the somatic component of tension/ anxiety, and the STAI may mainly measure cognitive aspects, or overlap of both measurements may occur at various points on a continuum of an anxiety-tension paradigm.

C. The results of the sixty nine subjects who completed the BTI after conclusion of an exercise session demonstrate that individuals do report a wide range of somatic tensions. This is in contrast with previous work with the BTI in treadmill exercise (Ashley *et al.*, 1995) who displayed standard errors of 1 and 1.1, but in conjunction with both normal and tension prone populations (Webster *et al.*, 1984).

Interestingly the mean results show that subjects feel neither tense nor relaxed following the University exercise sessions. Further research could investigate the change in tension levels, measured by the BTI, prior to and post varying physical activities.

D. Indications from the results of the reproducibility work, are that the BTI is reproducible in a relaxation situation, with a population of experienced meditators. The results showed that no significant differences were found between the BTI total score from trial 1 to trial 2, and regression analysis indicated that a high proportion of the variance in BTI total score can be predicted by a previous BTI total score under the same conditions. The conclusion is that the BTI total score may be accurately used to measure BTI score within individuals.

B1.2 Incredibly Short Profile of mood states. (ISP)

B1.2.1 Introduction

Mood has remained one of the key facets of a psychological athletic assessment. The measurement of mood is questionnaire based. The Profile of Mood States (POMS) questionnaire (McNair *et al.*, 1971) is used very effectively as both an affective state, and trait measure depending on the situation in which it is applied. The POMS measures six identifiable mood or affective states: tension, depression, anger, vigour, fatigue and confusion, and a Total Mood Disturbance (TMD). It was originally developed for use with psychiatric patients, but has been found to be effective in measuring mood states of normal patients (McNair *et al.*, 1971). The application of POMS to athletes has offered some differing profiles from the observed "norm". Morgan (1974) uncovered a representative athletic profile. The "iceberg profile" has become a common research finding in successful athletes. The profile indicates Low tension, depression, anger, fatigue and confusion, and high vigour.

A major drawback with the POMS appears to be its consumption of time. The 65 adjective construct is known to require approximately ten to fifteen minutes to complete (McNair *et al.*, 1971) and more than 20 minutes in specific populations, such as hospital patients (Malouff *et al.*, 1985) or handicapped athletes (Mastro *et al.*, 1986). There is an obvious need for a concise POMS which could allow the collection of multiple assessments within brief time periods. The benefits of an abbreviated instrument must be weighed against the validity and reliability of such a measure. Shacham (1983) analysed a POMS assessment and found that 28 items could be removed without statistical change. Concurrent research has proved positive evidence of the reliability and validity of the shortened POMS. However, due to time constraints, the 37 item POMS does not allow for assessment of immediate mood.

In answer to the time consumption problem, research has gone further to reduce the number of subscales down to a bare minimum. Whelan *et al.* (Personal communication), have developed a six scale "Incredibly Short POMS" (ISP), from constructs in the original POMS. Reddon *et al.* (1985), suggested that although mood dimensions are internally consistent, they are probably not independent, and therefore they recommended the use of the total mood disturbance score rather than the individual mood scores. With this counsel, Whelan *et al.* have tested the ISP against POMS in two samples. The first, college students, and the second athletes subsequent to performance. Results have indicated strong correlations between ISP and POMS total mood disturbance ($r = .88$, $p < .001$), and that ISP accounts for a significant proportion of the variance (76%) in the POMS in this population, with no effect of age or sex. The evaluation of the ISP against POMS following exposure to a mood altering experience was also examined. Again correlations between ISP and POMS were good ($r = .69$, $p < .001$) and the ISP accounted for 47.% of the variance in the POMS.

The ISP intuitively offers greater practicability. The clear indication is that mood may alter rapidly, especially after an event. The suggestion must be that the ISP instrument may more accurately capture the emotional reaction, or transient responses (affect) to stress inducing episodes.

The current research is promising, but use of the ISP is limited, and its response to situation, or other environmental factors is under-researched.

B1.2.2 Purpose

The purpose of this section of the study was to investigate the response of the ISP in comparison to the POMS subsequent to three different activities.

B1.2.3 Methods

Twenty regular exercisers (11 male, 9 female, mean age 19.2 $\pm$ 2.8) participated in pilot work. Each subject performed three types of activity which were randomly assigned. 1. University exercise session-Popmo based on aerobic dance (at a heart rate of 150-160bpm), 2. University muscle conditioning programme, and 3. A "steam and sauna". After each activity subjects were asked to complete both the bipolar POMS and the ISP in randomly assigned order. Comparisons of total ISP score to a Total Mood Score (TMS) of the bi-polar POMS, and of each of the six individual factors within the two questionnaires was calculated.

B1.2.4 Results

Correlations of the Total mood score of the POMS (TMS) and ISP scores for each of the activities imply that the questionnaires scores are associated for the aerobic activity (Popmo, $r = -.587$, $p = .017$) and for the steam and sauna ($r = -.606$, $p = .01$), but not for the muscle conditioning work ($r = .154$, $p = .555$).

Regression analysis acknowledges that the ISP can only account for between 35 and 37% of the variability of the TMS estimates in Popmo, and the steam and sauna. Variability in the TMS value at any value of the ISP is in the order of 26 units. The slope of the regression equations also suggests the underestimation of TMS from ISP at any value.

B1.2.5 Conclusion

The results from the work on the ISP questionnaire appear to concur with correlational work by Whelan *et al.* The ISP does seem able to measure similar constructs as the POMS, but further analysis does reveal its problems in accounting for the variability in the POMS. The major advantage of the ISP is its directness and speed, this also manifests the ISP's problems. The six questions do not allow the questionnaire to tease out subtle differences in the measured affects of mood. The 65 item

POMS allows subjects to contemplate a number of responses of similar mode, with the experimenter able to link these factors instigating a clearly measurable variation in the subscales. In conclusion the ISP shows adequate agreement, time advantage, and appears to be related to short term affect measures of mood rather than long term maeasurements. With these factors, it is felt that the ISP is a relavant tool for the main study.

B1.3 Training diaries

B2.1.3.1 Introduction

Training diaries have been used by athletes for a number of years in order to assess the mode, duration, intensity, number, and frequency of training sessions. Training Diaries have also allowed the coach and athlete to assess how the athlete feels prior to, during, and after training sessions.

The main purpose of implementing training diaries in this study are twofold. Firstly it allows an assessment of any changes in training during the period of the study, and secondly it allows an assessment of training in the 24-48 hours prior to test days. Williams (1991), noted that to avoid potential training induced changes in running economy, subjects did not alter their training regimen throughout the study. Williams verified this through the use of training logs. In contrast Morgan *et al.*, (1994a) showed that a 30 min exhausting run prior to testing does not alter measurements of running economy.

B1.3.2 Purpose

The purpose of piloting the training diary was to assess any changes needed to obtain the information required for the main study.

B1.3.3 Methods

Seven subjects, all regular exercisers, (mean age 24.0 $\pm$ 2.8 years) were asked to complete a training diary over a seven day period. The subjects were individually asked for written comments on the use of the diary and for any areas for which they felt improvements could be made.

B1.3.4 Results and Conclusions

Comments were generally positive, with the diary easy to use. One adjustment was made in order to allow subjects to make note of days in which two training sessions were completed. Future studies using diaries may also wish to condense the diary into a smaller format.

B1.4 Meditation tape/ Instructions

B1.4.1 Introduction

The meditation intervention was based on the mindfulness of breathing technique. The audio cassette and instructions were developed by the investigator, based on a commercial programme, in order to satisfy both the meditation and the protocol requirements.

B1.4.2 Purpose

The purpose of this section was to investigate the content, composition, and aesthetics of the meditation instructions.

B1.4.3 Methods

Seventeen subjects, non exercisers and exercisers, both trained and untrained in meditation, were asked to read and listen to the meditation instructions. The subjects were asked to provide their comments and criticisms.

B2.4.4 Results and Conclusions

The general comments from those asked were positive. The audio cassette provides all the basic components of the technique. The voice on the cassette proved generally very acceptable with only a two subjects indicating that it was not comfortable.

B2. Physiological parameters

B2.1 Reproducibility of Running Economy

B2.1.1 Introduction

As described in the introduction, Running Economy is a critical variable in the assessment of running performance in individuals of homogeneous aerobic power. The need for equipment to produce precise and reproducible measurement is paramount. The error due to equipment measurement inaccuracy must be considered and variation in this measurement error found in order to distinguish between the inaccuracy and the effect of an intervention.

B2.1.2 Purpose

The purpose of this section is to assess the reproducibility of running economy and respiratory parameters using the Sensormedics 2900 on-line expired gas analysis. And therefore to reaffirm previous validation of this particular system (Unnithan *et al.*, 1994) at the specified time and using the specified protocol of this study.

B2.1.3 Methods

Six subjects (2 Female, 4 Male; Age 23.8 $\pm$ 3.1; Body mass 69.9 $\pm$ 10.7; Height 173 $\pm$ 7) were asked to run on a Powerjog EG30 treadmill at two speeds, on separate occasions on two consecutive days, and using the identical protocol as suggested in the main study. To avoid any other factor influencing measured parameters subjects were asked to attend at the same time of day, wearing the same/ similar clothing, the same shoes, have the same dietary and hydration status (no consumption three hours prior to the test). Subjects were asked to refrain from training for the 24 hours prior to both tests and temperature remained between 21-24 degrees Celsius.

B2.1.4 Results

Mean data for each variable was taken over the last 4 (min 7-10), last 3 (min 8-10), last 2 (min 9 & 10), and the last minute (min 10) of the 10 min period of both run 1 and run 2. Statistical analysis contained 1-sampled t-tests on the difference between visit 1 and visit 2 for each variable, and for each run. Correlations of each variable for visit 1 against visit 2, and regression analysis of visit 1 against visit 2, were obtained.

Last 4 mins

No significant differences were found for any variable at either run, when the difference between visit 1 and visit 2 was taken. Correlations for variables between visit 1 and visit 2 ranged from r = .624 to r = .993 for run 1 and r = .647 to r = .954 for run 2. Regression analysis implied that variables remained on a line of identity (y = x) from visit 1 to visit 2.

Similar results were obtained for analysis of the last 3 mins, last 2 mins, and the last 1 min. Only tidal volume in run 2 was significantly different across visits, when the last 2 and the last 3 minute values were averaged (last 3 min, $t = 2.6$, $p = .049$; last 2 min, $t = 2.99$, $p = .03$).

B2.1.5 Conclusions

The main conclusion from the above study is that the Sensor medic 2900 appears to be particularly reproducible in it's data output when using this particular protocol in this subject population. The open circuit system also appears to be reproducible with data analysis averaged across any of the last 4 minutes of the test protocol.

B2.2 Validity of Sensor Medic 2900

B2.2.2.1 Introduction

Previous research has been carried out on numerous common on-line gas analysis systems (Miles, *et al.*, 1994; Smith, unpublished thesis). Findings have been extremely variable, but the majority of work has indicated that on-line systems can tend to misinterpret data. Miles *et al.* did find that 4 on-line metabolic carts had extremely good intra-instrument data reproducibility (less than 5% difference between days), but failed to give synonymous results for many variables. Biological variability and random instrumentation error account for the majority of this day to day variation. Miles suggested that since biological variability will always be present, their finding of a 2-3% test-retest variation for the parameters selected indicated that random instrument error is negligible.

B2.2.2 Purpose

The purpose of this section was to assess the validity of the Sensormedics 2900 on-line expired gas analysis system against Douglas bag analysis in the University of Glasgow British Association of Sport and Exercise Science(BASES) accredited laboratory.

B2.2.3 Methods

Six subjects (2 Female, 4 Male; Age 23.8 $\pm$ 3.1; Body mass 69.9 $\pm$ 10.7; Height 173 $\pm$ 7) attended the Yorkhill Hospital Respiratory lung function laboratory. Each subject was asked to run at two paces for ten minutes with a fifteen minute recovery period. Douglas bag collection of the exhaust port of the Sensormedics 2900 system was made in minute 8-9 of each pace. Comparisons of On-line analysis and Douglas bag collection were made.

B2.2.4 Results

Statistical analysis of the validation results included, 1 sample t-test on the differences between the sensormedic 2900 and Douglas bag readings, correlation and regressional analysis, between the metabolic cart and the Douglas bag results.

Analysis of the difference between the sensor medic system and the Douglas bags signify that the majority of variables are validly measured by the sensor medic system using this protocol and within this population, when compared with a BASES accredited system. Only VO_2 in run 1 was significantly different between the two systems. The mean difference was calculated as -1.667 $ml.kg^{-1}.min^{-1}$ ($t = -2.61$, $p = .047$) indicating that the sensor medic system may be overestimating VO_2 at lower workloads. The regression analysis implies the same trend but the line of best fit is not significantly different from the line of identity ($y = x$). Correlational analysis shows both run 1 and run 2 attain high correlations for each variable (Run 1, range $r = .866$ to $r = .968$; Run 2, range $r = .944$ to $r = .995$). Regression analysis also indicates that Douglas bag and sensor medic results do not differ from lying on an identical line.

B2.2.5 Conclusions

The major problem with validations using exhaust ports of metabolic carts is the time delay in the expired air reaching the Douglas bag. This delay is presumed not to be of enormous consequence in steady state running and is therefore discarded in the calculations.

In general the results do suggest that the sensor medic on line gas analysis system does agree with a BASES accredited laboratory in the analysis of expired gas. This information is vital if absolute results are to be accepted as true information, but is not as important in studies investigating changes in physiological variables over time within individuals.

Appendix 3.

Meditation Audio cassette: Mindfulness of breathing

Script

Introduction (Side A)

Hello, on this tape I'm going to introduce you to a meditation practice.

If you've never done any meditation before you could be about to make some very rewarding discoveries, because to learn about meditation means essentially learning about your own mind. And by your own mind I'm not talking about something abstract and philosophical, I'm talking about the mental state you find yourself in, this very moment, whatever they happen to be. It is with this very immediate, very straightforward experience of the mind that meditation starts.

Meditation is a way for us to engage fully with our actual experience. And if you do this over days and weeks of regular practice, you'll find that a gentle transformation will start to take place in your experience. Through practising meditation your capacity to think and feel will become less muddled. Your thinking and feeling will become more pure, more clear, more direct.

The meditation practice on this tape will develop this fundamental quality of mental clarity and may prove very useful in your running. I'm going to introduce the mindfulness of breathing meditation.

If you think about it, our ability to pay attention is a fundamental part of our lives. For example you know how it feels when your trying to get through to someone whose mind is actually on something else, they act as though they are listening they make all the right sounds, but you know very well that they aren't really paying attention. It can be such a frustrating experience. Yet surely it's very common. Perhaps it's more common even, than we usually think. Surely peoples minds are often on something other than what they are actually doing. Consult your own experience. For example, are you able to give your undivided attention to any one task. Our attention easily gets dissipated because we have so many things on our mind. Sometimes we get so side-tracked from our original purposes that we even lose sight of things that are very important and precious to us. Developing our ability to concentrate helps us avoid getting side-tracked in this way, in the longer term we will become a clearer more focused person.

3-4 secs - Silence

The meditation practice you are about to learn providès a way of relaxing the mind and focusing it on a single object. I mean focusing the mind without conflict, usually when we try to concentrate there is an element of conflict. Perhaps you've noticed that you can't force yourself to concentrate, at least you can't do it for very long or very effectively. If you do try to force yourself to concentrate, sooner or later your mind will go on the rebound. You'll lose your clarity, you'll become bored or restless, and then you will no longer be interested in whatever it was you were concentrating on.

The essential method of the mindfulness of breathing meditation is very simple. It could hardly be more simple. You simply watch the flow of your breath coming in, and going out of your body. Simply watch it, simply experience it, that's all you have to do. Just keeping your mind on that simple basic experience. If you notice your attention straying away from the breath, you gently bring it back again, and that's the practice. As you bring your mind back over and over again, it gradually gets used to staying with the breathing. The tendency for your mind to wander of lessens, and your attention becomes deeper and more continuous. It's a uniquely satisfying and enjoyable experience. But you might be wondering what's so special about the breath. In a way there is no reason why we shouldn't use any object to focus on. Breath is just one of 1000's of possible concentration objects. But what is good about the breath as an object of meditation is that it can engage our interest deeply, there's something inherently interesting about breathing. It's a very clear sensation, and it's got a certain rhythm, it's got a soft, sensuous quality about it that is aesthetically enjoyable.

Breathing is also a rather mysterious thing. It's the breath of life, it's something all creatures depend on each moment, for their existence. And there also seems to be some sort of correspondence between the quality of our breathing and our mental state.

Breathing is also very important in running, our breath allows us to transport the oxygen we need in to the lungs and through our body.

Notice that when we are emotionally stirred our breath quickens. As our body relaxes and becomes calm, our breathing quietens down, and as our breathing becomes quiet our mind becomes quiet too. So that's why the breathing is a traditional choice of meditation method. It's engaging, but you'll still need to make a certain amount of effort, because you'll almost certainly find yourself becoming distracted quite often.

So, there is a special method of countering this in the initial stages of the meditation.

This is to tag each breath with a number, from 1 to 10, and counting like this helps keep the mind on the task. Before we actually sit down to do the mindfulness of breathing, let me just run through it's 4 stages now, just to give you an overview; You might want to come back to this part of the tape later on.

So, a brief run through now.

First take a minute or so to relax and settle down. Have your hands resting together in you lap, or on your knees.

It's usually easier to concentrate if you close your eyes, still if you think you might become drowsy have them a little bit open.

Once you've settled down start to take your attention on to your breathing, let each breath come as it will, and try not to alter it's natural flow in any way. Each breath is different, sometimes a breath will be short, another one long, sometimes your breathing might feel awkward, might feel rough and jerky, another time it might be smooth and subtle. Sometimes it might be so subtle that you can hardly perceive it at all. But whatever it is like, experience each breath exactly as it comes. Now to establish your attention more continuously start marking the end of each out breath with a count.

So you experience the sensation of one breath passing through the nose or mouth, into the lungs and out again. And just after the out breath you silently count 1. Just say it to yourself;

Then, Breath in, Breath out, count 2
Breath in, Breath out, count 3,

And you keep counting off each breath in that way, one by one, until your counting reaches 10. Then you start again at the beginning, at number 1. And you repeat the cycle over and over again, 1 to 10, throughout this whole first stage.

Each time you notice that your attention has wandered, just bring your mind straight back to the experience of the breathing. Get into a habit of returning straight away without wandering how you became distracted or thinking any further about it. Because if you think about it your attention will get dispersed, so just keep returning to the sensation of breathing, and be patient with yourself, in time you will find it easier to stay fully focused. Now let's spend just a few moments getting the feel of the stage.

Slower: So, becoming aware of your breath. And counting , now after each breath.

28 sec silence

Now in the second stage there's a change. You start counting just before each breath comes in. In other words you anticipate each in breath.

So you count 1 and you breath in, ... and breath out again.
Then you count 2, and breath in, ... then breath out
And count 3, breath in, ... then breath out.
And so on, marking each breath up to 10, and then returning to 1, just as before.

3 sec-Silence

You might find that your attention sharpens up a little at this stage. You have to take a slightly more active stance and this helps to establish a firmer concentration. Again and again you keep bringing yourself back to the breath, everytime you notice it's wandered. You do need to be patient, it doesn't mater how far it has wandered or for how long it has been wandering don't even think about it, just come back, So we'll try this 2nd stage out now for a few moments, just to get the feeling of it

Slower: So, now counting before each in breath.

40 sec-Silence

Now, in the third stage you stop the counting altogether, and you simply follow the natural flow of your breathing.

3-4 sec-Silence

You feel the air flowing down into your lungs, expanding the diaphragm, and you feel your abdomen slightly rising and falling. So here you are aware of the whole of each breath. You are making your awareness continuous from breath to breath.

3-4 sec-Silence

Allow the breathing to quieten naturally and allow your mind and your body to quieten with it. As you continue into this stage your attention and your physical posture are likely to become calmer and more refined.

So you stay with the breath in this way for the rest of the stage. And keep patiently brining your attention back whenever it wanders

2 sec- Silence

So now try this stage out just for a few moments:

Slower: So, just experiencing the natural flow of the breath.

43 sec- Silence

Then, we come to the final stage of the practice. When we focus our attention on 1 single aspect of the breath. This is the physical sensation you can feel just where the air is entering and leaving the body. You choose any point that seems right. It will probably be in or around your nostrils or upper lip, or it could be further in towards your throat. Exactly where is not important.

2 sec- Silence

Now as your breath passes this point you'll feel it as a soft brushing sensation. Stay with that single point of sensation as continuously as you can. Be receptive to it, feel all it's details, all the slight changes in sensation as the breath comes and goes. Focus in so closely that you almost listen to the sensation.

Doing this will require very close attention and this is because the sensation is subtle, and it's quality changes at each moment. You'll find that as the breathing becomes increasingly fine and delicate, so also does your mind.

3-4 sec- Silence

This is the end of the introduction to the Mindfulness of Breathing technique.

Thank you.

Side B - Actual Practice-10mins

In just a moment I'm going to be leading through the 4 stages of the practice, so get yourself comfortable, in fact make sure that you are going to be as comfortable as possible, we will be practising for about 10 minutes. If your able to engage with the practice 10 minutes will pass very quickly. It will be difficult to engage in the practice if you are not comfortable, and then 10 minutes could seem rather a long time.

4-5 sec-Silence

Okay, I'll assume your ready now. And your comfortable. So first of all let yourself settle into your running, have your body relaxed as you run.

4 sec-Silence

Check that your running evenly, your weight falls evenly on the left and the right sides of your body

3-4 sec-Silence

Now, extending awareness in to your body, deeply inhale and exhale a few times so that you can feel the chest and the rib cage opening. Feel your shoulders and arms lifting slightly on the inward breath and on the outward breath allow them to roll back slightly.

3-4 sec-Silence

Then let your breath return to normal.

3-4 sec-Silence

And as you do that let your shoulders relax, so that the chest remains more open. The adjust your hands in your lap to keep this openness in the chest.

4-5 sec-Silence

Let your spine be upright but relaxed not rigid.

2-3 sec-Silence

And allow your head to balance evenly at the top of your spine.

2 sec-Silence

Now relax your eyes

2 sec-Silence

Relax your face

3-5 sec-Silence

Relax your shoulders

2-3 sec-Silence

Relax your stomach

5 sec-Silence

Now experiencing your breath naturally as it goes into your body and goes out again

5 sec-Silence

Experiencing each breath just as it comes, each one; slightly different from the last one. And simply experiencing the present moment of each breath

10 sec-Silence

Now establishing your attention continuously on the breath and counting after each out breath or after each 2nd out breath, from 1 to 10 then starting again at 1, over and over again. And this is the first stage of the practice

25 sec-Silence

So aware of the breath coming in, aware of the breath going out

1 min 30 sec-Silence

If you find your attention has wandered from the breath just bring it back

1 min 5 sec-Silence

Coming back to the breathing every time you find your attention has wandered of

55 sec-Silence

Now, counting <u>before</u> each in breath or each 2nd in breath

18 sec-Silence

Experiencing the breath, coming in, ... turning round, ... going out, ... turning round, ... coming in, ... continuously aware of each moment, of each breath.

2 min 40 sec-Silence

And patiently bringing your mind back to the breathing every time you become distracted.

46 sec-Silence

And now stopping the counting, simply experiencing the natural flow of the breathing

2-3 sec-Silence

Letting each breath come just as it will. Whether it's a long breath or a short breath

1 min 55 sec-Silence

Again everytime you find you've become distracted bring your attention back and resting it in the breathing

3-4 sec-Silence

Aware of the breath coming in and going out.

60 sec-Silence

So concentrating now on the touch of the breath. Just at the point where you can feel the air entering and leaving the body. Choosing a point and experiencing a sensation just at that point

2min 30 sec-Silence

So now gently bring the practice to an end, keeping the body relaxed.

5 sec-Silence

This is the end of the Meditation Practice. This practice will repeat itself on this tape if you wish to continue running.

Thank you.

MEDITATION INSTRUCTIONS

You will have attended the laboratory on 2 occasions and now you have received an Audio cassette. The cassette contains an introduction to a meditation practice (Side A) and a short and concise meditation practice (Side B).

Week 1

- Please listen to the "Introduction to a meditation practice - The mindfulness of breathing" on about 3 occasions this week.
- Try to listen to the introduction in a comfortable, quiet place, either sitting or lying. The introduction is approximately 16 minutes long.
- Please complete the diary with the actual number of times you listened to the tape.

- No laboratory visit

Week 2

- Please listen to the "Meditation practice" while running with a walkman about 3-4 occasions this week. The practice is approximately 10 minutes long. **While running it is essential that you continue to be aware of your surroundings.**
- You will be asked to repeat this procedure on your laboratory visit at 2 paces.
- Please complete the diary with the actual number of times you listened to the tape.

- Laboratory visit - Run on the treadmill listening to meditation practice on walkman at 2 paces.

Week 3

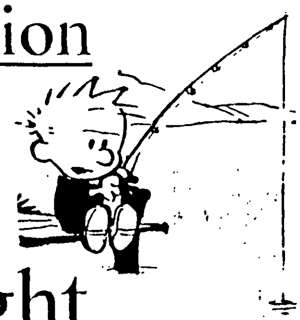
- Please attempt to follow the learned meditation practice while running without the tape about 3-4 occasions this week
- You will be asked to run on the treadmill and attempt the meditation technique at 2 paces.
- Please complete the diary with the number of times you re-listened to the tape.

- Laboratory visit - Run on the treadmill using the learned Meditation practice, no walkman, at 2 paces.

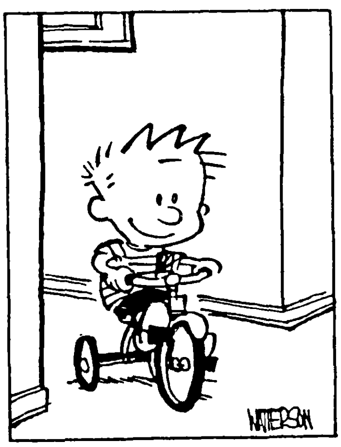
THANK YOU!

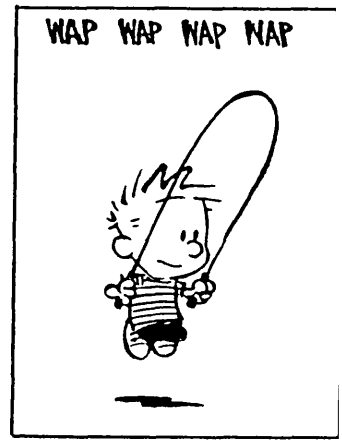
If you require any further information or help,
please do not hesitate to contact me at work or at home.
Lee, Work: 330 6838 or 330 5429; Home: 248 8069

Rating of Percieved Exertion

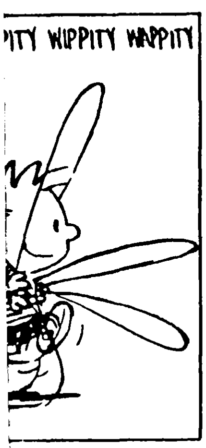


6
7 Very, very light
8

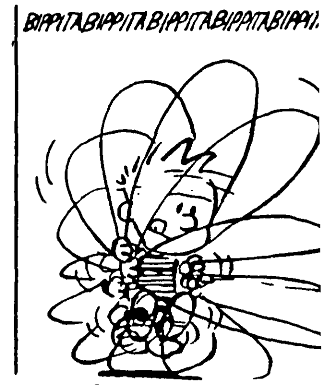




9 Very light
10
11 Fairly light
12
13 Somewhat hard

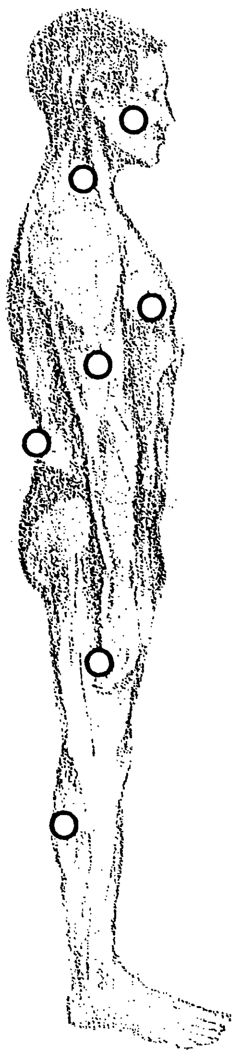


14
15 Hard
16
17 Very hard

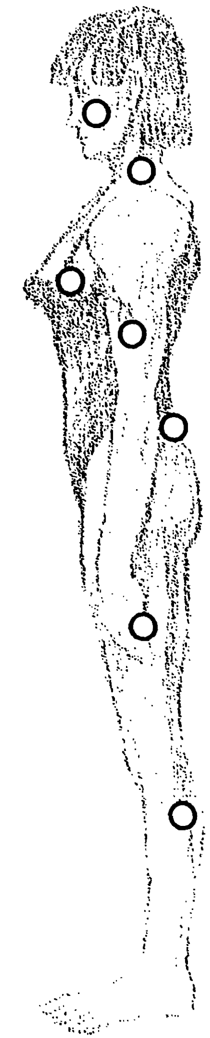


18
19 Very, very hard
20

CIRCLE THE APPROPRIATE SENSATION FOR YOU DURING THE ACTIVITY



	Very relaxed	Slightly relaxed	Neither relaxed nor tense	Slightly tense	Very tense
FACE	1	2	3	4	5
SHOULDERS and NECK	1	2	3	4	5
CHEST	1	2	3	4	5
ARM	1	2	3	4	5
LOWER BACK	1	2	3	4	5
THIGH MUSCLE	1	2	3	4	5
CALF MUSCLES	1	2	3	4	5
GENERAL OVERALL LEVEL	1	2	3	4	5



Initials ________ ID ____________

ISP

	Not at all	A Little	Moderately	Quite a bit	Extremely
1. How ANXIOUS did you feel during the activity?	0	1	2	3	4
2. How SAD or DEPRESSED did you feel during the activity?	0	1	2	3	4
3. How CONFUSED did you feel during the activity?	0	1	2	3	4
4. How ANGRY did you feel during the activity?	0	1	2	3	4
5. How ENERGETIC did you feel during the activity?	0	1	2	3	4
6. How FATIGUED did you feel during the activity?	0	1	2	3	4

SELF-EVALUATION QUESTIONNAIRE

Developed by Charles D. Spielberger
in collaboration with
R. L. Gorsuch, R. Lushene, P. R. Vagg, and G. A. Jacobs

STAI Form Y-1

Name ______________________________ Date __________ S ____

Age __________ Sex: M ____ F ____ T ____

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

Consulting Psychologists Press
577 College Avenue, Palo Alto, California 94306

SPORT SCIENCE RESEARCH

UNIVERSITY OF GLASGOW

PLEASE LIST WHAT THOUGHT, OR THOUGHTS YOU HAVE DURING THE 10 MINUTE RUN:

- **RUN 1**

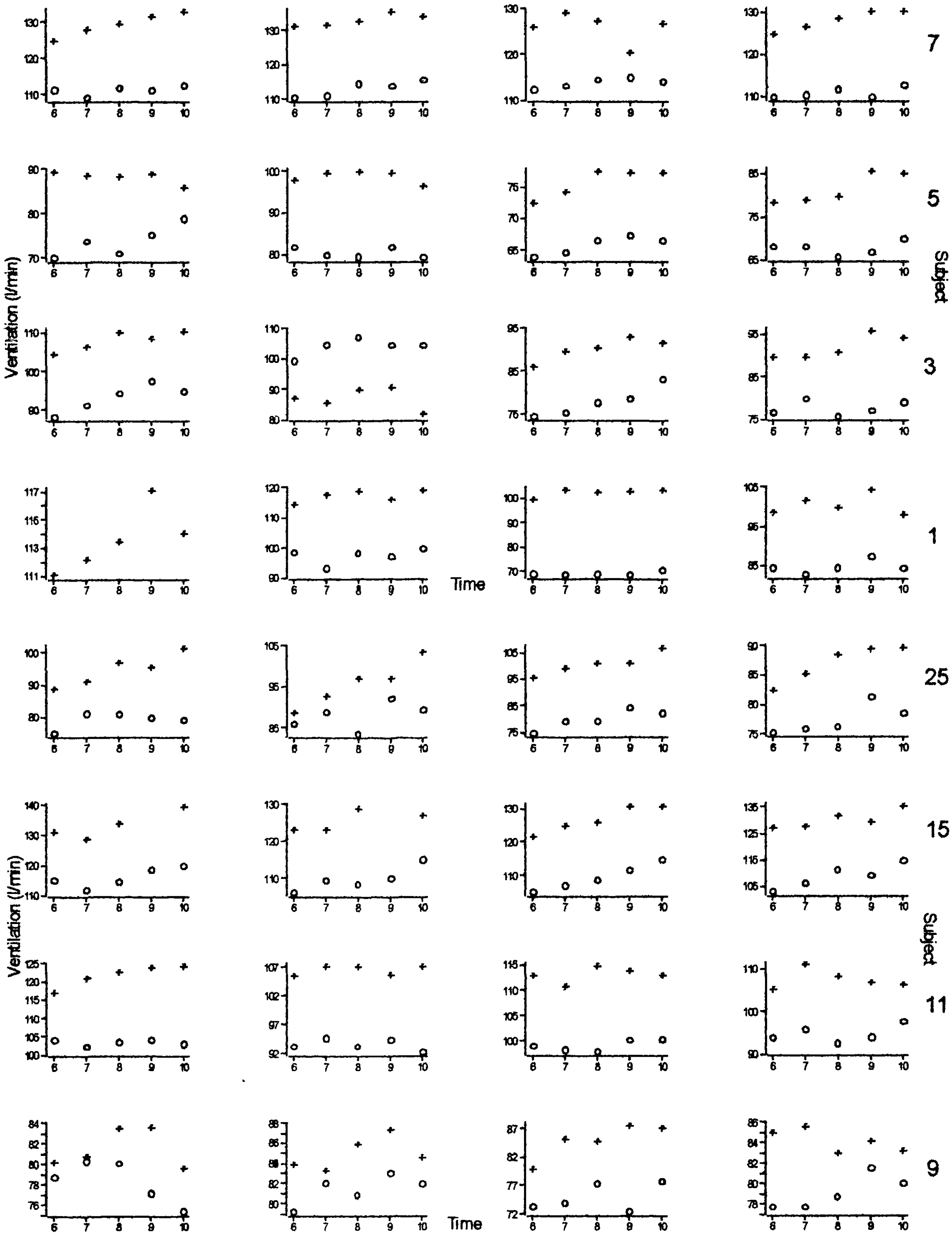
- **RUN 2**

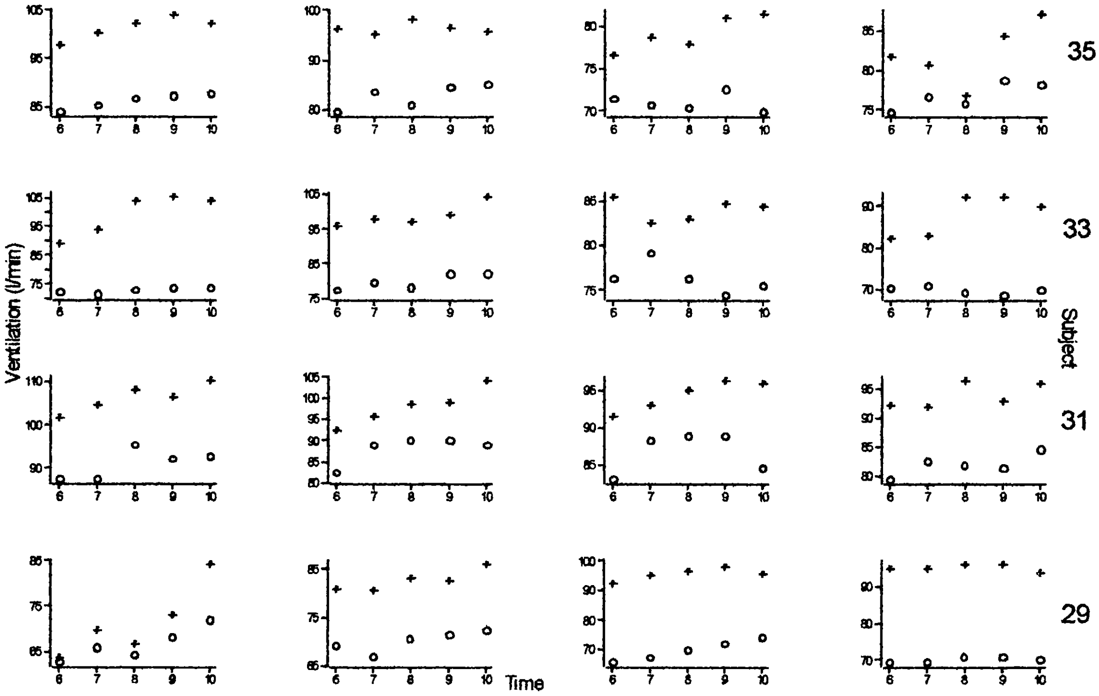
Appendix 6.

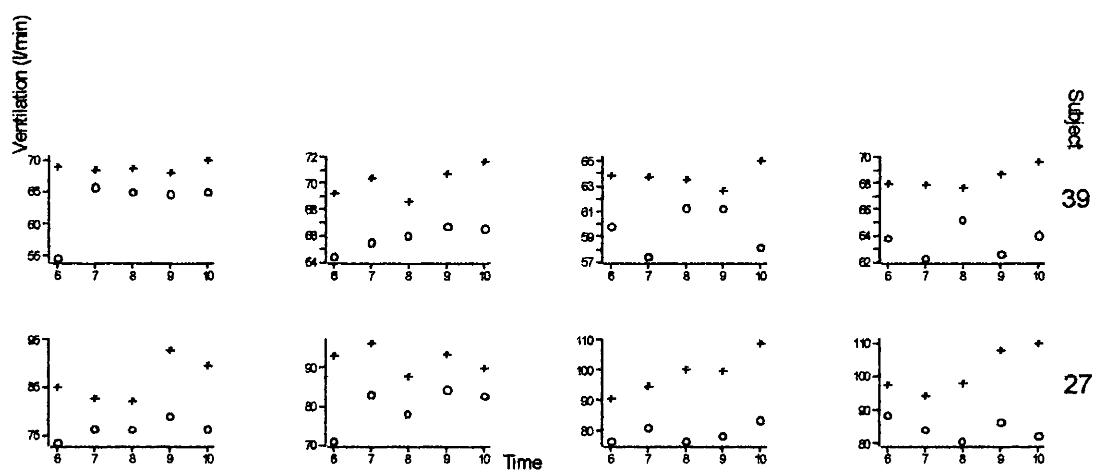
Representative graphs of stability in physiological measures over mins 6 to 10, for all visits. Ventilation and Oxygen consumption, for run 1 (+) and run 2 (o).

Intervention

Ventilation

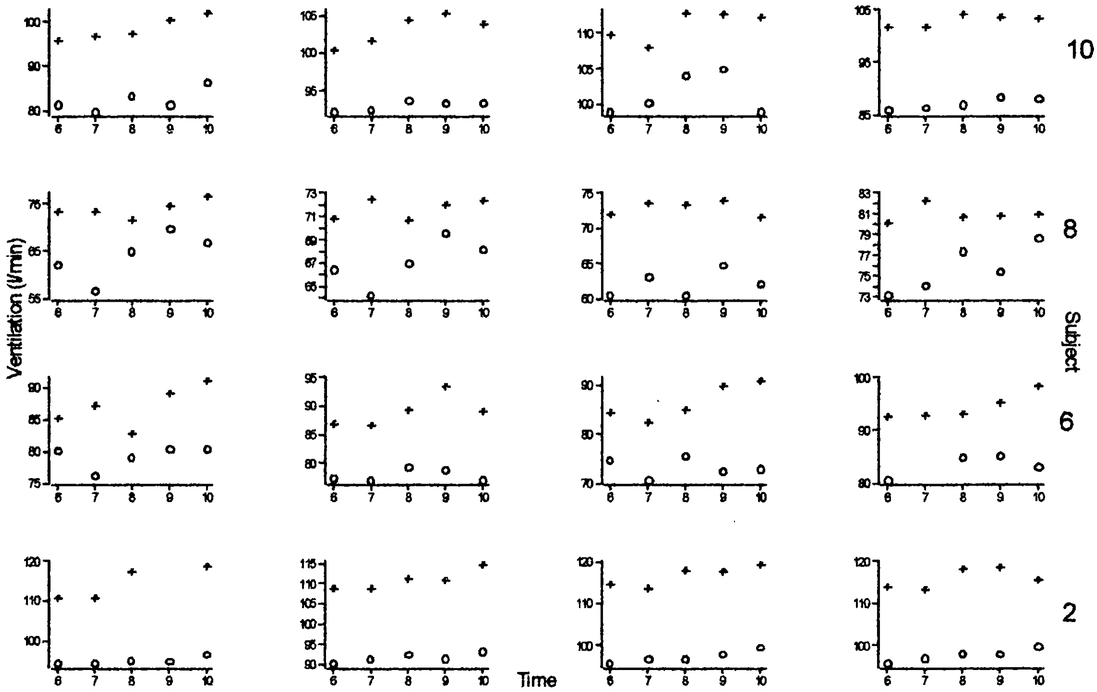


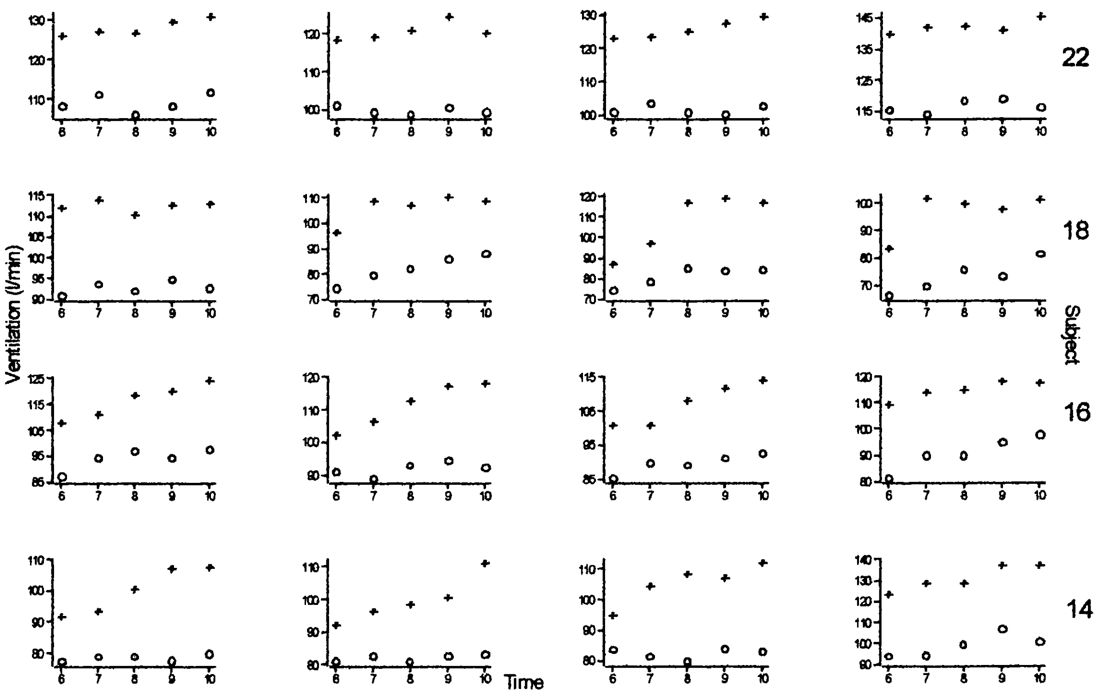

Ventilation (l/min)
Time
Subject
35
33
31
29

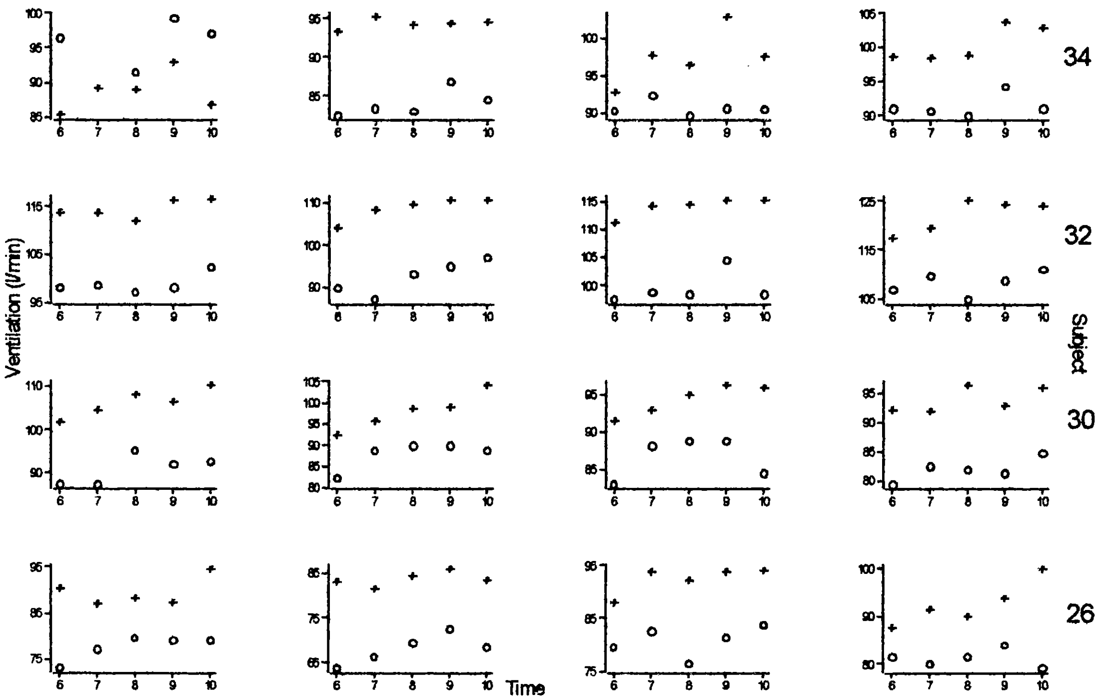

Ventilation (l/min)
Time
Subject
39
27

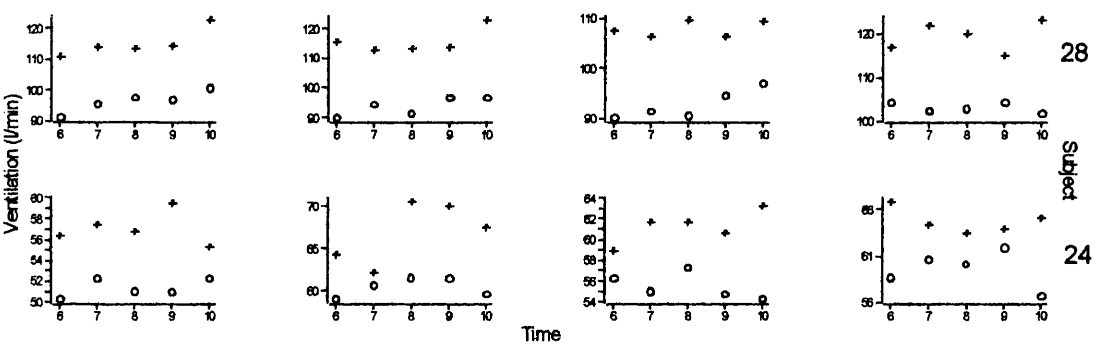
Control

ff

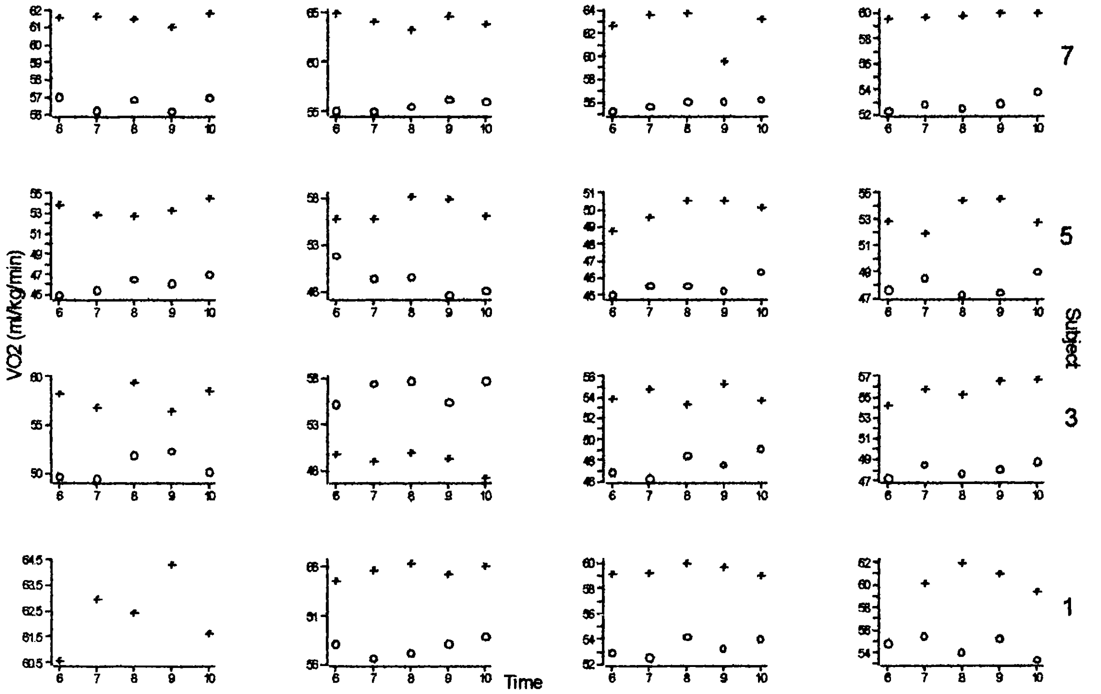

Ventilation (l/min)
Time
Subject
10
8
6
2

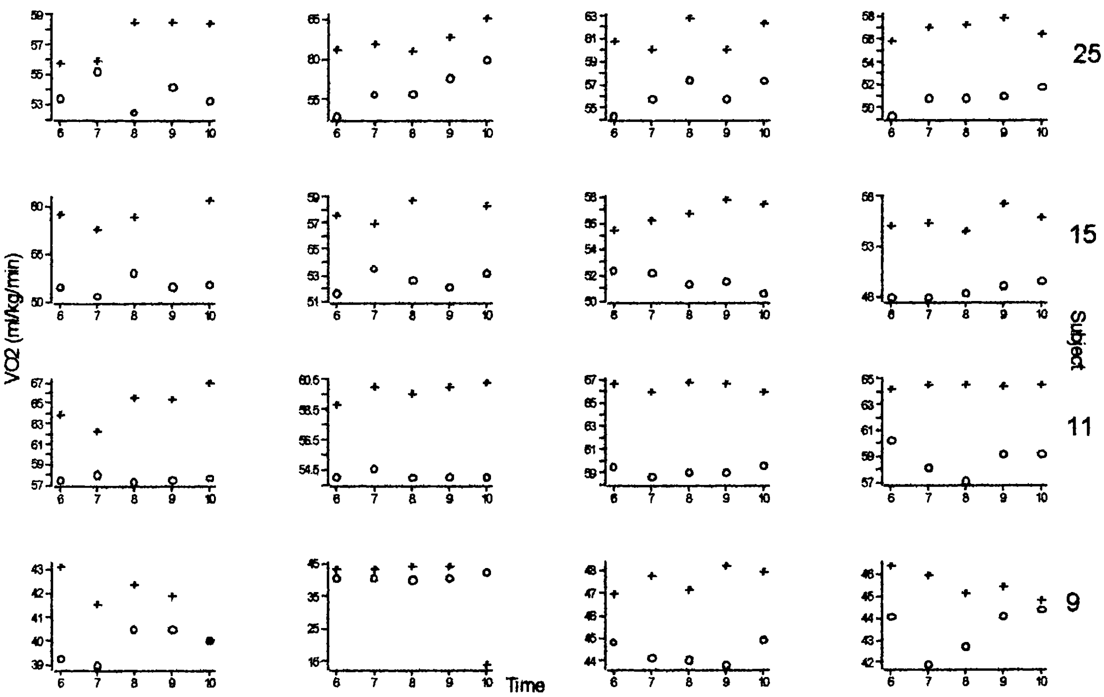

Ventilation (l/min)
Time
Subject
22
18
16
14

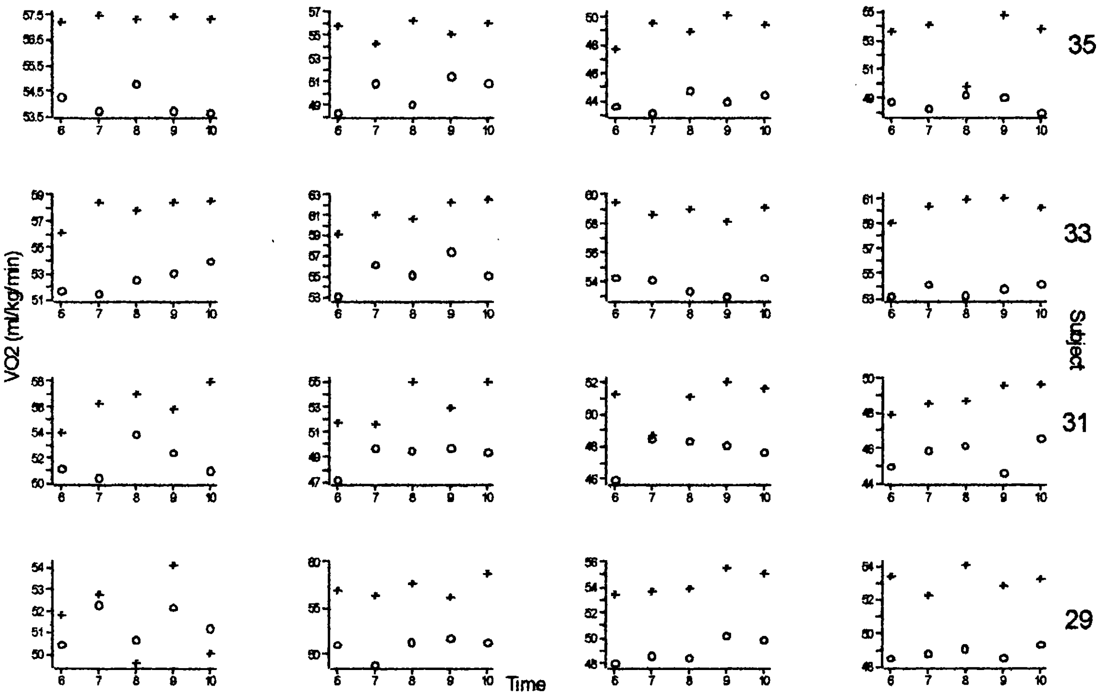

Ventilation (l/min)
Time
Subject
34
32
30
26

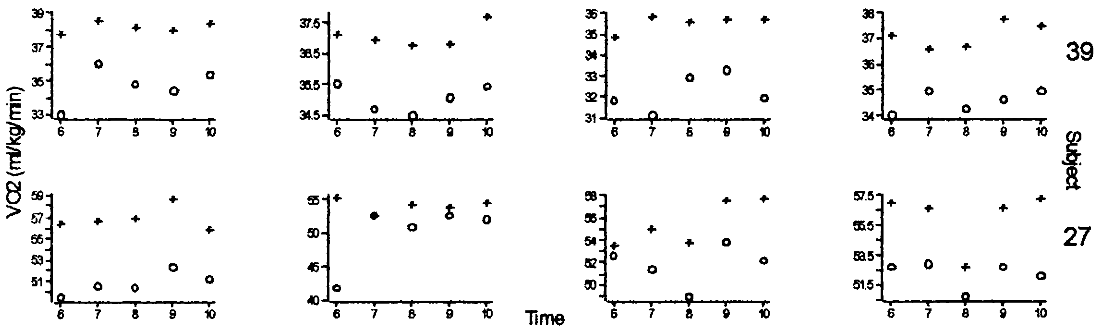

Ventilation (l/min)
Time
Subject
28
24

VO_2

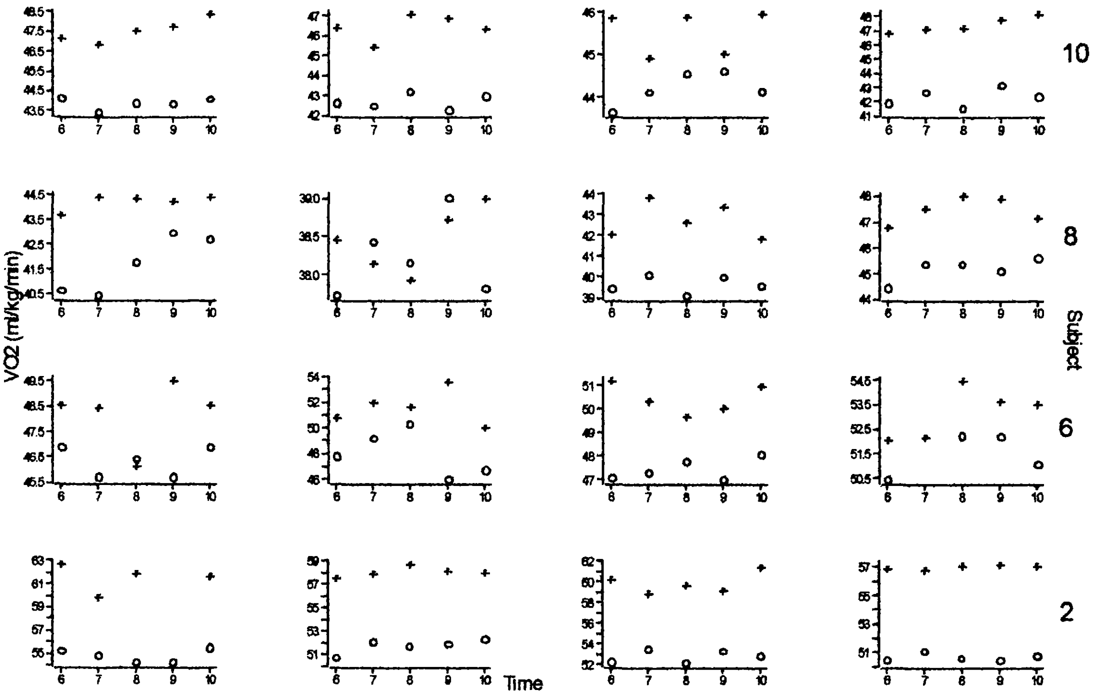

VO2 (ml/kg/min)
Time
Subject
7
5
3
1

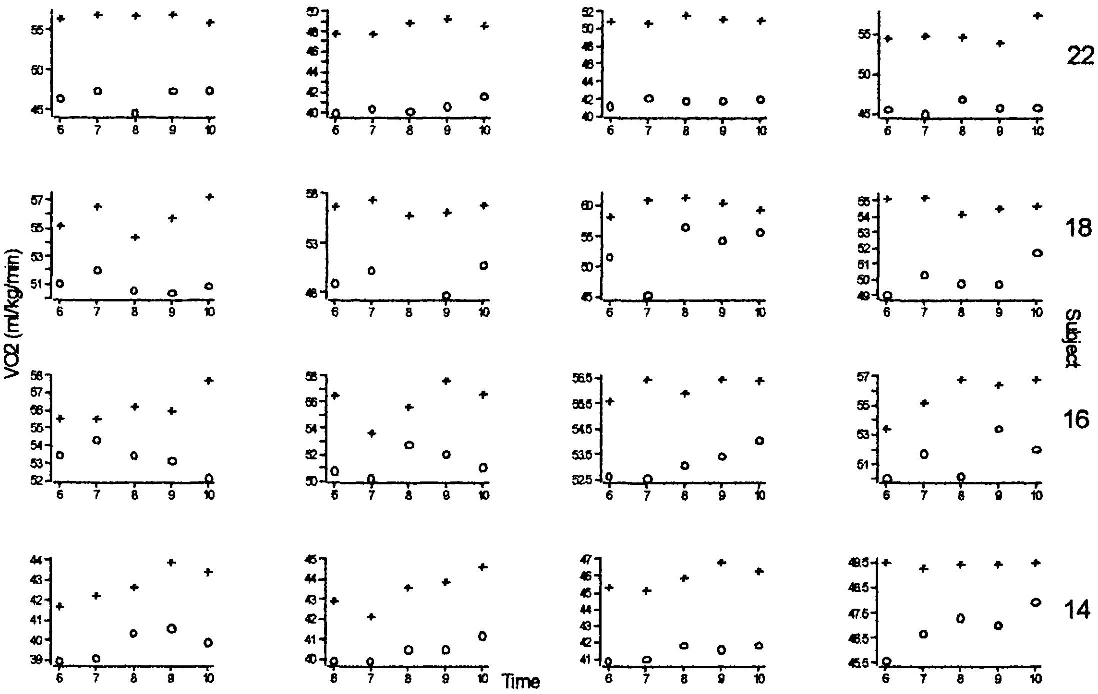

VO2 (ml/kg/min)
Time
Subject
25
15
11
9

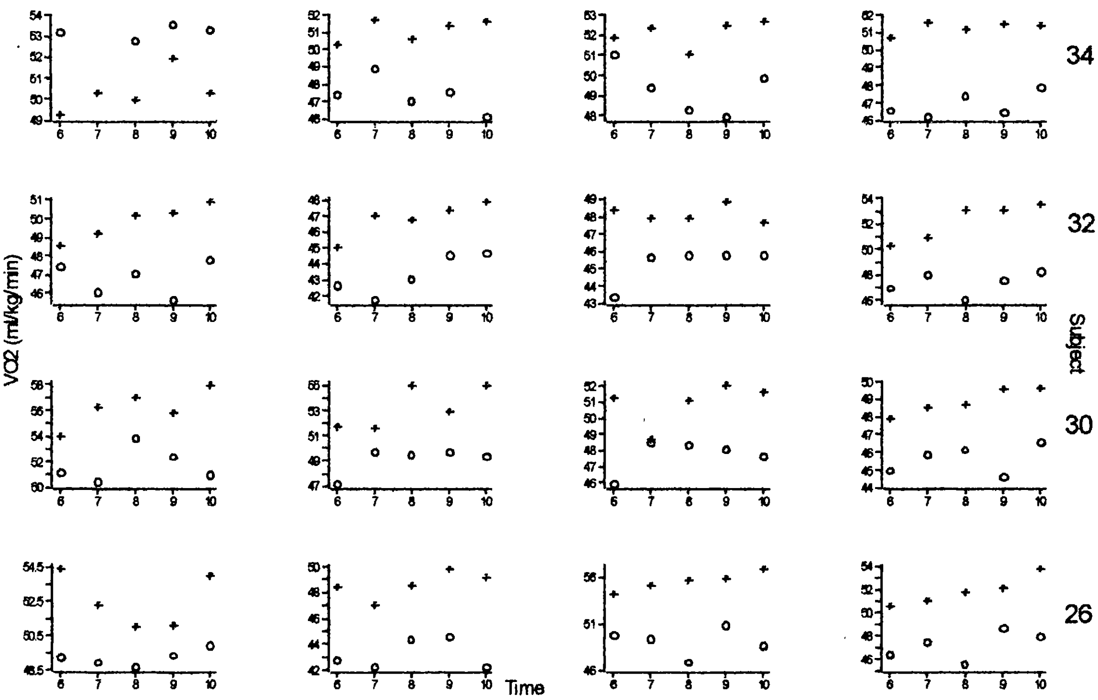

VO2 (ml/kg/min)
Time
Subject
35
33
31
29

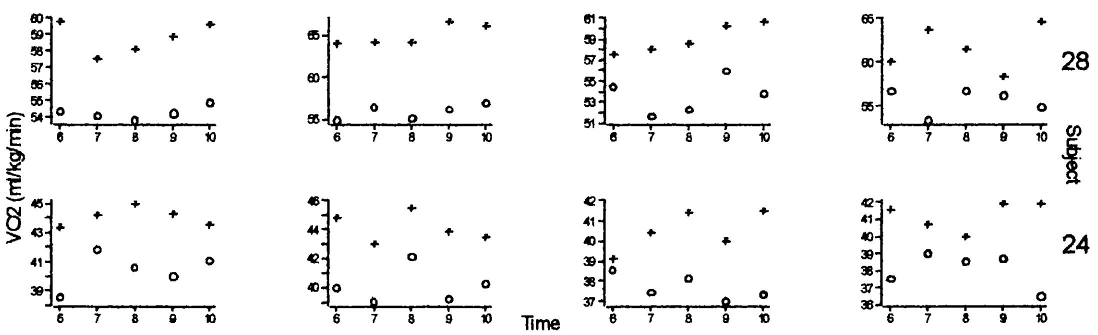

VO2 (ml/kg/min)
Time
Subject
39
27

Control


VO2 (ml/kg/min)
Time
Subject
10
8
6
2


VO2 (ml/kg/min)
Time
Subject
22
18
16
14


VO2 (ml/kg/min)
Time
Subject
34
32
30
26


VO2 (ml/kg/min)
Time
Subject
28
24

Appendix 7.

UNIVERSITY OF GLASGOW

Institute of Biomedical and Life Sciences

Sports Science Support/ Research - Lee Regan

INFORMATION SHEET
SPORT SCIENCE SUPPORT/ RESEARCH - RUNNING ECONOMY

You are invited to participate in a research study into Running Economy. If you agree to participate you will be asked to be involved in the following tests:

Testing will comprise of four visits;

Visit 1 & 2:

1. Measures of height, weight and an estimation of body fat.
2. You will be asked to run on a treadmill at two different speeds for 10 minutes each, with a 20 minute break between each 10 min run
3. You will be asked to complete 3 questionnaires after each run.

Visit 3:

1. You will be asked to run on a treadmill at two different speeds for 10 minutes each, with a 20 minute break, during the treadmill run you will listen to a walkman.
2. You will be asked to complete 3 questionnaires after each run.
3. You may be asked to carry out training runs at home with a walkman and audio cassette.

Visit 4:

1. You will be asked to run on a treadmill at two different speeds for 10 minutes each, with a 20 minute break.
2. You will be asked to complete 3 questionnaires after each run.

You will be invited to attend the laboratory a total of four occasions over a five week period. You may be asked to listen to an audio cassette at home and while running. You will also be asked to complete a basic training diary during the study.

The results of the study will be confidential and in no way influence any team selection, but may be of use to you in the assessment of your training. During the testing you may be asked to answer some questions relating to the testing and your training. Results of testing may be published with confidentiality maintained.

It is considered that participation is of minimal risk. All tests will be submaximal and test speeds will be similar to your training paces.

If you do not wish to participate in the testing or wish to withdraw at any time after commencing you may do so at your own discretion.

Consent

I, (please print name)...
give my consent to the research procedures described above, the nature, purpose and possible consequences of which have been described to me by L.Regan.

Signed... Date ....
Tel: .... Date of Birth ....
Witness...

Appendix 8. - Test protocol list

Control Group

1. Enter Lab
2. Height
3. Weight
4. Skinfolds
5. Pace selection
6. Attach Heart rate monitor
7. Warm up/ Pace selection trial-5min
8. Flexibility-5min
9. Calibrate 2900
10. Attach mouthpiece/ noseclip
11. 1 min Resting values
12. Treadmill to 10K + 0.5min.mile^{-1} pace
13. Subject jump on/ Start 2900 exercise section
14. Min 2-Treadmill Calibration (Trundel wheel)
15. Min 7-Heart rate
16. Min 8-Stride Frequency count
17. Min 9-Heart rate
18. End-Heart rate
19. RPE
20. Stop 2900
21. Flexibility
22. 3Questionnaires[BTI, ISP,STAI]
23. 10-15 min break
24. Warm up
25. Flexibility
26. Attach mouthpiece/ noseclip
27. 1 min Resting values
28. Treadmill to 10K pace
29. Subject jump on/ Start 2900 exercise section
30. Min 2-Treadmill Calibration (Trundel wheel)
31. Min 7-Heart rate
32. Min 8-Stride Frequency count
33. Min 9-Heart rate
34. End-Heart rate
35. RPE
36. Stop 2900
37. Flexibility
38. Questionnaires[BTI, ISP,STAI,Open ended]

Intervention Group

1. Enter Lab
2. Height
3. Weight
4. Skinfolds
5. Pace selection
6. Attach Heart rate monitor
7. Warm up/ Pace selection trial-5min
8. Flexibility-5min
9. Calibrate 2900
10. Attach mouthpiece/ noseclip
11. 1 min Resting values
12. Treadmill to 10K + 0.5min.mile^{-1} pace
13. Start Audio cassette
14. Subject jump on/ Start 2900 exercise section
15. Min 2-Treadmill Calibration (Trundel wheel)
16. Min 7-Heart rate
17. Min 8-Stride Frequency count
18. Min 9-Heart rate
19. End-Heart rate
20. RPE
21. Stop 2900
22. Flexibility
23. 3Questionnaires[BTI, ISP,STAI]
24. 10-15 min break
25. Warm up
26. Flexibility
27. Attach mouthpiece/ noseclip
28. 1 min Resting values
29. Treadmill to 10K pace
30. Start Audio cassette
31. Subject jump on/ Start 2900 exercise section
32. Min 2-Treadmill Calibration (Trundel wheel)
33. Min 7-Heart rate
34. Min 8-Stride Frequency count
35. Min 9-Heart rate
36. End-Heart rate
37. RPE
38. Stop 2900
39. Flexibility
40. Questionnaires[BTI, ISP,STAI, Open ended]