The effects of a moderate physical activity program on heat tolerance in men.

by
Casie Shields

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the requirements
For the Degree of

MASTER OF SCIENCE

Department of Physical Education and Recreation Studies
University of Manitoba

July 2001

0-612-62846-9

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

THE EFFECTS OF A MODERATE PHYSICAL ACTIVITY PROGRAM ON HEAT TOLERANCE IN MEN

BY

CASIE SHIELDS

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

of

MASTER OF SCIENCE

The effects of a moderate physical activity program on heat tolerance in men.

Table of Contents

Acknowledgments

Firstly, I would like to thank my advisor, Dr. Elizabeth Ready, for her support, guidance, and encouragement during the last three years. She has made a significant contribution towards my knowledge base, and has also helped me gain valuable career experience. Not only has she been a positive role model throughout my university career, but also a friend.

I would also like to thank Dr. Gordon Giesbrecht for welcoming me into his laboratory. He has taught me how to critically think and problem solve in both a research setting, and in every day life.

Drs. Grant Pierce and Tom Hassard have also provided me with insight towards the development of my study.

I express my thanks to Matt Nishi and Nicole LaRiviere for graciously volunteering their time and support in helping with data collection in the laboratory.

The University of Manitoba has provided me with financial support throughout the past two years, allowing me to concentrate more fully on my schooling.

Finally, I would like to thank all of my subjects who kindly volunteered to participate in the study. This work would not have been possible without them.

List of Figures

List of Tables

Abstract

Moderate intensity training induces health benefits, however its influence on heat tolerance is unclear. Twelve inactive males (mean ± SD) (age=24 ± 6 yrs, BMI=25.3 ± 3.2 kg/m2, V02peak=40.2 ± 8.1 ml/kg/min) performed work-heat tolerance and V02peak tests pre and post a moderate training intervention. All subjects were initially below the guidelines for physical activity set forth by the US Surgeon General, Health Canada, and CSEP. Eight randomly assigned subjects underwent the 12-week program, participating in activities such as cycling, walking, and recreational sports. Subjects were instructed to train at 50% V02Reserve, and gradually increased energy expenditure to reach a mean of 2158 kcal/week, which is beyond the above mentioned recommendations. Four control subjects remained sedentary. In the training group, V02peak increased 19% ($p<0.01$), and resting peripheral blood flow during heat stress increased ($p<0.01$), indicating some initial thermoregulatory benefits. No significant differences were observed in esophageal temperature or sweat threshold. Health benefits associated with heat adaptations may require more vigorous exercise than recommended by current physical activity guidelines.

Chapter 1. Overview

A. Introduction

The recommendations for appropriate levels of physical activity and exercise set forth by national agencies have evolved from a traditional fitness approach, to a broader scope focusing on physical activity and health. The most recent guidelines for the general public emphasize energy expenditure and moderate intensity physical activity, rather than high intensity exercise and concentrate on disease prevention and well-being rather than fitness (Health Canada and the Canadian Society for Exercise Physiology, 1998b; US Department of Health and Human Services, 1996; Pate et al., 1995). Since the current trend in health promotion focuses on moderate intensity activity, it is fundamental that exercise physiologists fully understand the effects of moderate physical activity on both health and fitness.

Heat intolerance is a health issue for certain populations such as the elderly, young children, and those with underlying cardiovascular and respiratory diseases. Heat intolerance causes, or significantly contributes to, numerous cases of heat-related illnesses and mortality among these populations each year (Center for Disease Control and Prevention, 1994; 1995b; 1996; 1999; Barrow & Clark, 1998). Therefore, the ability to efficiently thermoregulate has significant implications for one's health. Classical longitudinal and cross-sectional studies have established that high intensity exercise training induces improvements in heat tolerance (Gisolfi, 1973; Roberts, Wenger, Stolwijk, and Nadel, 1977; Henane et al., 1977), however, there is little research regarding the effects of moderate intensity physical activity on heat tolerance. The few studies that have addressed this issue employed different training protocols and assessment tools, making it exceedingly difficult to make direct comparisons (Houmard et al., 1990; Shvartz et al., 1979). Accordingly, there is no clear consensus among the research community as to the effects of moderate intensity activity on heat tolerance. There has been no examination as to whether engaging in an active living training program, as prescribed by Health Canada, CSEP, and the U.S. Surgeon General induces improvements in heat tolerance.

Statement of Purpose

To determine the effects of a twelve-week moderate physical activity program on heat tolerance in men.

Importance of the Study

The importance of the present study is two fold. Firstly, it will help clarify the dose-response relationship between physical activity and heat tolerance, and play a role in identifying the threshold exercise stimulus required to induce improvements in heat tolerance. Secondly, the present study will address the issue of whether engaging in lifestyle physical activity, as recommended by national agencies, induces benefits in heat tolerance, an important but unexamined health variable.

Hypotheses

It is hypothesized that a moderate physical activity program will improve heat tolerance among subjects. It is hypothesized that the training program will not evoke a large increase in peak oxygen uptake (V02peak).

Assumptions

It is assumed that high intensity physical training improves one's heat tolerance. Secondly, it is assumed that subjects in the training group engaged in appropriate physical activity during unsupervised training sessions. Similarly, it is assumed that subjects in the control group did not drastically change their physical activity patterns during the course of the study. It is also assumed that esophageal temperature (T_{es}) accurately represents core temperature (T_{co}), and that fingertip and forearm blood flow accurately reflects the pattern of total body peripheral blood flow. It is assumed that seasonal climate effects will be the same extent in both training and control groups, and that the null theory of thermoregulation is valid.

Delimitations and Limitations

Only healthy male subjects aged 18 to 45 participated in this study. Therefore, the results may not be generalized to other populations.

All training was conducted in the fall and winter seasons. Thus the results may not be generalized to training programs conducted during other seasons.

Dietary intake was a variable that was not controlled in this study.

<u>Definition of Terms</u>

Sedentary - Those individuals who expend less than approximately 10% of their daily energy expenditure in performance of exercise of at least four metabolic equivalents, or expend less than 2600 kcal/day (Bernstein, Morabia, & Sloutskis, 1999).

Physical Activity – Any movement requiring energy expenditure.

Exercise – Bout of physical activity performed with the intention of improving various physiological parameters.

Active Living – Process by which physical activity is incorporated into one's lifestyle.

Core Temperature – temperature of the core organs of the body (i.e. heart and brain).

Thermoregulation – process by which the body maintains a relatively constant core temperature of approximately 37°C.

Null Theory of Thermoregulation – There is a range of core temperature values in which active thermoregulation is absent (Cabanac & Massonet, 1977).

Heat Tolerance – the ability of the body to maintain a core temperature of approximately 37°C during a heat stress.

B. Review of Related Literature

Benefits of Physical Activity

Regular physical activity is an important component of a healthy lifestyle. There is ample evidence that regular physical activity is associated with decreased morbidity and mortality, increased longevity, and improved quality of life (Kesaniemi et al., 2001; Lee & Paffenbarger, 2000; Paffenbarger, Hyde, Wing, & Hsieh, 1986; US Department of Health and Human Services, 1996). Regular physicai activity decreases the risk of chronic diseases such as heart disease, non-insulin dependent diabetes mellitus, osteoporosis, certain cancers, and depression, among many others (US Department of Health and Human Services, 1996).

Dose-Response Relationships of Fitness and Health Benefits

Recent literature regarding active living and health promotion has focused on the optimal quantity and quality of physical activity for various fitness and health benefits. This is best reflected by a dose-response curve which represents the relationship between the change in the amount and/or the intensity of physical activity, or dose, and the change in a specific health benefit, or response, according to baseline physical activity status (Haskell, 1994). Currently, there are two main models of dose-response curves. The first proposes that low to moderate intensity, frequency, and duration exercise will provide little to no benefit, and higher thresholds of physical activity are necessary to attain benefits. This model is generally associated with the variable of cardiovascular fitness (Pollock et al., 1998; Health Canada and the Society for Exercise Physiology, 1998b).

An alternative model suggests that low to moderate activity levels will provide significant benefits, and that increasing the intensity, duration, or frequency beyond this threshold will not provide additional benefits. This model is generally associated with health benefits (Pollock et al., 1998; Health Canada and the Society for Exercise Physiology, 1998b).

Recent literature has attempted to define the dose-response relationship of various health and fitness parameters, and the optimal exercise stimulus required to attain such benefits. However, it appears that different parameters require different stimuli, making the relationships somewhat difficult to define. The American College of Sports Medicine (ACSM) recognizes that the quantity and quality of exercise needed to obtain fitness benefits differs from that required to induce health-related benefits (Pollock et al., 1998). From this, a trigger theory has evolved, which states that a specific training stimulus evokes specific benefits via specific physiological mechanisms (Haskell, 1985). This represents the specificity of training and the need to define the optimal or threshold exercise stimulus for various fitness and health-related benefits. For example, there appears to be an inverse and generally linear relationship between total caloric energy expenditure and risk of cardiovascular disease, type II diabetes mellitus, and all cause mortality (Kesaniemi et al., 2001). However, it is difficult to determine a dose-response relationship for other health outcomes. This is partially due to the lack of controlled dose-response research studies, and low accuracy in measuring energy expenditure in the field. The following sections will examine the dose-response paradigm of physical activity in terms of both fitness and health benefits.

Fitness Benefits

Cardiovascular or aerobic fitness is most commonly expressed in terms of maximum oxygen consumption (V02max), or the maximal rate at which oxygen can be consumed per minute. The ACSM Position Stand on physical activity states that the exercise training intensity threshold for improvements in V02max is 40-50% of V02 or heart rate reserve, or 50-65% maximum heart rate (Pollock et al., 1998). Thus, a relatively high training intensity is required to evoke improvements in cardiovascular fitness. This position stand recommends individuals accumulate 20 to 60 minutes of exercise at this intensity, in minimum of 10 minute bouts, three to five times per week in order to achieve improvements in aerobic fitness. Training at such an intensity is also associated with health benefits (Lee & Paffenbarger, 2000; Manson et al., 1999).

Training programs of unequal intensity, duration, and frequency will induce similar improvements in cardiovascular fitness provided the total energy expenditure is similar (Pollock et al., 1998). To illustrate, Debusk, Stenestrand, Sheehan, and Haskell (1990) evaluated the threshold duration required to produce aerobic training effects. They observed similar improvements in V02max among subjects who performed one continuous bout of exercise and those who expended the same amount of energy in short bouts of exercise, suggesting that total energy expenditure induces improvements in aerobic capacity regardless of whether it is continuous or intermittent. However, because subjects in both groups trained at the same relative intensity, this study cannot make conclusions as to the role of training intensity on V02max.

Duncan, Gordon, and Scott (1991) reported that exercise programs of differing intensities of walking for three miles, with similar overall caloric expenditure, produced significantly different effects on V02max. They noted a linear relationship with the highest intensity group yielding the greatest improvement in aerobic fitness, and the lowest intensity group showing the least improvement. Similarly, high intensity training with low energy expenditure has been shown to yield greater improvements in V02max relative to training at a lower intensity for a longer duration, with higher overall energy expenditure (Tabata et aL, 1996). Classical studies also report that more vigorous exercise is associated with the greatest improvements in aerobic fitness at the same energy expenditure (Paffenbarger, Hyde, Wing, & Steinmetz, 1984; Gaesser & Rich, 1984).

In summary, it appears that a higher threshold of intensity is required to induce improvements in cardiovascular fitness, and that physical activity can be performed either continuously, or in intermittent bouts. Thus, there is a preponderance of literature that supports the above mentioned guidelines set forth by the ACSM. Nonetheless, controversy remains regarding the effects of total energy expenditure on aerobic fitness. This issue must be further examined in future research endeavors.

Health Benefits

The quantity and quality of physical activity needed for cardiovascular health is different from that required for cardiovascular fitness (Kesaniemi et al, 2001; Pollock et al., 1998). The differences between physical fitness and clinical health status must be considered when defining dose-response relationships, as improvements in health parameters and improvements in fitness often occur through different physiological mechanisms (Haskell, 1985). This suggests that specific exercise stimuli produce specific benefits. For example, it is well established that weight bearing physical activity and resistance training provide the specific stimulation required for improvements in bone mineral density, whereas more dynamic aerobic activity acts more to stimulate weight loss (Haskell, 1985). These specific stimuli may be expressed as intensity, duration, or frequency thresholds, or by activity type, or total caloric expenditure.

Classical cohort studies have revealed an inverse relationship between occupational activity level and risk of cardiovascular disease, suggesting that high intensity activity is not required to induce health benefits (Morris et al., 1953; Morris and Crawford, 1958). These findings have prompted researchers to examine the relationship between health benefits, energy expenditure, and cardiovascular fitness. For example, Paffenbarger, Hyde, Wing, & Hsieh (1986) report that men who expended 2000 or more kcal/wk experienced a decreased death rate relative to those who expended 500 kcal/wk or less. They also report that men who expended more than 3500 kcal/wk during exercise did not receive any additional benefit in terms of relative risk of death. Recent research provides evidence against the above mentioned plateau effect at which increasing energy expenditure provides no additional benefits. Lee and Paffenbarger (2000) noted a significant inverse relationship between energy expenditure and mortality rate, thus failing to observe a plateau. Wareham et al. (1998) also emphasized the importance of energy expenditure as they found metabolic cardiovascular syndrome to be associated with reduced habitual energy expenditure rather than V02max. Many other studies have linked health benefits to overall energy expenditure (Paffenbarger et al., 1984; Gaesser & Rich, 1984; Pate et al., 1995; Ballor, McCarthy, & Wilterdink, 1990). Thus it appears that overall caloric expenditure is the most important stimulus in inducing health benefits.

There is substantial scientific evidence that health benefits can be attained through moderate intensity activity. For instance, data obtained from Harvard University alumni demonstrate that moderate amounts of physical activity can lead to a reduced risk of all-cause mortality, cardiovascular mortality, all cancers, stroke, and respiratory disease (Paffenbarger et al., 1984). Correspondingly, in a clinical trial Duncan et al. (1991) observed similar improvements in high-density lipoprotein cholesterol concentration among women who trained at a moderate intensity, and those who expended the same amount of energy at more vigorous intensities. Another intervention trial revealed that a high intensity training group did not acquire improvements in lipid profiles beyond that observed in the moderate intensity group (Spate-Douglas & Keyser, 1999). Many other studies report that individuals with moderate levels of energy expenditure have more desirable health parameters, and/or lower relative risk of disease compared to sedentary individuals (Lee, Rexrode, Cook, Manson, & Buring, 2001; Manson et al., 1999; Villeneuve, Morrison, Craig, & Schaubel, 1998; Wilbur, Naftzger-Kang, Miller, Chandler, & Montgomery, 1999; Paffenbarger et al., 1993). Such health benefits include a decreased risk of developing coronary artery disease, non-insulin dependent diabetes mellitus, and osteoporosis. This indicates that high intensity exercise is not required to attain health benefits associated with physical activity, but rather overall energy expenditure plays a more prominent role in one's health. Therefore, regular physical activity provides numerous health benefits, even if it is below the threshold for aerobic fitness.

Exercise programs of similar energy expenditure appear to be independent of the mode of physical activity (Lieber, Lieber, & Adams, 1989; Pollock, Dimmick, Miller, Kendrick, & Linnerud, 1975). Similarly, it appears that incorporating physical activity into one's lifestyle may be just as effective as a structured exercise program of similar energy expenditure. For example, Dunn et al. (1999) examined the effect of a structured intervention exercise program at a prominent health club versus a non-structured lifestyle program. Both programs increased participant's energy expenditure by 3 kcal/kg/day, and resulted in similar health and fitness benefits. This provides more evidence that accumulating physical activity throughout the day may be just as effective as participating in one bout of structured exercise, as overall energy expenditure is the most important factor in the attainment of health benefits.

In summary, health benefits can be attained through moderate intensity activity (Pate et al., 1995; Pollock et al., 1995; Lee & Paffenbarger, 2000), which is commonly quantified as that consisting of three to six metabolic equivalents, 50 to 69% of maximum heart rate, or 45 to 59% V02max (eg., US Department of Health and Human Services, 1996; Pate et al., 1995; Talbot, Metter, & Fleg, 2000; Lee & Paffenbarger, 2000). This has prompted national agencies to set forth appropriate physical activity guidelines for the general public. For example, Canada's Physical Activity Guide recommends that individuals accumulate 30 minutes of moderate intensity activity four days per week, 20 minutes of vigorous activity four days per week, or 60 minutes of any intensity activity daily. This is the equivalent of expending approximately 3 kcal/kg/day (Health Canada and Canadian Society for Exercise Physiology, 1998). The ACSM recommends that individuals accumulate 20 minutes of moderately-intense physical activity on most days of the week, which is approximately equivalent to expending 200 kcal/day (Pate et al., 1995). Similarly, the Surgeon General recommends individuals accumulate at least 30 minutes of endurance type physical activity of at least moderate intensity, on most days of the week, which is approximately equivalent to 150 kcal/day or

1000 kcal/wk (US Department of Health and Human Services, 1996). Very recent reports state that health benefits are attained from accumulating 30 minutes of moderate activity per day, which can be accumulated in five to ten minute bouts (Kjaer, Anderson, & Hansen, 2000). These recommendations extend beyond the traditional fitness model of physical activity, and present a broader model of activity and health.

Heat Tolerance as a Health Issue

Prevalence of Heat-Related Illness and Mortality

Heat intolerance holds significant implications for one's health, as hyperthermia causes or significantly contributes to numerous cases of heat-related illnesses and mortality each year (Center for Disease Control and Prevention, 1994; 1995b; 1996; 1999; Barrow & Clark, 1998). Heat-related illnesses include heat rash, edema, cramps, syncope, exhaustion, and heat stroke, and range from mild to life-threatening conditions (Davis, 1997).

However, epidemiologists encounter great difficulty reporting the true prevalence of heat-related illness and mortality, as there are no clear diagnostic criteria (Center for Disease Control and Prevention, 1996). This may be a reflection of the acute nature of this type of illness or death. The National Association of Medical Examiners has recently put forth criteria for diagnosis, however they are somewhat obscure. For instance, one criteria for diagnosis states that core temperature must reach 40.6ºC in order for a death to be classified as heat-related. Since many individuals are found postmortem, firm adherence to this criteria would result in artificially low estimates of heat-related deaths. In these situations, heat exposure can be listed as a cause of death if the environmental temperature was high at the time of collapse. In victims who have pre-existing medical conditions, the pre-existing disease may be listed as a contributor to death, or as a primary cause of death (Donoghue et al., 1997). Clearly, ambiguity exists in these guidelines, causing the above mentioned statistics to be somewhat unreliable.

Risk Factors

Recent research has focused on identifying individuals who may be at greater risk for heat-related medical conditions. Interestingly, prepubescent individuals and those beyond their fifth decade seem to be at greater risk of developing a heat-related illness, and having hyperthermia be a cause of death (Ballester, Corella, Perez-Hoyos, Saez, & Hervas, 1997; Center for Disease Control and Prevention, 1995a; 1999). There is little research regarding the heat tolerance of young children and the physiological mechanisms attributing to their greater risk is unclear. Early research proposed that a lessened evaporative heat loss cause children have lower heat tolerance than their adult counterparts (Wagner, Robinson, Tzankoff, & Marino, 1972). However, although the children in this study demonstrated lower evaporative heat loss relative to adult, they also demonstrated less metabolic heat production, thus making the conclusions somewhat misleading. Drinkwater and Horvath (1979) drew different conclusions, reporting that the lower heat tolerance seen in children is a reflection of an immature cardiovascular system, rather than an inadequate sweating response. Further investigation is evidently required.

In contrast, the effects of heat on older individuals have been extensively researched. In general, the efficiency of heat dissipation mechanisms such as cutaneous blood flow and sweat gland sensitivity, seem to decline with age (Shoenfeld, Udassin, Shapiro, Ohri, & Sohar, 1978; Minson, Wladkowski, Cardell, Pawelczyk, & Kenny, 1998; Inoue, Havenith, Kenny, Loomis, & Buskirk, 1999). This may explain the greater prevalence of heat-related illness and mortality among older individuals. However, when looking at an older population, it is difficult to determine if age primarily contributes to a decline in heat tolerance, or whether factors associated with aging, such as a decreased V02max, increased body fatness, decreased energy expenditure, and increased prevalence of chronic diseases, contribute to their greater risk of hyperthermia. Recent literature suggests that fitness is a more important predictor of heat tolerance than age itself. For example, in a clinical trial, Drinkwater and Horvath (1979) found that age was not a significant predictor of heat tolerance. Similarly, Tankersley, Smolander, Kenny, and Fortney (1991) observed no significant difference in heat tolerance during an acute bout of submaximal exercise between younger sedentary and older physically active men with similar V02max. However, when they compared young sedentary men to older sedentary men without controlling for aerobic fitness, the older men demonstrated a significantly lower heat tolerance when assessed by forearm blood flow and sweat rate sensitivity, as well as a significantly lower V02max . This suggests that age may not have a direct primary effect on the heat loss response, but rather age-associated declinations in heat tolerance are a reflection of declinations in V02max with age. These findings also suggest that if in fact heat tolerance declines with age, it can be counteracted by physical training. Therefore, we can state that those who are not acclimatized to heat exposure, and those who are physically unfit, are also at greater risk of heat-related illness or mortality (eg., Jones et al., 1982; Davis, 1977).

Chronic disease has also been reported to be a significant predisposing factor in heat-related illness and mortality. In a retrospective analysis, Austin and Berry (1956) reported individuals with chronic diseases to be more at risk. Of these diseases, individuals with cardiovascular deficiencies were particularly vulnerable. Recent data supports this association (Center for Disease Control and Prevention, 1995a; Ballester et al., 1997). In addition, the fact that there is a higher incidence of deaths from cardiovascular and respiratory origins during heat waves, indicates that heat intolerance may exacerbate underlying medical conditions (Center for Disease Control and Prevention, 1995a).

Although the association between chronic disease and heat-related illness and mortality is well defined, the nature of the relationship remains unclear. For instance, the effects of age and chronic disease on risk of heat-related illness and death must be clarified. The greater vulnerability seen in individuals with chronic disease may be a reflection of their low aerobic capacity rather than their disease status. In addition, most individuals with chronic or degenerative diseases take various drug cocktails, which may interact negatively with high core temperatures. For example, anticholinergic drugs block sympathetic stimulation to the sweat glands, and thus may cause a substantial reduction in heat dissipation. Clearly, this issue requires further examination in a research context.

Other, less pronounced risk factors for heat-related illness or mortality include alcoholism, and major tranquilizer use (Kilbourne, Choi, Jones, & Thacker, 1982). There is also evidence indicating that women may have lower heat tolerance than men, thus making them more prone to heat-related illnesses (Shoenfeld, Udassin, Shapiro, Ohri, &

Sohar, 1978). However, it is difficult to evaluate heat tolerance among women as estrogen and progesterone can have profound effects on blood flow, and therefore heat tolerance (Stephenson & Kolka, 1999; Tankersley, Nicholas, Deaver, Mikita, and Kenney, 1992; Brooks et al., 1997). Further research in this area is undoubtedly required.

Pathophysiology

Historically, there are two opposing theories regarding the pathophysiology of heat-related illness and mortality. Firstly, the peripheral or neural theory suggests that high core temperatures induce thermal injury to target thermoregulatory tissues, such as the hypothalamus. Logically, this is thought to lead to a decline in thermoregulatory function, an attenuation of the sweating response, and eventually shock. This peripheral view of heat related illness is supported by Ladell (1955) as he noted a decline in sweating with increasing core temperature.

The second theory is referred to as the central or cardiovascular theory, and suggests that circulatory or cardiovascular failure leads to heat related illness and mortality. For instance, Adolph and Fulton (1923) report that peripheral blood vessels are greatly dilated during exposure to high temperatures. This lack of vascular resistance prevents blood from returning to the heart. This in turn leads to shock. However, Barger, Greenwood, DiPalma, Stokes, and Smith (1949) demonstrated somewhat different results as they noted a decline in cutaneous blood flow during exhaustive exercise, followed by reactive hyperemia 10 minutes post exercise. This decline in cutaneous blood flow lessens heat dissipation through the skin surface, causing a spiraling increase in core temperature, thus leading to shock. Regardless of whether mean arterial pressure decreases due to cutaneous perfusion, or whether peripheral vasodilation occurs at exhaustion, the body endures significant physiologic stress.

The onset of shock links these theories together. Most likely, the etiology of hyperthermia and heat related mortality involves both central and peripheral factors. This is reflected in the fact that victims of heat-related illness demonstrate both cellular membrane damage due to overheating, as well as ischemic damage due to the massive shunting of blood away from internal organs (Lifschultz. & Donoghue. 1998). Further evaluation of these viewpoints is required to determine the extent to which each contributes to the cause of illness or death.

Mechanisms of Heat Dissipation

The human body maintains thermoregulatory homeostasis against adverse heat conditions via radiation, conduction, and evaporation. The regulation of peripheral blood flow serves to adjust heat loss via conduction and radiation. Core and mean skin temperatures provide neural input to cutaneous vasculature causing active cutaneous vasodilation. This plays an important role in the increased skin temperature in response to a heat stress, as it causes subsequent heat loss via conduction and radiation through capillaries and arterio-venous astamoses (Sawka, Wenger, & Pandolf, 1996).

While active cutaneous vasodilation occurs in peripheral tissue during heat stress, splanchnic, renal, and skeletal muscle circulation undergo reduced blood flow (Sawka et al, 1996). This redistribution of blood flow allows for greater heat dissipation. However, during exercise, skeletal muscle requires increased blood flow. This creates competition between skeletal muscle and cutaneous tissue for blood flow, and thus attenuates heat dissipation via conduction and radiation. For example, Johnson and Park (1981) observed a significantly higher core temperature threshold for cutaneous vasodilation during dynamic exercise compared to that during rest. This is consistent with the vasoconstrictor effect of exercise in non-cutaneous tissue. However, other studies have demonstrated differently, as they have failed to observe a reduction in leg blood flow during exercise in the heat (Savard, Nielson, Laszczynska, Larson, & Saltin, 1988; Nielson et al., 1993). This suggests that the additional cutaneous blood flow seen during exercise in the heat must be due to redistribution of blood away from the vascular beds of tissue other than active skeletal muscle. Such contrary findings are most likely a reflection of the different exercise and heat exposure protocols of the experiments. It is most likely that skeletal muscle blood flow is compromised at higher exercise intensities and in situations when the active muscle mass is quite large.

Significant heat dissipation is also achieved through evaporation of water from the skin surface. Rises in core and skin temperatures provide the hypothalamus with afferent thermal signals, which initiate a sympathetic thermal command signal to the sweat glands. This causes the onset of sweating (Stitt, 1993). Heat acclimatization has been shown to increase the sensitivity of sweat glands to neural and hormonal stimuli, which may be due to an increase in receptor density, and/or an increase in the size or number of active sweat glands (Nielson, 1998). In sum, the human autonomic nervous system functions fairly efficiently to maintain thermal homeostasis via central and peripheral components of the thermoregulatory system.

Effects of Physical Training on Heat Tolerance

Heat acclimatization and physical training influence heat tolerance (eg., Pandolf, 1979; Gislofi, 1973). Heat acclimatization refers to benefits in heat tolerance attributable to heat exposure. Gisolfi (1973) reports that training accounts for approximately 50% of the total improvements in heat tolerance, and the rest is thought to come from heat acclimatization. Therefore, it is generally accepted that high levels of fitness are associated with high levels of heat tolerance. However, physical training and heat acclimatization do not act entirely independently. Since exercise usually results in an increase in core temperature, it acts as an internal source of heat, thus it contributes to heat exposure. Therefore, it is difficult to completely separate the effects due to training, and those due to heat acclimatization.

During submaximal exercise in the heat, physical training has been shown to lead to an increased sweat rate, decreased sweat and vasodilatory thresholds, increased potential for heat storage, a slower rise in core temperature, and a decreased mean skin temperature. Other physiological adaptations to physical training include a lessened energy cost of exercise, increased heat tolerance time, and an increase in blood volume (Aoyagi, McLellan, & Shephard, 1997; Senay, 1979).

It is also well established that the mode of training must permit core temperature to rise during exercise, in order for heat tolerance benefits to ensue. For example, Avellini, Shapiro, Fortney, Wenger, and Pandolf (1982) examined the effects of a four week training program on untrained, non-heat-acclimatized males. Subjects were matched on aerobic capacity and assigned to exercise on a cycle ergometer at 75% V02max for one hour per day, five days per week. One third of the subjects trained on land, one third in water of 32°C, and one third in water of 20°C. When assessed by sweat rate and final core temperature, the groups who trained on land and in the warmer water demonstrated improvements in heat tolerance, whereas the group who trained in the cool water did not experience benefits in heat tolerance. This suggests that a rise in core temperature is a mandatory stimulus for thermoregulatory adaptations.

Classical studies have demonstrated that the training environment plays an important role in the training period required for the induction of heat tolerance benefits. Basically, when training is performed in the heat, thermoregulatory benefits can be obtained within 4 to12 days of training (Nadel, Pandolf, Robers, & Stolwijk, 1974; Shvartz et al., 1979; Inbar et al., 1981; Strydom et al., 1966). In comparison, when training in a thermoneutral environment, a substantially longer training period is required for such benefits to ensue (Gisolfi, 1973; Inbar et al., 1981; Henane et al., 1977). In general, best improvements are seen subsequent to training programs of 8 to 12 weeks in duration. In contrast, the benefits in heat tolerance decay after as little as a few days or a week of inactivity (Wyndham & Jacobs, 1957; Adams, Fox, Grimby, Kidd, & Wolff, 1960).

Nonetheless, the exercise stimulus required to elicit the above mentioned thermoregulatory benefits is unclear, and the dose response relationship is not well defined. It is also important to note that the various adaptations that occur in response to training may have different exercise stimulus thresholds.

The following review of literature will summarize the effects of both high and moderate intensity training on heat tolerance. For the purposes of this review, exercise protocols were classified as either of moderate or high intensity. As stated in the Surgeon

General's Report, moderate intensity activity refers to intensities corresponding to 50-69% of maximum heart rate, or 45-59% V02max (US Department of Health and Human Services, 1996). Therefore, exercise was classified as high intensity if the workload exceeded this guideline.

High Intensity Training

High intensity training is associated with improvements in heat tolerance. For instance, in a study of six college students, high intensity training in a cool environment, combined with 12 sessions of heat acclimatization, resulted in a marked improvement in heat tolerance when assessed by performance time and core temperature (Gisolfi, 1973). This was accompanied by a 15-20% increase in V02max. However, no significant increase in sweat rate was observed. Similarly, Aoyagi, McLellan, and Shephard (1994) noted an improvement in heat tolerance, as well as a 15% improvement in V02max in response to an eight-week high intensity training program. Henane et al. (1977) reported that three months of high intensity training significantly increased sweat output and V02max among originally sedentary men. They suggest that endurance training accompanied by a 15-20% increase in V02max is necessary to produce improvements in heat tolerance. However, they failed to examine a training program that did not increase V02max, making their conclusions somewhat questionable.

The findings of Roberts et al. (1977) also demonstrate that high intensity training leads to improved heat tolerance. They reported a significant downwards shift in vasodilatory and sweating thresholds among previously sedentary subjects subsequent to them undergoing a ten day training program of 75% V02max for one hour per day. Recently, Cheung and McLellan (1999) have examined this issue further by attempting to replicate the high heat tolerance seen in very fit individuals by having moderately fit individuals participate in a training program of 65% V02peak, one hour per day, for six days. They concluded that although the training program lead to an increased sweat rate and decreased skin temperature in the heat, and an attenuated rise in heart rate and rectal temperature during exercise in a thermoneutral environment, it was not a substitute for a high level of aerobic fitness. This suggests that short-term aerobic training can improve heat tolerance, yet the benefits are not as pronounced as in those who have undergone such training for longer periods of time.

Cross-sectional comparisons support the idea that high intensity training is associated with greater heat tolerance, as athletes have been shown to demonstrate greater sweat outputs relative to unfit cohorts (Henane et al., 1977). Conversely, in a longitudinal analysis, Shvartz, Saar, Meyerstein, and Benor (1973) observed no improvement in heat tolerance, as assessed by sweat rate, subsequent to high intensity training. It is possible that the duration of the training program was insufficient to elicit adaptations in heat tolerance, as the subjects trained for a mere six days. Another noteworthy weakness of the above mentioned study is that the prescribed training workload was the same for all subjects, rather than assigning each subject to train at a workload relative to his/her fitness level. Therefore, it is difficult, if not impossible to know how intensely each subject trained.

Although training in a thermoneutral environment may improve heat tolerance, it is inferior to acclimatization by exposure to exercise in heat. For example, in a study of ten mine laborers, training under cool conditions resulted in only partial acclimatization, relative to those individuals who trained at the same relative workload in a temperate environment (Strydom et al., 1966). This is supported by the work of Gisolfi and Robinson (1969) and Strydom and Williams (1969). For instance, Strydom and Williams (1969) reported an improvement in heat tolerance, among subjects following high intensity training in a cool environment. However, after two hours of heat stress, the physiologic responses of the subjects to the heat stress were similar to that seen prior to training. This suggests that training offers no benefit in terms of heat tolerance when heat exposure is prolonged. Thus, while training in a thermoneutral environment offers some benefit in heat tolerance, maximum improvements are demonstrated subsequent to training in a heated environment.

In general, high intensity training improves one's tolerance to heat. However, studies examining this relationship employ various training protocols, both in terms of workload and environmental temperature, and use different tools for assessing heat tolerance. This makes it exceedingly difficult to make direct comparisons. In addition, similar adaptations occur in response to acclimation and physical training, thus it is difficult to isolate the effects of training and heat stimuli (Cheung, McLellan, & Tengalia, 2000).

Moderate Intensity Training

Current literature suggests that benefits in heat tolerance may be attained through moderate intensity training. In a study employing a cross-over design, fit males underwent two differing training programs. One consisted of exercising at 75% V02max for 30-35 minutes per day, whereas the other consisted of training at 50% V02max for 60 minutes per day. Both programs resulted in decreases in core temperature and heart rate under a given heat and exercise stress, yet no changes in sweat rate or V02max was observed (Houmard et al., 1990). This suggests that a training program of lesser intensity, but longer duration can produce improvements in heat tolerance. Similarly, Shvartz et al. (1979) observed a significant improvement in heat tolerance, as assessed by sweat rate and sweat threshold, unaccompanied by an increase in V02max, subsequent to a moderate intensity training program in a temperate environment. However, it is difficult to separate the effects of training versus those of heat acclimation.

Using an animal model, Geor and McCutcheon (1998) report that although physical training in a cool environment improves one's physiologic response to the heat, exercise training in more adverse heat conditions are necessary for the attainment of optimal thermoregulatory benefits. However, it is unclear as to whether this can be generalized to a human population. Inbar, Bar-Or, Dotan, and Gutin (1981) demonstrated somewhat different results in a population of young boys. They examined the effects of moderate intensity training, in both thermoneutral and heated environments, on heat tolerance among young males. They noted a similar degree of heat tolerance among those who trained in a thermoneutral environment, and those who trained in the heat. No increase in V02max was demonstrated.

In sum, it appears that benefits in heat tolerance can be attained through moderate intensity training, without a corresponding dramatic increase in V02max. However, there are limited studies that support this concept, and like in studies looking at high intensity training, different protocols and assessment tools are employed, making it difficult to make direct comparisons. Clearly, the relationship between physical activity levels and heat tolerance requires further study, as the precise exercise stimulus required to induce heat tolerance benefits is undefined. In addition, the effects of total energy expenditure, exercise intensity, and heat tolerance must be clarified.

C. References

Adams, J., Fox, R., Grimby, G., Kidd, D., & Wolff, H. (1960). Acclimatization to heat and its rate of decay in man. Journal of Physiology, 152, 26P-27P.

Adolph, E., & Fulton, W. (1923). The effects of exposure to high temperatures upon the circulation in man. The American Journal of Physiology, 67(3), 573-88.

Aoyagi, Y., McLellan, T., & Shephard, R. (1994). Effects of training and acclimation on heat tolerance in exercising men wearing protective clothing. European Journal of Applied Physiology, 68, 234-45.

Aoyagi, Y., McLellan, T., & Shephard, R. (1997). Interactions of physical training and heat acclimation: the thermophysiology of exercising in a hot climate. Sports Medicine, 23(3), 173-210.

Austin, M. & Berry, J. (1956). Observations on one hundred cases of heatstroke. Journal of the American Medical Association, 161(16), 1525-9.

Avellini, B., Shapiro. Y., Fortney, S., Wenger, C., & Pandolf, K. (1982). Effects on heat tolerance of physical training in water and on land. Journal of Applied Physiology, 53(5), 1291-8.

Ballester, F., Corella, D., Perez-Hoyas, S., Saez, M., & Hervas, A. (1997). Mortality as a function of temperature. A study in Valencia Spain, 1991-1993. International Journal of Epidemiology, 26(3), 551-61.

Ballor, D., McCarthy, J., & Wilterdink, E. (1990). Exercise intensity does not affect the composition of diet and exercise induced body mass loss. American Journal of Clinical Nutrition, 51, 142-6.

Barger, A., Greenwood, W., DiPalma, J., Stokes, J. III, & Smith, L. (1949). Venous pressure and cutaneous reactive hyperemia in exhaustive exercise and certain other circulatory stresses. Journal of Applied Physiology, 2(1), 81-96.

Barrow, M. W. & Clark, K. A. (1998). Heat –related illnesses. American Family Physician, 58(3), 749-56.

Bernstein, M., Morabia, A., & Sloutskis, D. (1999). Definition and prevalence of sedentarism in an urban population. American Journal of Public Health, 122, 794-804.

Cabanac, M. & Massonet, B. (1977). Thermoregulatory responses as a function of core temperature in humans. Journal of Physiology, 265, 796-800.

Center for Disease Control and Prevention. (1994). Heat-related deaths- Philadelphia and United States, 1993-1994. Morbidity and Mortality Weekly Report, 43(25), 453-5.

Center for Disease Control and Prevention. (1995a). Heat-related illnesses and deaths, - United States, 1994-1995. Morbidity and Mortality Weekly Report, 44(25), 465-8.

Center for Disease Control and Prevention. (1995b). Heat-related mortality – Chicago, July 1995. Morbidity and Mortality Weekly Report, 44(31), 577-9.

Center for Disease Control and Prevention. (1996). Heat-wave-related mortality – Milwaukee, Wisconsin, July 1995. Morbidity and Mortality Weekly Report, 45(24), 505-7.

Center for Disease Control and Prevention. (1999). Heat-related illnesses and deaths- Missouri, 1998, and United States, 1979-1996. Morbidity and Mortality Weekly Report, 48(22), 469-73.

Cheung, S. & McLellan, T. (1999). Comparison of short-term aerobic training and high aerobic power on tolerance to uncompensable heat stress. Aviation, Space, and Environmental Medicine, 70(7), 637-43.

Cheung, S., McLellan, T., & Tenaglia, S. (2000). The thermophysiology of uncompensable heat stress: physiological manipulations and individual characteristics. Sports Medicine, 29(5), 329-59.

Davis, L. (1997). Environmental heat-related illnesses. Medicine and Surgery in Nursing, 6(3), 153-61.

Debusk, R., Stenestrand, U., Sheehan, M., & Haskell, W. (1990). Training effects of long versus short bouts of exercise in healthy subjects. American Journal of Cardiology, 65, 1010-13.

Donoghue, E. R., Graham, M. A., Jentzen, J. M., Lifschultz, B. D., Luke, J. L., & Mirchandani, H. G. (1997). Criteria for the diagnosis of heat-related deaths: National Association of Medical Examiners. Position Paper. American Journal of Forensic Medical Pathology, 18(1), 11-14.

Drinkwater, B., & Horvath, S. (1979). Heat tolerance and aging. Medicine and Science in Sports and Exercise, 11(1), 49-55.

Duncan, J., Gordon, N., & Scott, C. (1991). Women and walking for health and fitness; How much is enough? Journal of the American Medical Association, 266(23), 3295-9.

Dunn, A., Marcus, B., Kampert, J., Garcia, M., Kohl, H., III, & Blair, S. (1999). Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: A randomized trial. Journal of the American Medical Association, 281(4), 327-34.

Gaesser, G. & Rich, R. (1984). Effects of high and low intensity exercise training on aerobic capacity and blood lipids. Medicine and Science in Sports and Exercise, 16(3), 269-74.

Gisolfi, C. (1973). Work-heat tolerance derived from interval training. Journal of Applied Physiology, 35(3), 349-354.

Gisolfi, C. & Robinson, S. (1969). Relations between physical training, acclimatization, and heat tolerance. Journal of Applied Physiology, 26(5), 530-4.

Geor, R. J. & McCutcheon, L. J. (1998). Thermoregulatory adaptations associated with training and heat acclimation. Veterinary Clinics and North American Equine Practices, 14(1), 97-120.

Hardy, J., & Dubois, E. (1938). The technique of measuring radiation and convection. Journal of Nutrition, 15, 461-75.

Haskell, W. (1994). Health consequences of physical activity: understanding and challenges regarding dose-response. Medicine and Science in Sports and Exercise, 26(6), 649-60.

Haskell, W. (1985). Physical activity and health: need to define the required stimulus. American Journal of Cardiology, 55(10), 4D-9D.

Health Canada and the Canadian Society for Exercise Physiology. (1998b). Canada's Physical Activity Guide for Healthy Active Living. Ottawa, ON: Health Canada and the Canadian Society for Exercise Physiology.

Henane, R., Flandrois, R., and Charbonnier, J. P. (1977). Increase in sweating sensitivity by endurance conditioning in man. Journal of Applied Physiology, 43(5), 822-8.

Houmard, J. A., Costil, D. L., Davis, J. A., Mitcell, J. B., Pascoe, D. D., & Robergs, R. (1990). The influence of exercise intensity on heat acclimation in trained subjects. Medicine and Science in Sports and Exercise, 22(5), 615-20.

Inbar, O., Bar-Or, O., Dotan, R., & Gutin, B. (1981). Conditioning versus exercise in heat as methods for acclimatizing 8 to 10-yr-old boys to dry heat. Journal of Applied Physiology, 50(2), 406-11.

Inoue, Y., Havenith, G., Kenney, W., Loomis, J., & Buskirk, E. (1999). Exercise and methylcholine induced sweating responses in older and younger men: effect of heat acclimation and aerobic fitness. International Journal of Biometeorology, 42(2), 210-16.

Johnson, J. M. & Park, M. K. (1981). Effect of upright exercise on thresholds for cutaneous vasodilation and sweating. Journal of Applied Physiology, 50, 814-18.

Jones, T., Liang, A., Kilbourne, E., Griffin, M., Patriarca, P., Wassilak, S., Mullan, R., Herrick, R., Donnell, H. Jr., Choi, K., & Thacker. S. (1982). Morbidity and mortality associated with the July 1980 heat wave in Sr. Louis and Kansas City, Mo. Journal of the American Medical Association, 227(24), 3327-31.

Kesaniemi, Y.A., Danforth, E. Jr., Jensen, M., Kopelman, P., Lefebvre, P., & Reeder, B. (2001). Dose-response issues concerning physical activity and health: an evidence-based symposium. Medicine and Science in Sports and Exercise, 3(6), S347-S350.

Kilbourne, E., Choi, K., Jones, T., & Thacker, S. (1982). Risk factors for heatstroke: A case control study. Journal of the American Medical Association, 247(24), 3332-6.

Kjaer, M., Anderson, L., & Hansen, I. (2000). [Physical activity- what minimal level is sufficient seen from a health perspective?] Ugeskr Laeger, 162(15), 2164-9.

Ladell, W. (1955). The decline in sweating with raised rectal temperature. Journal of Physiology, 128, 8-9.

Lee, I., & Paffenbarger, R., Jr. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity: The Harvard Alumni Health Study. American Journal of Epidemiology, 151(3), 293-9.

Lee, I., Rexrode, K., Cook, N., Manson, J., & Buring, J. (2001). Physical activity and coronary heart disease in women. Is "no pain no gain" passe? Journal of the American Medical Association, 285(11), 1447-54.

Lieber, D., Lieber, R., & Adams, W. (1989). Effects of run-training and swim-training at similar absolute intensities on treadmill V02max. Medicine and Science in Sports and Exercise, 21(6), 655-61.

Lifschultz, B. & Donoghue, E. (1998). Forensic pathology of heat and cold-related injuries. Clinics in Laboratory Medicine, 18(1), 77-90.

Manson, J., Hu, F., Rich-Edwards, J., Colditz, G., Stampfer, M., Willett, W., Speizer, F., & Hennekens, C. (1999). A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. New England Journal of Medicine, 341(9), 650-8.

Minson, C., Wladkowski, S., Cardell, A., Pawelczyk, J., & Kenney, W. (1998). Age alters the cardiovascular response to direct passive heating. Journal of Applied Physiology, 84(4), 1323-32.

Morris, J., Heady, J., Raffle, P., Roberts, C., & Parks, J. (1953). Coronary heart disease and physical activity of work. Lancet, 2, 1111-20.

Morris, J., & Crawford, M. (1958). Coronary heart disease and physical activity of work: evidence of a national necropsy survey. British Medical Journal, 2, 1485-96.

Nielsen, B. (1998). Heat acclimation-mechanisms of adaptation to exercise in the heat. International Journal of Sports Medicine, 19, S154-6.

Nielsen, B., Hales, J., Strange, S., Christensen, N., Warberg, J., & Saltin, B. (1993). Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. Journal of Physiology, 460, 467-85.

Paffenbarger, R., Hyde, R., Wing, A., & Hsieh, C. (1986). Physical activity, all-cause mortality, and longevity of college alumni. New England Journal of Medicine, 314, 605-13.

Paffenbarger, R., Hyde, R., Wing, A., Lee, I., Jung, D., & Kampert, J. (1993). The association of changes in physical activity level and other lifestyle characteristics with mortality among men. New England Journal of Medicine, 328, 538-45.

Paffenbarger, R., Hyde, R., Wing, A., & Steinmetz, C. (1984). A natural history of athleticism and cardiovascular health. Journal of the American Medical Association, 252(4), 491-5.

Pandolf, K. B. (1979). Effects of physical training and cardiorespiratory physical fitness on exercise-heat tolerance: recent observations. Medicine and Science in Sports, 11(1), 60-65.

Pate, R., Pratt, M., Blair, S., Haskell, W., Macera, C., Bouchard, C., Buchner, D., Ettinger, W., Heath, G., King, A., Krista, A., Leon, A., Marcus, B., Morris, J., Paffenbarger, R. Jr., Patrick, K., Pollock, M., Rippe, J., Sallis, J., & Wilmore, J. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. Journal of the American Medical Association, 1(273), 402-7.

Pollock, M., Dimmick, J., Miller, H. Jr., Kendrick, Z., & Linnerud, A. (1975). Effect of mode of training on cardiovascular function and body composition of adult men. Medicine and Science in Sports and Exercise, 7(2), 139-45.

Pollock, M., Gaesser, G., Butcher, J., Despres, J., Dishman, R., Franklin, B., & Ewing Garber, C. (1998). The American College of Sports Medicine Position Stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in health adults. Medicine and Science in Sports and Exercise, 30(6), 975-91.

Roberts, M., Wenger, C., Stolwijk, J., & Nadel, E. (1977). Skin blood flow and sweating changes following exercise training and heat acclimation. Journal of Applied Physiology, 43(1), 133-7.

Savard, G., Nielsen, B., Laszczynska, J., Larsen, B., & Saltin, B. (1988). Muscle blood flow is not reduced in humans during moderate exercise and heat stress. Journal of Applied Physiology, 64(2), 649-57.

Sawka, M. N., Wenger, C. B., & Pandolf, K. B. (1996). Thermoregulatory responses to acute exercise-heat stress and heat acclimation. In M. Fregley & C. Blatteis (Eds.), Handbook of Physiology (pp. 157-185). New York: Oxford University Press.

Senay, L. Jr. (1979). Effects of exercise in heat on body fluid shift distribution. Medicine and Science in Sports and Exercise, 11(1), 42-8.

Shoenfeld, Y., Udassin, R., Shapiro, Y., Ohri, A., & Sohar, E. (1978). Age and sex differences in response to short term exposure to dry heat. Journal of Applied Physiology, 44(1), 1-4.

Shvartz, E., Bhattacharya, A., Sperinde, S. J., Brock, P. J., Sciaraffa, D., & Van Beaumont, W. (1979). Sweating responses during heat acclimatization and moderate conditioning. Journal of Applied Physiology, 46(4), 675-680.

Shvartz, E., Saar, E., Meyerstein, N., & Benor, D. (1973). A comparison of three methods of acclimatization to dry heat. Journal of Applied Physiology, 34(2), 214-19.

Spate-Douglas,T. & Keyser, R. (1999). Exercise intensity: Its effects on the high-density lipoprotein profile. Archives of Physical and Medical Rehabilitation, 80, 691-5.

Stitt, J. (1993). Central regulation of body temperature. In G. Gisolfi, D. Lamb, & E. Nadel (Eds.), Perspectives in exercise Science and Sports Medicine: Exercise, Heat, and Thermoregulation (pp. 6-20). Dubuque, IA: Brown and Benchmark.

Strydom, N. B. & Williams, C.G. (1969). Effect of physical conditioning on state of heat acclimatization of Bantu laborers. Journal of Applied Physiology, 27(2), 262-65.

Strydom, N. B., Wyndham, C. H., Williams, C. G., Morrison, J. F., Bredell, G. A. G., Benade, A. J. S., & Von Rahden, M. (1966). Acclimatization to humid heat and the role of physical conditioning. Journal of Applied Physiology, 21(1), 636-42.

Tabata, I., Nishimura, M., Kouzaki, M., Hirai, Y., Ogita, F., Miychi, M., & Amamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and V02max. Medicine and Science in Sports and Exercise, 28, 1327-30.

Talbot, L., Metter, E., & Fleg, J. (2000). Leisure-time physical activities and their relationship to cardiorespiratory fitness in healthy men and women 18-95 years old. Medicine and Science in Sports and Exercise, 32(3), 417-25.

Tankersley, C., Smolander, J., Kenney, W., & Fortney, S. (1991). Sweating and skin blood flow during exercise; effects of age and maximal oxygen uptake. Journal of Applied Physiology, 71(1), 236-42.

US Department of Health and Human Services. (1996). Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services, National Center for Chronic Disease Prevention and Health Promotion.

Villeneuve, P., Morrison, H., Craig, C., & Schaubel, D. (1998). Physical activity, physical fitness, and risk of dying. Epidemiology, 9(6), 626-31.

Wagner, J., Robinson, S., Tzankoff, S., & Marino, R. (1972). Heat tolerance and acclimatization to work in the heat in relation to age. Journal of Applied Physiology, 33(5), 616-22.

Wareham, N., Hennings, S., Bryne, C., Hales, N., Prentice, A., & Day, N. (1998). A quantitative analysis of the relationship between habitual energy expenditure, fitness and the metabolic cardiovascular syndrome. British Journal of Nutrition, 80, 235-41.

Wilbur, J., Naftzger-Kang, L., Miller, A., Chandler, P., & Montgomery, A. (1999). Women's occupations, energy expenditure, and cardiovascular risk factors. Journal of Women's Health, 8(3), 377-87.

Wyndham, C., & Jacobs, G. (1957). Loss of acclimatization after 6 days of work in cool conditions on the surface of a mine. Journal of Applied Physiology, 11(2), 197-9.

Chapter 2. The effects of a moderate physical activity program on heat tolerance in men.

A. Introduction

The most recent recommendations that describe the appropriate levels of physical activity for the general public emphasize increased energy expenditure via moderate intensity physical activity, rather than high intensity exercise. These recommendations concentrate on disease prevention and well-being, rather than on fitness (Health Canada, 1998b; US Department of Health and Human Services, 1996; Pate et al., 1995). These recommendations are based on research which demonstrates that health benefits are attainable through moderate intensity lifestyle physical activity, and that more vigorous activity, resulting in equivalent energy expenditure, does not provide additional health benefits (Lee, Rexrode, Cook, Manson, & Buring, 2001; Duncan et al., 1991; Manson et al., 1999).

Heat intolerance is a health issue for certain populations such as the elderly, young children, and those with underlying cardiovascular and respiratory diseases. Heat intolerance causes or significantly contributes to numerous cases of heat-related illnesses and mortality among these populations each year (Center for Disease Control and Prevention, 1994; 1995b; 1996; 1999; Barrow & Clark, 1998). Classical longitudinal and cross-sectional studies have established that high intensity exercise training induces improvements in heat tolerance (Gisolfi, 1973; Roberts, Wenger, Stolwijk, and Nadel, 1977; Henane et al., 1977), however there is little research regarding the effects of moderate intensity lifestyle physical activity on heat tolerance.

The purpose of the present study was to examine the effects of a twelve week moderate physical activity program on heat tolerance, and to determine whether such a program elicits improvements in heat tolerance.

B. Methods

Subjects

A voluntary response sample of 12 healthy, and relatively unfit men (mean V02peak = 40.2 ml/kg/min) were recruited to participate in the study. Written informed consent was obtained from all subjects (Appendix A), and the study was approved by the Ethics Committee for Research Involving Human Subjects. Medical questionnaires were used to eliminate those individuals for whom physical activity may be inappropriate or those who should obtain medical advice prior to beginning an exercise program (Appendix B). All men over 45 years of age were excluded from the study, as their inclusion would require that a physician be present for maximal testing (ACSM, 2000). Women were also excluded, as estrogen and progesterone have been found to have profound effects on thermoregulation (Stephenson & Kolka, 1999; Tankersley, Nicholas, Deaver, Mikita, and Kenney, 1992; Brooks et al., 1997).

All subjects were inactive, as assessed by a seven-day recall questionnaire (Blair et al., 1985) (Appendix C), and had not participated in structured endurance training for the six months previous to the study. Those who expended less than 10% of their daily energy expenditure in performance of exercise of at least four metabolic equivalents were accepted as subjects. This criteria is generally accepted to constitute sedentarism and physical inactivity (Bernstein, Morabia, & Sloutskis, 1999; Pate et al., 1995). Two individuals were not accepted into the study as their seven-day recall questionnaire revealed they did not meet this definition of being sedentary. In addition, one individual was not accepted as he refused the esophageal probe.

Study Design

The present study employed a pre and post test randomized group experimental design. Subsequent to initial testing, subjects were randomly assigned to either a training or control group using a random table of numbers, with 8 subjects in the training group and 4 in the control group (Figure 1).

Testing Procedures

Subjects were asked to refrain from caffeine and nicotine for at least two hours prior to exercise testing. They were also asked to refrain from exercise and alcohol use for six hours prior to testing. All testing was completed on a manually calibrated Ergomedic 818 Monarch bike.

All subjects underwent an initial V02peak test on a cycle ergometer, with power output increasing by 240 kpm/min every two minutes until exhaustion (Canadian Society for Exercise Physiology, 1996). The endpoint of the V02peak test was subjective exhaustion, and attainment of either age predicted maximum heart rate, or a respiratory exchange ratio of at least 1.1. Subjective exhaustion was determined by a rating of perceived exertion on a Borg scale of 6-20. These variables were used to determine whether subjects reached a true maximal effort (Brooks, Fahey, & White, 1996).

Height and weight were measured prior to the V02peak test. In addition, five skinfold measurements (tripcep, bicep, subscapular, suprailiac, and medial calf) were obtained (Health Canada and the Canadian Society for Exercise Physiology, 1998a). Each site was measured twice, and a third time if the difference was greater than 0.4mm. The means of the two closest measurements determined the skinfold value. The same

Certified Fitness Consultant conducted all of the skinfold testing, and all measurements were made with the same pair of calipers.

On a separate day, subjects completed a heat tolerance test. This test consisted of the subject cycling at 40% of their initial V02peak for 45 minutes in a climatic chamber (Conviron CMP 3244 climatic chamber) at 32ºC, 32% relative humidity with minimal forced air movement. The heat tolerance test also included 15 minutes of passive baseline conditions and 15 minutes of passive recovery, both at 32ºC, 32% relative humidity. During the baseline and recovery periods, subjects sat in a chair. Approximately 2.5 minutes prior to the start of exercise they sat on the bike. Measurements included heart rate, V02, esophageal temperature, sweat rate and threshold, average skin temperature, and skin blood flow. All subjects wore shorts for the heat tolerance test. Following the 12 week training and control periods, all subjects performed a second V02peak and heat tolerance test with the same protocol as that used for pre-testing. For each subject, the second heat tolerance test was conducted at the same time of day as that of the first heat tolerance test.

Intervention Program

In terms of physical activity, those assigned to the control group were instructed to continue their lifestyle as they had prior to being accepted into the study, thus not to start a structured exercise program until the completion of the study. The training group engaged in regular, moderately intense physical activity for approximately twelve weeks. This consisted of cycling, walking, intramural sports, and other forms of aerobic exercise. Subjects were permitted to participate in moderate intensity resistance training to increase energy expenditure, however they were encouraged to have the majority of their training be aerobic in nature. Initially, training subjects were instructed to exercise at approximately 50% V02reserve, which results in expending approximately 750 kcal/wk during exercise. This intensity corresponds to between four and six metabolic equivalents. As the training program progressed, subjects were instructed to add 10 minutes of activity per week to their training program, still at approximately 50% V02reserve, resulting in the expenditure of approximately 2000 to 3000 kcal/wk. Training was performed in a supervised setting approximately once per week. All other days of the week subjects were instructed to accumulate the required energy expenditure in other modes of moderate aerobic activity as desired. All subjects kept a log book of their physical activity (Appendix D).

Moderate intensity activity requires energy expenditure of 5.0 to 7.4 kcal/min (McArdle, Katch, & Katch, 1994). Energy expenditure during the training program was calculated based on this estimate. For low/moderate activity as determined by heart rate, energy expenditure was demonstrated to be 5.0 kcal/min X number of minutes, whereas high/moderate activity was calculated as 7.4 kcal/min X number of minutes. These values were then adjusted for each subject's weight.

All subjects received a complementary three month facility pass to the University of Manitoba Athletic Facilities. The control group received this at the completion of the study. In addition, subjects received financial remuneration of $25 for initial testing, and another $25 for final testing.

Instrumentation

Oxygen consumption was measured by direct gas analysis. Expired air was collected in a rubber face mask with one-way valves and directed to a mixing chamber. Mixed expired air was continually measured in the mixing box at a rate of 500 ml/kg/min and analyzed by a Vmax 229D series Pulmonary Function Analysis/ Cardiopulmonary Exercise Testing Instrument. The Vmax system was calibrated prior to the start of each test.

Heart rate was continuously monitored by a DC battery operated 43100A Defibrillator/ECG monitor (Hewlett-Packard) with electrodes in a modified V5 arrangement. A Polar Vantage XL heart rate monitor was used during the V02max tests to confirm the heart rate reading on the ECG. An Ohmeda Biox 3700 pulse oximeter (Datex-Ohmeda, Louisville, CO) was also used to monitor heart rate during the heat tolerance test.

Core temperature was continuously monitored by a Mon-a-therm, esophageal thermocouple (Mallinckrodtt, St. Louis, MO) inserted through the nostril to the level of the heart. Probe insertion length was determined from sitting height according to the formula given by Mekjavic and Rempel (1990).

Skin temperature was measured by twelve thermal flux transducers (Concept Engineering, Old Saybrook, CT). The transducers had been calibrated using a Rapid-k instrument (Dynatech, Cambridger, Ma). Body surface area was calculated by [area (m2) = weight0.425 (kg) X height0.725(cm) X 0.007184]. Regional weightings were assigned based on Hardy and Dubois (1938) as follows: forehead 7%, upper chest 8.7%, abdomen

8.8%, scapula 8.7%, lower back 8.8%, anterior thigh 9.5%, posterior thigh 9.5%, shin 6.5%, calf 6.5%, upper arm 14%, dorsum of hand 5%, and dorsum of foot 7%.

Data from the thermocouples and gas analyzers were collected using an electrically isolated Mackintosh IIci computer equipped with a MIO-16L 16 channel analog-digital converter (National Instruments, Austin TX). Data was digitized at 2 Hz, averaged over 5 seconds, and scales using appropriate corrections.

Fingertip blood flow was monitored by an Ohmeda Biox 3700 Pulse Oximeter (Datex-Ohmeda, Louisville, CO). The sensor was placed on the left index finger. Blood flow was quantified as a relative perfusion index (PIr).

Sweat rate was measured at the forehead with a small sealed ventilated capsule through which dry air was flushed at a fixed flow rate of 1 L/min (Brooks 5850 Mass Flow Controller, Emerson Electric, Hatfield PA). The relative humidity under the capsule was measured by an Omega HX93 Humidity and Temperature sensor (Omega Engineering, Stanford CT). Sweat rate was calculated as the product of the change in water vapor content under the capsule and the flow rate through the capsule.

Sweat threshold was identified as the calculated esophageal temperature at which there is a significant increase in relative humidity under the capsule. It is well established that the cutaneous contribution to sweating is linear and the fractional contribution of T_{skavg} to the sweating threshold is approximately 10% (Nadel, Metchell, & Stolwijk, 1971). Thus, the following formula was used to adjust T_{es} for a common designated skin temperature: $T_{es(calculated)} = T_{es} + (ß / 1 - ß) [T_{skavg} - T_{sk(designated)}]$. The designated T_{sk} was set at 34.5ºC, with ß =0.10 (Matsukawa et al., 1995).

Data Analysis

Baseline esophageal temperature and relative perfusion index were calculated as the mean values of the last five minutes of baseline conditions. Esophageal temperature means during exercise and recovery were calculated as the mean of the two minutes prior to the specified time. Relative Perfusion Index means during exercise and recovery were calculated as the mean of the five minutes surrounding the specified time.

All data was analyzed using SPSS Version 9.0 for Windows. A repeated measures multi-way analysis of variance was used to determine whether a relationship exists both within and between the groups. Independent and paired t-tests were then used to examine these relationships. However, multiple testing in this manner increases the probability of type I error. Thus, the p value for significance was adjusted using a Bonferroni correction of 0.05/the number of comparisons (Hassard, 1991). In this case, four t-tests were performed, making the p value 0.0125. This more stringent standard ensures the overall probability of a type I error is held at an acceptable level of 0.05. All dependent variables were analyzed separately. In addition, a one-way analysis of variance was used to identify differences in esophageal temperatures from baseline. Histograms revealed that the data did not breach a normal distribution, and that the variances of the groups were similar.

No data was available to conduct sample size calculations prior to the onset of the study, as there was not sufficient literature in the area of thermoregulatory adaptations associated with moderate physical activity. A power analysis was conducted post-hoc using methods described by Keppel (1982).

C. Results

Subject Characteristics

Pre-test values for subject age and estimated energy expenditure for physical activity are presented in Table 1. All subjects were sedentary prior to the start of the study, and there were no significant differences in energy expenditure as determined by the seven-day recall questionnaire, between training and control groups. Pre and post-test values for weight and BMI are presented in Table 2. There were no significant differences between training and control groups at pre-test.

Table 1. Pre-test values for subject age and energy expenditure during physical activity in training and control groups. Values are means (SD).

Group	Age	% energy expenditure	estimated energy expenditure	estimated energy expenditure
	(years)	>4 METS	(kcal/week)	(kcal/kg/day)
Training (n=8)	25.13 (7.47)	4.9 (2.0)	907 (348.3)	1.56 (0.57)
Control (n=4)	22.25 (2.50)	4.2 (1.0)	801 (281.9)	1.40 (0.35)

Table 2. Pre and post test values for aerobic fitness and body composition for training and control groups. Values are means (SD).

Group	Weight (kg)		BMI (kg/m^2)		SO5S (mm)		V02peak (ml/kg/min)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Training (n=8)	82.79 (11.53)	79.55 (15.66)	26.31 (2.76)	25.59 (3.42)	47.58 (15.61)	57.26* (16.65)	39.71 (7.52)	44.98** (8.32)
Control (n=4)	80.63 (13.74)	79.89 (14.07)	23.25 (3.63)	23.38 (3.21)	42.53 (25.02)	46.20 (17.75)	41.05 (10.27)	41.15 (11.56)

**Significant difference with training (p<0.01).
*Significant difference with training (p<0.025).

Compliance

All 8 subjects of the initial training group completed the training program. There were no drop-outs or injuries.

Training Program Characteristics and Energy Expenditure

The training group commenced the 12 week training program immediately following the initial testing and randomization of subjects. This occurred at the end of September, therefore final testing was completed in December and January. No testing was conducted with the training group during the first two to three weeks of January in order to avoid confounding results due to detraining that may have occurred during the exam and holiday break (n=4). Therefore subjects who completed the 12 weeks of training during the holiday break, engaged in an additional two to three weeks of training. Although the training program was slightly longer in duration for these subjects, little training occurred during the holiday. Figure 1 illustrates the timeline of the study.

The first week of the training program resulted in a mean estimated energy expenditure of 918.9 ± 128.0 kcal/wk, and gradually increased in time to yield a peak activity level of 289 ± 37 minutes of physical activity, or 2158.1 kcal/wk ± 672.0 kcal of energy expenditure. Figure 2 illustrates the progression of time during the moderate intensity training program. The mean duration of exercise sessions was 39 ± 8 minutes.

The most common form of physical activity was recreational sports such as hockey, volleyball, and badminton. The next most popular activities were stationary biking and moderate intensity resistance training. Table 3 presents the types of activities the training group participated in, and the relative proportion of time spent participating in each. Training subjects attended a mean of 0.8 supervised training sessions per week. Subjects in the training group who participated in very little supervised training, were contacted by the investigator on a weekly basis. The control group participated in a mean of 25 ± 29 minutes of physical activity per week, or 179.1 ± 207.1 kcal/wk of estimated energy expenditure. This was not statistically different from energy expenditure at pre-test.

Table 3. Relative time spent participating in each activity by the training group.

	% Exercise Time					
	Bike	Walk/Jog	Recreational Sports	Other Cardio Machines	Resistance Training	Supervised Training
Subject 1	26	10	33	2	29	15.2
Subject 2	7	14	69	-	10	8.9
Subject 3	23	5	72	-	-	10.9
Subject 4	5	16	41	35	3	29
Subject 5	18	5	66	7	4	17.5
Subject 6	34	7	9	9	41	5.8
Subject 7	31	3	32	34	-	11.9
Subject 8	53	4	17	3	23	2
Mean	24.6	8	42.4	11.3	13.8	12.7
SD	(15.5)	(4.8)	(24.2)	(14.7)	(15.4)	(8.2)

Effect of Training on Anthropometric Variables

Mean values for weight, body mass index, and sum of five skinfolds for training and control groups are displayed in Table 2. There were no significant differences in weight or BMI either between groups or with the intervention. There was a significant increase in the sum of five skinfolds during the training period.

Effect of Training on Aerobic Fitness

The mean V02peak values for the training and control groups are displayed in Table 2. There was a significant increase of approximately 13% in V02peak with training.

All subjects reached subjective exhaustion, as determined by a rating of perceived exertion, during the V02peak tests. During the initial V02peak tests, 11 of the 12 subjects were within 10 beats of their age predicted maximum heart rate, or had a respiratory exchange ratio of at least 1.1. During the final V02peak tests, 10 of the 12 subjects reached this criteria. This suggests that the V02peak values were near maximal (Brooks, Fahey, & White, 1996).

Mean heart rate values during V02max tests were also used to assess aerobic fitness. Improvements in aerobic fitness were evident among the training group as mean submaximal heart rates were significantly lower than pre-test values at given points during the V02peak tests. No such changes were observed in the control group (Figure 3).

Mean values for exercise tolerance time during the V02peak test for the training group were 9.08 ± 1.93 minutes and 10.76 ± 1.81 minutes for pre and post tests respectively. Mean values for the control group were 9.46 ± 2.36 minutes and 9.18 ± 2.95 minutes for pre and post tests, respectively. Exercise tolerance time increased significantly ($p<0.001$) with training. Mean tolerance time in the training group increased by approximately 19% (Figure 3).

Effects of Training on Heat Tolerance Variables

The heat tolerance tests were conducted at a constant 32°C and 32% relative humidity. Data from only the first ten minutes of the recovery period was analyzed, as three subjects requested to end the test prior to completing the entire 15 minute recovery period. Eleven of the 12 subjects completed at least ten minutes of the recovery period. During the pre-test, one subject in the control group (Subject #10) experienced a vasovagal response 1.1 minutes post-exercise. Extreme vasodilation, nausea, and dizziness characterized this reflex. Therefore, the heat tolerance test was concluded prior to the end of the recovery period, and all recovery data obtained from this subject was excluded from data analysis.

Esophageal Temperature

Due to personal discomfort, one subject in the training group (Subject #8) refused the insertion of the esophageal temperature probe during the final heat tolerance test. For this subject, a tympanic temperature probe was inserted through the left aural canal to the tympanic membrane. The aural canal was then covered with cotton and sealed from the outside environment. In addition, the ear was covered with an insulated ear muff. Therefore, the post-intervention core temperature data reflects one tympanic temperature, and 11 esophageal temperatures.

Figure 4 presents the esophageal temperatures of training and control groups. No significant differences were observed between groups or with intervention. Data was re-analyzed excluding subject #8, and again no significant differences were observed.

Core temperature data were also analyzed as a change in esophageal temperature relative to baseline, as this negates the influence of differences in baseline temperature between initial and final heat tolerance tests. Figure 5 presents the changes in esophageal temperature throughout the heat tolerance tests. No significant differences were observed between groups or with intervention. The mean values for the decrease in T_{es} from the end of exercise to the end of the recovery period in the training group were 0.43ºC ± 0.44 and 0.27ºC ± 0.28 for pre and post tests respectively. Mean values for the control group were 0.29ºC ± 0.15 and 0.32ºC ± 0.23 for pre and post tests respectively. No significant differences were observed between groups or with intervention. Data was re-analyzed excluding subject #8, and again no significant differences were observed between groups.

A one-way ANOVA revealed a significant change in esophageal temperature from baseline in the training group at pre-test, and in the control group at both pre and post-test. However, no significant change in esophageal temperature from baseline was observed in the training group at post-test.

Average Skin Temperature

Figure 6 presents average skin temperature of training and control groups. A significant difference ($p<0.05$) in baseline T_{skavg} was observed between training and control groups during the post-test. At this point, the T_{skavg} of the training group was significantly higher than that of the control group. No significant time effect was observed in baseline T_{skavg}. No other significant differences were observed either between groups or with intervention for the duration of the heat tolerance test.

During three heat tolerance tests, various thermocouples became untaped from the skin surface. In these tests, the regional weightings were redistributed in such a manner where the thermocouples that came away from the skin surface were ignored for the duration of the test, and their regional weighting reassigned to other representative thermocouples. One subject had 11 sites, one 10 sites, and one 9 sites. To remain consistent, initial and final heat tolerance tests used the same regional weightings for T_{skavg} for each subject. In these cases, sweat threshold was calculated using the revised skin temperature.

Sweat Threshold

Table 4 presents the T_{skavg}, T_{es}, and $T_{es(calculated)}$ at the sweat threshold for training and control groups. No significant differences in calculated Tes at the sweat threshold were observed either between groups or with intervention. Data was re-analyzed excluding subject #8, and again no significant differences were observed between or within groups. In order to account for daily variability in baseline esophageal temperatures, threshold data was also analyzed as a change in calculated T_{es} from baseline. No significant differences were observed between or within subjects. Data was re-analyzed excluding subject #8, and again no significant differences were observed between or within groups. Figure 7 presents the changes in calculated Tes for training and control groups.

Table 4. Esophageal, average skin temperatures, and calculated esophageal temperatures at sweat threshold for training and control groups. Values are means (SD).

	Tes (ºC)		Tskavg (ºC)		Calculated Tes (ºC)	
	Pre	Post	Pre	Post	Pre	Post
Training (n=8)	36.93 (0.33)	37.03 (0.38)	34.35 (0.43)	34.53 (0.27)	36.91 (0.34)	36.95 (0.40)
Control (n=4)	36.74 (0.49)	36.64 (0.18)	34.27 (0.36)	34.03 (0.27)	36.71 (0.52)	36.59 (0.19)

Relative Perfusion Index

Figure 8 presents PIr for training and control groups. At 12.5 minutes prior to the start of exercise, and at 7.5 minutes prior to exercise, there was a significant ($p<0.01$)

increase in PIr with training. No differences were observed in the control group. There were no significant differences either between groups or with intervention for the remainder of the test. Although not statistically significant, the mean PIr among the post-test control group tended to be higher during the recovery period. This was due to one subject's PIr reading rising to 4.11. There was no evidence to suggest this value was confounded in any way. Since there was only data from three control subjects at this point, the increase in PIr of the one subject drove up the mean substantially.

Power Analysis

The calculations for V02peak, sum of five skinfolds, average skin temperature, and relative perfusion index, revealed that less than six subjects were required to reach the 80% power level with alpha at 5%. Sample size calculations on the core temperature variables; esophageal temperature, change in esophageal temperature from baseline, and change in calculated esophageal temperature, revealed that an acceptable power level cannot be reached with 12 subjects. In the present study, the error variation for these core temperature variables was relatively low and the (sum of deviations from the mean)^2 was very small.

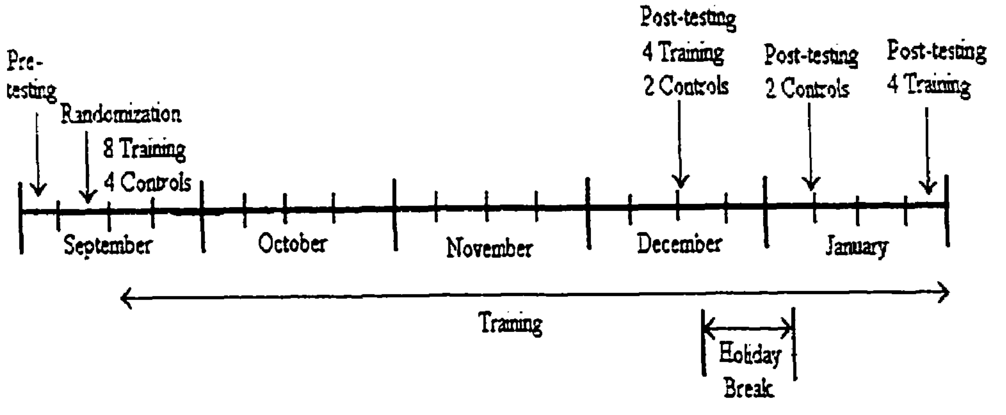
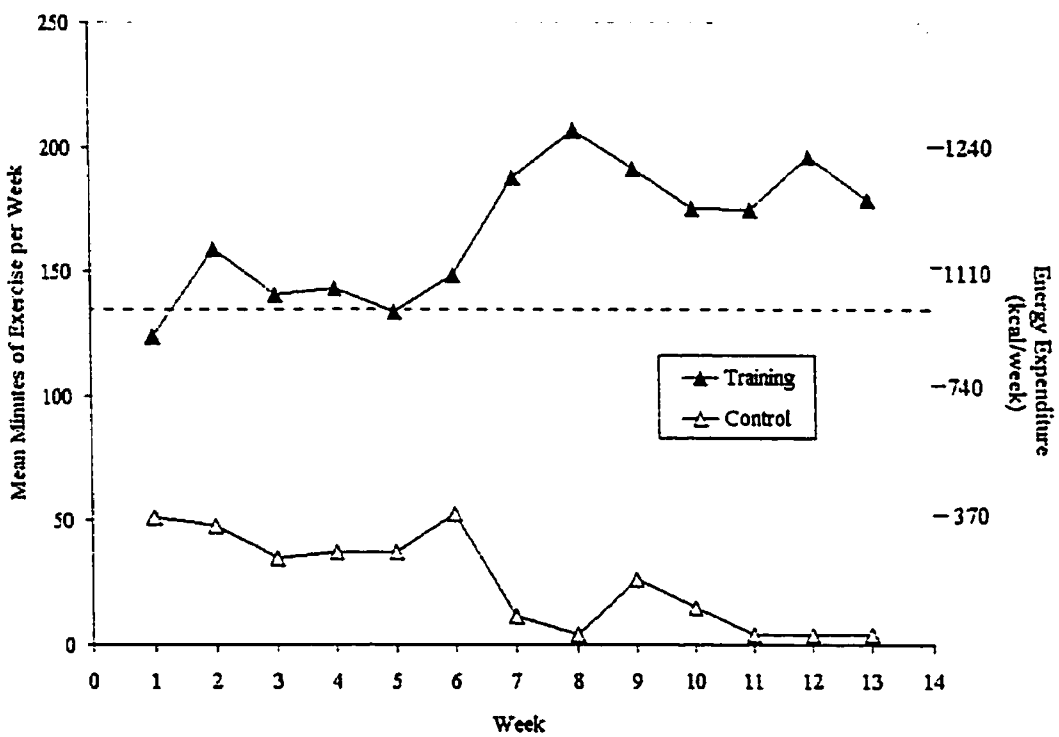
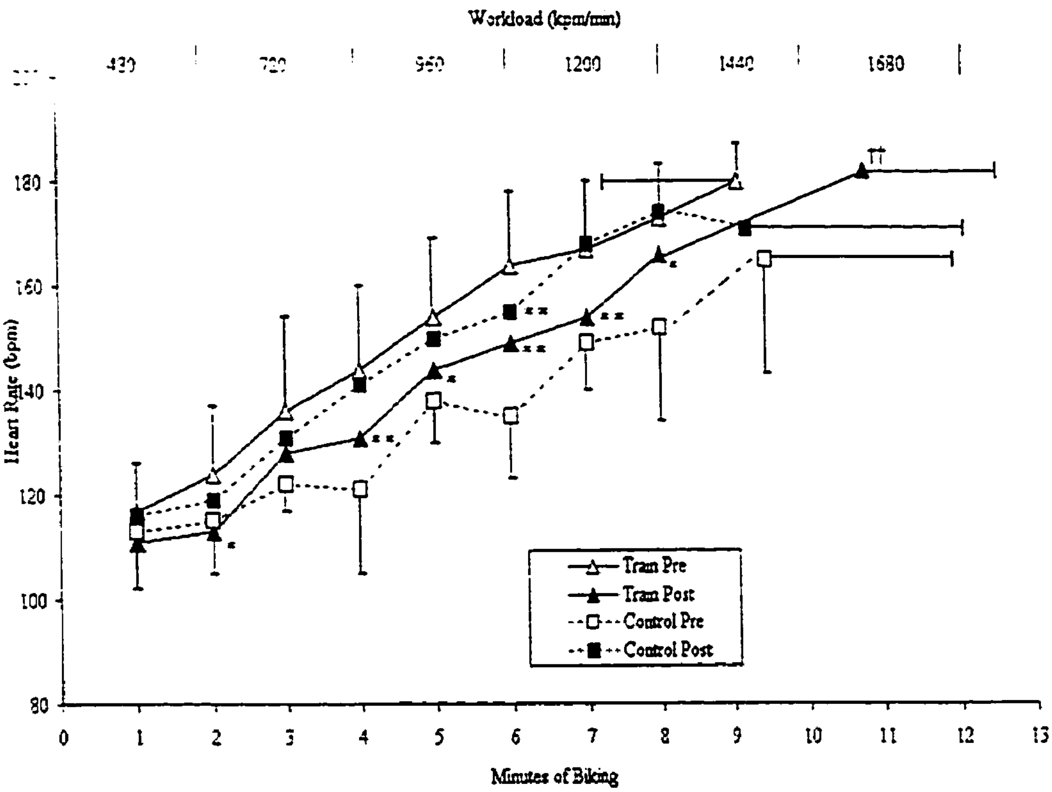


Figure 1. Timeline of present study.



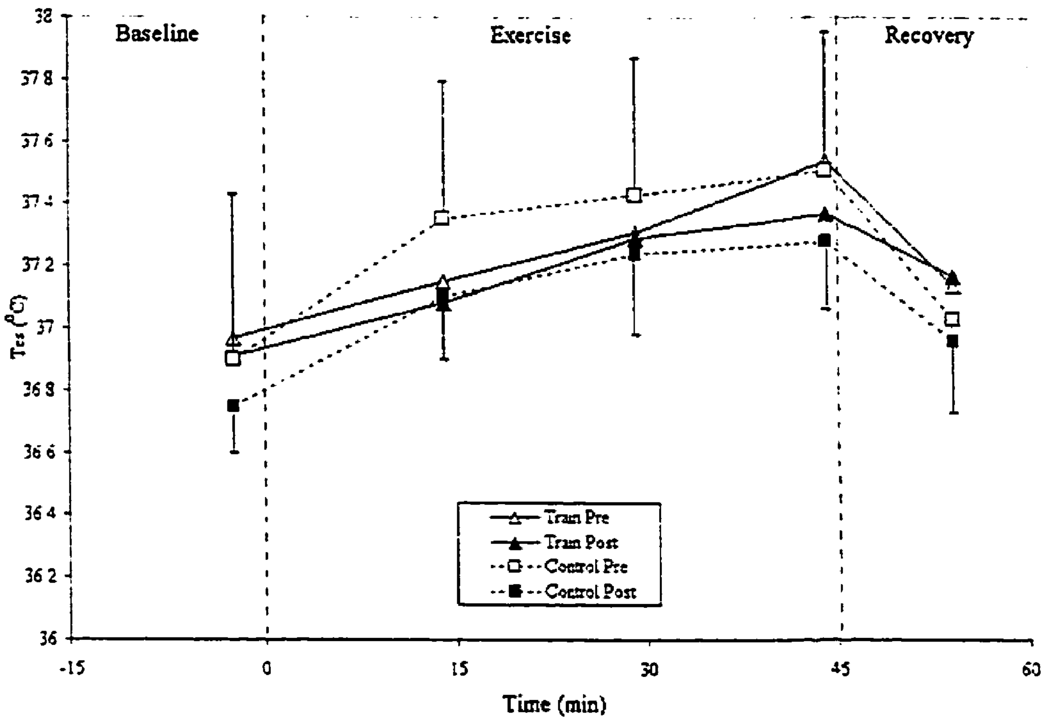
Dotted line represents energy expenditure recommended by the Surgeon General and Health Canada and CSEP, based on mean weight of subjects.

Figure 2. Mean minutes of physical activity for training and control group during intervention period.



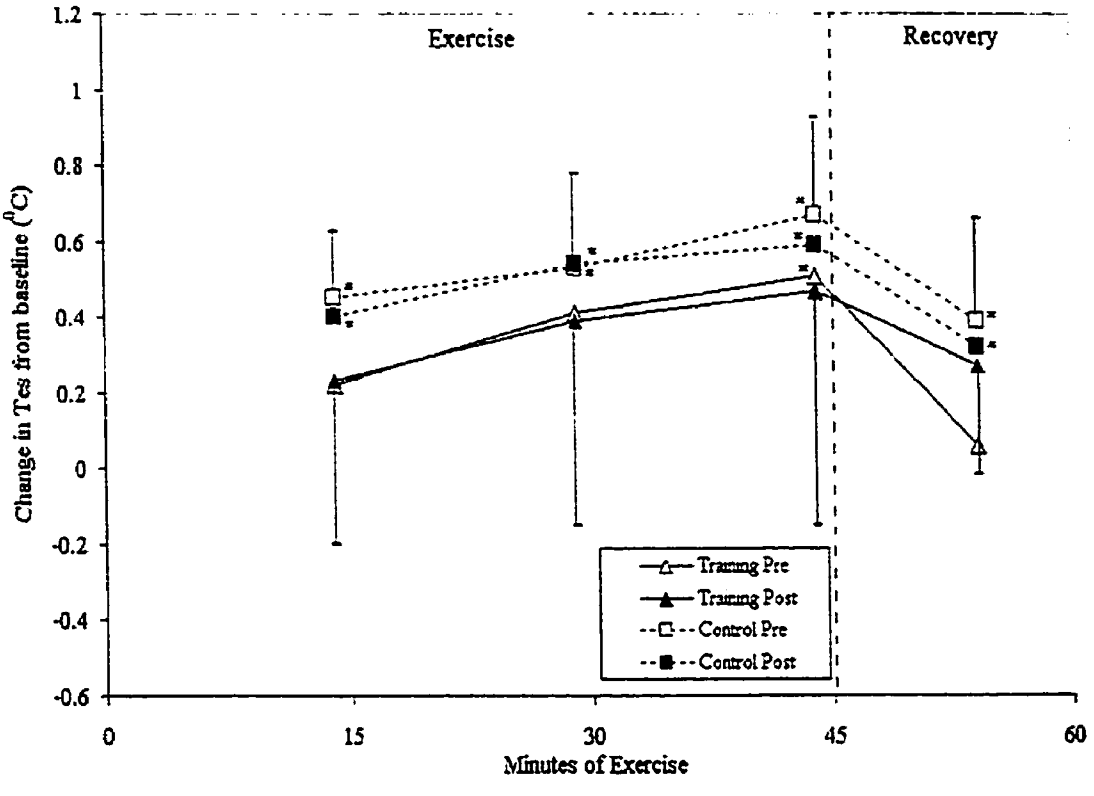
* Significant difference in heart rate within group pre to post (p<0.025).
**Significant difference in heart rate within group pre to post (p<0.01).
†† Significant difference in exercise tolerance time pre to post (p<0.01).
Horizontal bars represent standard deviation of exercise tolerance time.

Figure 3. Heart rates during pre and post V02peak tests for training and control groups.



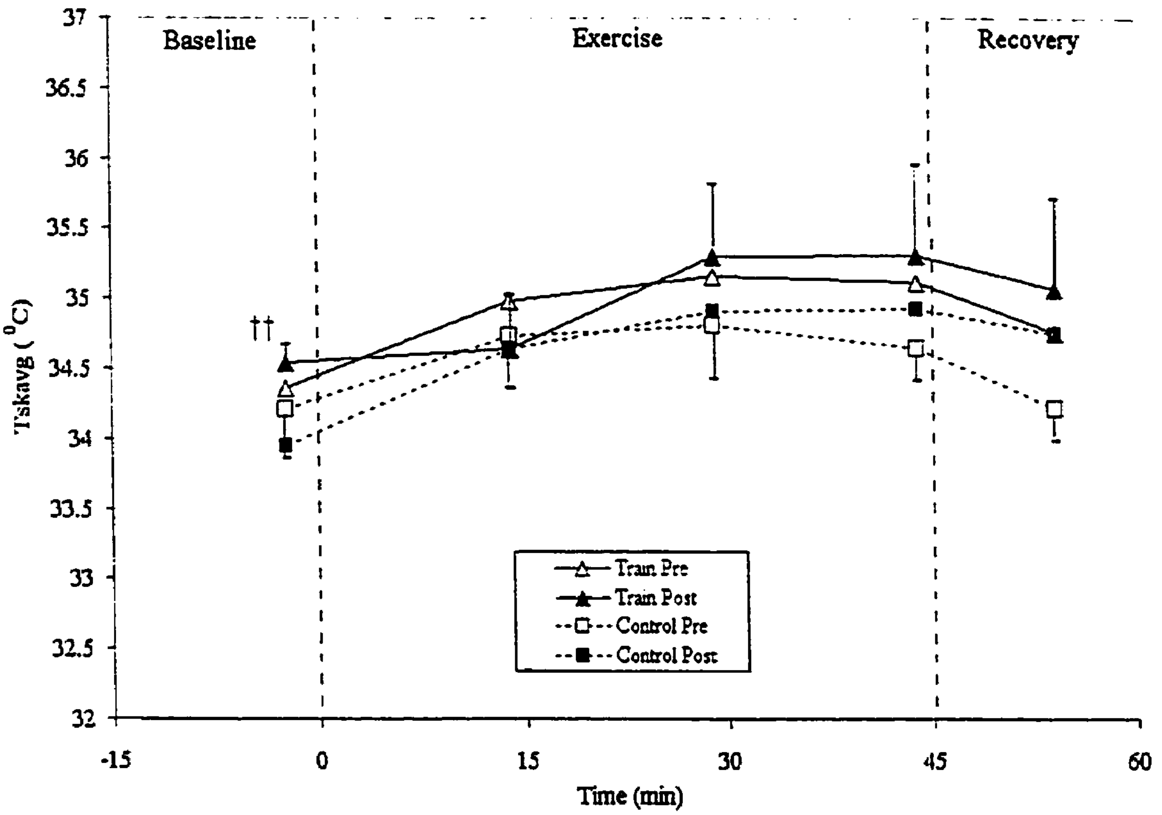
No significant differences between groups or with intervention.

Figure 4. Mean esophageal temperatures for training and control groups.



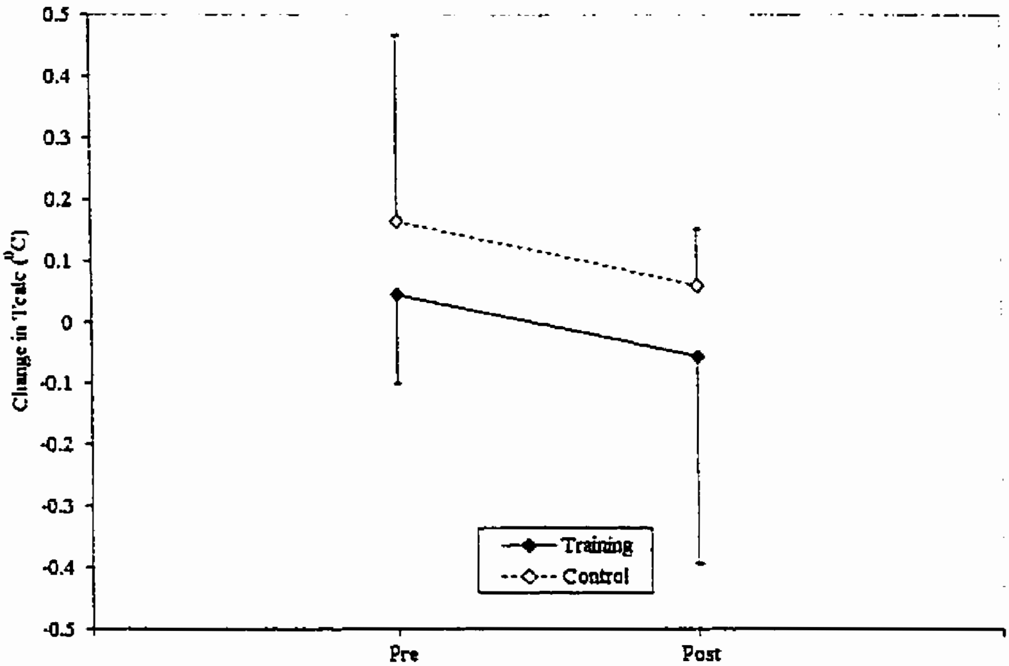
No significant differences between groups or with intervention.
* Significantly different from baseline ($p<0.05$).

Figure 5. Mean changes in esophageal temperature from baseline for training and control groups.



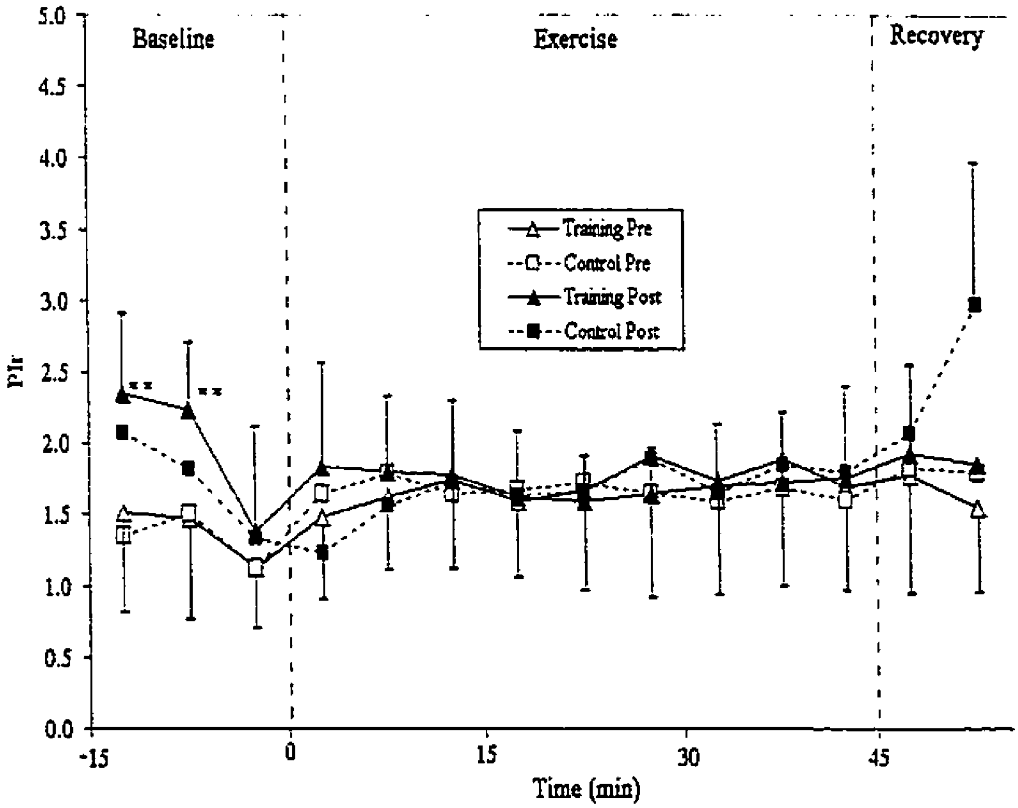
†† Significant difference between training and control groups at post-test ($p<0.01$).

Figure 6. Mean average skin temperatures for training and control groups.



No significant differences between groups or with intervention.

Figure 7. Mean change in calculated esophageal temperatures at the sweat thresholds for training and control groups.



**Significant difference within group with training (p<0.01).

Figure 8. Mean relative perfusion index for training and control groups.

D. Discussion

This study is unique in that it addresses heat tolerance as a health issue, and examines the effects of a moderate training intervention on thermoregulation during moderate exercise in the heat. This study is based on an active living model, which proposes that health benefits are related to energy expenditure in a dose-response fashion. To our knowledge, it is the first study to examine the relationship between moderate exercise and thermoregulation in the context of health.

Although some positive fitness changes were observed in the training group, this program provided a minimal improvement in heat tolerance. The present study shows evidence that training increased blood flow to the periphery during rest in a warm environment, suggesting a moderate intensity training program increases heat loss via conduction of heat through the skin while at rest. This finding is important because it is a primary mechanism by which one's heat tolerance is improved. However this increased efficiency of blood flow did not yield a decrease in core temperature. No adaptive changes were present during exercise in the heat, indicating that metabolic demand of the working muscle competed with the demand of the blood flow from the skin. This suggests health benefits associated with heat adaptations may require more vigorous exercise than recommended by current physical activity guidelines.

Subject Characteristics

All subjects were male, and under 45 years of age. When energy expenditure was expressed as a percentage of activities >4 METS, subjects were deemed to be sedentary (Bernstein, Morabia, & Sloutskis, 1999). At the pre-test, subjects expended a mean of

871 kcal/week during physical activity, thus below the 1000 kcal/wk or 150 kcal/day recommended for health benefits by the U.S. Surgeon General (US Department of Health and Human Services, 1996). In addition, they were only moderately active, as they expended a mean of 1.5 kcal/kg/day prior to pre-testing. This is well below the 3 kcal/kg/day recommended by Health Canada and the Canadian Society of Exercise Physiology (1998b).

Training Program Characteristics

The training program progressed to a mean estimated energy expenditure of 2158 kcal/week during activity, and thus exceeded the 1000-2000 kcal/week guidelines set forth by the U.S. Surgeon General. In terms of Health Canada and the Canadian Society of Exercise Physiology's recommendation of energy expenditure greater than 3 kcal/kg/day, the training program resulted in subjects expending a mean of 3.85 kcal/kg/day. Therefore, the subjects were initially below the recommendations for physical activity set forth by these agencies, and progressed to activity levels beyond the recommendations. It took two weeks to achieve the amount of physical activity recommended by the Surgeon General and Health Canada and CSEP. Interestingly, the energy expenditure of the control group, measured by the 7-day recall at pre-test, was quite different from that measured by the log book during the control period. This is due to the difference in instruments used to assess energy expenditure during these periods.

Although subjects were instructed to train at approximately 50% of their V02reserve, it is likely that the recreational sports were of greater intensity. Due to the intermittent nature of these recreational sports, it is difficult to determine the exact training intensity during these activities. This further demonstrates the active living concept of accumulating physical activity in enjoyable lifestyle activities. Energy expenditure was calculated in accordance to heart rates recorded in the log book.

Effects of Training on Aerobic Fitness

In terms of aerobic fitness, the effects of the 12 week training program are typical. The decrease in submaximal heart rates during the V02peak tests represents an improvement in aerobic fitness, and is characteristic following a moderate intensity aerobic training program. Other studies employing a similar training program demonstrate similar improvements in V02peak (Wenger & Bell, 1986; Seals, Hagberg, Hurley, Ehsani, & Holloszy, 1984; Santiago, Alexander, Stull, Serfrass, Hayday, & Leon, 1987). Furthermore, the 13% increase in V02peak following the training intervention is consistent with the ACSM Position Stand, which states that a training program of approximately 40-50% V02peak regularly results in a 10-15% improvement in V02peak (Pollock et al., 1998). Based on this Position Stand, we would not expect V02peak to increase any further if this type of training continued beyond 12 weeks.

The increase in V02peak observed in the present study is below the suggested threshold of a 15-20% increase required to elicit improvements in heat tolerance. This allows for the comparison of different intensity training programs, and allows us to address the hypothesis that moderate intensity training resulting in an increase in V02peak below 15-20% may evoke thermoregulatory adaptations to heat.

Effects of Training on Anthropometric Variables

In terms of body composition, there was a noted increase over time in the sum of skinfolds among the training group, however the changes in amounts of intramuscular and intrabdominal fats are unknown. Although the training group increased their energy expenditure, they may also have increased their energy intake during the intervention period. Four of the eight training subjects demonstrated a mean increase of 10% in SO5S, therefore dramatically raising the post-test mean.

The coefficient of variation of skinfold measurements in the training group ranged from 29-33%, which is about 10% higher than that seen by Nordhamn et al. (2000). This variation is most likely due to the relatively small sample size, confounded by the highly variable nature of the skinfold measurement.

Effects of Training on Thermoregulatory Variables

The present study reveals evidence of adaptations to the thermoregulatory system under resting conditions in the heat, as training led to increased peripheral blood flow. Physiologically, this occurs via a removal of vasoconstrictor activity to blood vessels (Sawka, Wenger, & Pandolf, 1996), allowing heat dissipation to occur with little energy cost, and without the loss of sodium. However, this increased peripheral blood flow was not sufficient to lessen the change in core temperature from baseline, therefore the training program did not yield improvements in heat tolerance. There is evidence that the training program started the beginning of a process that would favor heat loss and attenuate the increase in core temperature. It is possible that had passive baseline conditions continued for a greater duration, the improved peripheral blood flow may have prevented the increase in core temperature that may have been evident in the control group.

Once exercise commenced, the training group was at no thermoregulatory advantage to the control group, nor were their thermoregulatory responses different from that of the pre-test. Therefore, the training program did not yield any significant changes in core temperature variables during an exercise-heat stress, and the vasodilatory effect seen at rest was not present during exercise. This is most likely a function of the metabolic demand of the active muscle for blood flow, competing with the thermoregulatory demand of the skin (Sawka, Wenger, & Pandolf; 1996).

There is evidence of some thermoregulatory effect of training. For instance, adaptations in blood flow distribution at rest were evident as a result of training. In addition, a one-way ANOVA reveals significant changes in Tes from baseline in the training group at pre-test, yet not at post-test. However, when data is analyzed using a more powerful statistical tool, a repeated-measures MANOVA, no significant differences were noted. Furthermore, during post-tests, Tes in two training subjects decreased with exercise. Again, this is evidence that we are on the verge of a threshold of activity required for thermoregulatory adaptations.

In agreement with the present study, Cheung & McLellan (1998) found no significant changes in core temperature in response to one hour per day of continuous moderate intensity training in a thermoneutral environment for 12 days. Interestingly, unlike the present study, Cheung & McLellan noted significant decreases in skin temperature throughout the heat-exercise stress.

There is an important difference between the study of Cheung & McLellan and the present study. The previous training program consisted of one hour of continuous exercise, whereas subjects in the present study were permitted to accumulate physical activity in bouts of 10 minutes or more. It is well established that health benefits can be attained by accumulating physical activity in bouts of 10 minutes or more, as overall caloric expenditure is directly associated with health benefits (Paffenbarger et al., 1984; Gaesser & Rich. 1984; Pate et al., 1995; Ballor, McCarthy, & Wilterdink, 1990). However, there is ample evidence that physical activity must increase one's core temperature in order to evoke benefits in heat tolerance (Avellini, Shapiro, Fortney, Wenger, & Pandolf, 1982). It is possible that the exercise bouts of 10 minutes or less did not allow for sufficient time for heat strain to ensue, and thus for thermoregulatory adaptations to occur. The accuracy of the reported mean exercise session duration of 39 minutes is questionable, as subjects may have only recorded their total minutes of activity for the day, and not the duration of the bouts throughout the day. Therefore, in terms of exercise duration, the manner in which physical activity was accumulated is unclear. It is possible that if the training is moderately intense, 20-30 minutes of continuous exercise is key to eliciting thermoregulatory adaptations to a heat-exercise stress, as it allows for adequate internal heat strain.

The present study supports the classical suggestion that a minimum 15-20% increase in V02max is required to elicit improvements in heat tolerance when training in a thermoneutral environment (Gisolfi, 1973). It appears that the training stimulus employed by the present study lies near a threshold for stimulus associated with thermoregulatory adaptations in response to heat. As demonstrated in the present study, moderate intensity training in a thermo-neutral environment may stimulate a small degree of adaptation to the thermoregulatory system. However, since this intensity of training does not evoke changes in core temperature, it does not provide a substantial health benefit. The present study supports the concept that the intensity of training is a major determinant of the magnitude of adaptations with training (Cheung & McLellan, 1999; Houmard et al., 1990; Gislofi, 1973). In addition, the extent to which core temperature rises during training also plays a role in determining the extent of adaptation (Houmard et al., 1990; Avellini, Shapiro, Fortney, Wenger, & Pandolf, 1982). This helps to explain why moderate intensity training in the heat evokes improvements in heat tolerance more so than moderate intensity training in a thermonuetral environment.

Power Analysis

Sample size calculations for V02peak, S05S, T_{skavg}, and PIr, confirm that at points where no significant differences were observed, it is safe to assume that there truly are no differences in means. The calculations for core temperature variables; T_{es}, change in T_{es} from baseline, and change in $T_{es(calculated)}$ revealed that an acceptable power level cannot be reached with 12 subjects. However, it is critical to note that this is due to the very small (sum of deviations from the mean)^2, or in other words the very small difference between means, rather than a large error variation.

Previous studies report significant differences in T_{es} variables with less than 10 subjects (Nadel, Pandolf, Roberts, & Stolwijk, 1974; Roberts. Wenger, Stolwijk, & Nadel, 1977). In addition, numerous studies with less than 10 subjects have reported significant differences in rectal temperature with training (Houmard et al., 1990; Cheung & McLellan, 1998; Gisolfi, 1973), which has been shown to be a more variable measure of core temperature (Cooper & Kenyon, 1957; Mariak, Lewko, Luczaj, Polocki, & White, 1994). It is also important to note that although one heat tolerance test utilized a tympanic temperature, the literature supports it as a valid and reliable method to measure core temperature (Ablonik et al., 1999; Mariak et al., 1994; Benzinger, 1969). Therefore, it is likely that no significant differences in T_{es} were observed in the present study, because unlike the previously mentioned studies, the means truly were very similar. We can reasonably assume the active living training intervention did not elicit true changes in T_{es} responses to a heat-exercise stress.

Role of Exercise Duration and Intensity

The literature has established clear differences in the exercise intensity required to yield health versus fitness benefits. For instance, accumulating energy expenditure in performance of physical activity, be it moderate or high intensity, yields benefits in various health parameters (Lee & Paffenbarger, 2000; Manson et al., 1999). Although still controversial, certain studies have demonstrated that when overall caloric expenditure is held constant, high intensity training does not produce benefits beyond which can be attained by moderate intensity activity (Paffenbarger, Hyde, Wing, & Hsieh, 1986; Duncan, Gordon, & Scott; 1991). However, in terms of fitness benefits, high intensity exercise is key to producing benefits, rather than overall caloric expenditure.

According to recent literature, a training program resulting in this degree of energy expenditure should yield health benefits (Pate et al., 1995; Pollock et al., 1995; Lee & Paffenbarger, 2000). The training program employed in the present study encouraged subjects to participate in a given amount of moderate intensity exercise, on most days of the week. Since health benefits can be attained by accumulating short bouts of activity (Kjaer, Anderson, & Hansen, 2000) subjects were permitted to accumulate this time in bouts of 10 minutes or longer in duration. The Surgeon General and Health Canada state that accumulating activity in this manner will evoke health benefits (US Department of Health and Human Services, 1996; Health Canada and the Canadian Society of Exercise Physiology, 1998b).

Unlike health benefits, accumulating moderate intensity physical activity does not yield substantial fitness benefits. In this case, training must be beyond a threshold intensity to yield large improvements (Tabata et al., 1996). The ACSM Position Stand report this threshold to be approximately 65% V02Reserve (Pollock et al., 1998). Since our training program was above the energy expenditure required for health benefits as recommended by the Surgeon General and Health Canada and CSEP, yet below that required for large improvements in fitness, we can determine whether our training program evoked health benefits in terms of heat tolerance.

Our training program demonstrated small effects in terms of thermoregulatory adaptation, and did not yield substantial improvements in heat tolerance. This suggests the training-heat adaptation relationship follows more of a fitness response than a health response.

E. Conclusions and Recommendations

In summary, a moderate physical activity program elicits improvements in heat loss via conduction and radiation through the skin surface during resting conditions in the heat. A training stimulus of this nature does not appear to provide changes in core temperature or sweating responses. It is well established that moderate intensity training in the heat, as well as high intensity training, provides a thermoregulatory health benefit. It would be imprudent for health professionals to encourage high intensity exercise, or exercise in the heat to an untrained individual, as undue cardiovascular stress and dehydration may ensue. In addition, in cooler climates it may be impractical to find facilities that allow for exercising in the heat.

An ideal follow up study would involve three groups; one moderate intensity training of 10 minute bouts, one with 30 minute bouts of moderate intensity training, and one control group. Both training groups would have the same energy expenditure. This would help to better define the dose-response relationship of heat tolerance benefits associated with exercise, and help set physical activity guidelines to the general population.

In addition, future research opportunities should examine the effects of moderate intensity training on the thermoregulatory system during passive conditions in the heat. It would be interesting to see whether the core temperature of a control group increases, thus suggesting moderate training prevents increases in core temperature.

It is also important to note that these results are not generalizable to other populations. Heat-related illness and mortality is more of an issue for elderly and sick populations, rather than for healthy men. Therefore, future studies should include older populations. In addition, the full effects of heat tolerance among pre, peri, and post-menopausal women, as well as among pregnant women should be addressed. It is concluded that although a moderate intensity training program in a thermo-neutral environment improves one's aerobic fitness, it provides only a small degree of adaptation to a heat-exercise stress. This suggests that health benefits associated with heat adaptations may require more vigorous exercise than recommended by current physical activity guidelines.

E. Reference List

Abolnik, I. Z., Kithas, P. A., McDonnald, J. J., Soller, J. B., Izrailevsky, Y. A., & Granger, D. L. (1999). Comparison of oral and tympanic temperatures in a veterans administration outpatient clinic. American Journal of Medicine and Science, 317(5), 301-303.

American College of Sports Medicine. (2000). ACSM's Guidelines for Exercise Testing and Prescription. Media, PA: Williams and Wilkins.

Barrow, M. W. & Clark, K. A. (1998). Heat –related illnesses. American Family Physician, 58(3), 749-56.

Benzinger, M. (1969). Tympanic thermometry in surgery and anesthesia. Journal of the American Medical Association, 209(8), 1207-1211.

Bernstein, M., Morabia, A., & Sloutskis, D. (1999). Definition and prevalence of sedentarism in an urban population. American Journal of Public Health, 89(6), 862-7.

Blair, S., Haskell, W., Ho, P., Paffenbarger, R. Jr., Vranizan, K., Farquhar, J., & Wood, P. (1985). Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. American Journal of Epidemiology, 122, 794-804.

Brooks, E. M., Morgan, A. L., Pierzga, J. M., Wladkowski, S. L., O'Gorman, J. T., Deer, J. A., & Kenney, W. L. (1997). Chronic hormone replacement therapy alters thermoregulatory and vasomotor function in postmenopausal women. Journal of Applied Physiology, 83(2), 477-84.

Brooks, G. A., Fahey, T., & White, T. (1996). Exercise Physiology. Human Bioenergetics and its applications, 2nd Edition. Mountain View, CA: Mayfield Publishing Company, 290.

Canadian Society for Exercise Physiology. (1996). Professional Fitness and Lifestyle Consultant Resource Manual. Ottawa, ON: Canadian Society for Exercise Physiology.

Center for Disease Control and Prevention. (1994). Heat-related deaths- Philadelphia and United States, 1993-1994. Morbidity and Mortality Weekly Report, 43(25), 453-5.

Center for Disease Control and Prevention. (1995b). Heat-related mortality – Chicago, July 1995. Morbidity and Mortality Weekly Report, 44(31), 577-9.

Center for Disease Control and Prevention. (1996). Heat-wave-related mortality – Milwaukee, Wisconsin, July 1995. Morbidity and Mortality Weekly Report, 45(24), 505-7.

Center for Disease Control and Prevention. (1999). Heat-related illnesses and deaths-Missouri, 1998, and United States, 1979-1996. Morbidity and Mortality Weekly Report, 48(22), 469-73.

Cheung, S., & McLellan, T. (1998). Influence of short-term aerobic training and hydration status on tolerance during uncompensable heat stress. European Journal of Applied Physiology, 78, 50-8.

Cheung, S. & McLellan, T. (1999). Comparison of short-term aerobic training and high aerobic power on tolerance to uncompensable heat stress. Aviation, Space, and Environmental Medicine, 70(7), 637-43.

Cooper, K. E., & Kenyon, J. R. (1957). A comparison of temperatures measured in the rectum, esophagus, and on the surface of the aorta during hypothermia in man. The British Journal of Surgery, 44, 616-619.

Duncan, J., Gordon, N., & Scott, C. (1991). Women and walking for health and fitness; How much is enough? Journal of the American Medical Association, 266(23), 295-9.

Gisolfi, C. (1973). Work-heat tolerance derived from interval training. Journal of Applied Physiology, 35(3), 349-354

Hassard, T. (1991). Understanding Biostatistics. St. Louis: Mosby Year Book.

Health Canada and the Canadian Society for Exercise Physiology. (1998a). Canadian Physical Activity, Fitness and Lifestyle Appraisal Manual. Ottawa, ON: Health Canada and the Canadian Society for Exercise Physiology.

Health Canada and the Canadian Society for Exercise Physiology. (1998b). Canada's Physical Activity Guide for Healthy Active Living. Ottawa, ON: Health Canada and the Canadian Society for Exercise Physiology.

Henane, R., Flandrois, R., and Charbonnier, J. P. (1977). Increase in sweating sensitivity by endurance conditioning in man. Journal of Applied Physiology, 43(5), 822-8.

Houmard, J. A., Costil, D. L., Davis, J. A., Mitcell, J. B., Pascoe, D. D., & Robergs, R. (1990). The influence of exercise intensity on heat acclimation in trained subjects. Medicine and Science in Sports and Exercise, 22(5), 615-20.

Keppel, G. (1982). Design and analysis: A Researcher's Handbook, 2nd Ed. New

Jersey: Prentice-Hall.

Kjaer, M., Anderson, L., & Hansen, I. (2000). [Physical activity-what minimal level is sufficient seen from a health perspective?] Ugeskr Laeger, 162(15), 2164-9.

Lee, I., & Paffenbardger, R., Jr. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity: The Harvard Alumni Health Study. American Journal of Epidemiology, 151(3), 293-9.

Lee, I., Rexrode, K., Cook, N., Manson, J., & Buring, J. (2001). Physical activity and coronary heart disease in women. Is "no pain no gain" passe? Journal of the American Medical Association, 285(11), 1447-54.

Manson, J., Hu, F., Rich-Edwards, J., Colditz, G., Stampfer, M., Willett, W., Speizer, F., & Hennekens, C. (1999). A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. New England Journal of Medicine, 341(9), 650-8.

Mariak, Z., Lewko, J., Luczaj, J., Polocki, B., & White, M. D. (1994). The relationship between directly measured human cerebral and tympanic temperatures during changes in brain temperatures. European Journal of Applied Physiology, 69(6), 545-549.

Matsukawa, T., Kurz, A., Sessler, D., Bjorken, A., Merrifield, B., & Cheng, C. (1995). Propofol linearly reduces vasoconstriction and shivering thresholds. Anesthesiology, 82(5), 1169-80.

McArdle, W., Katch,F. & Katch, W. (1994). Essentials of Exercise Physiology. Lea & Febiger, PE. p.544

Mekjavic, I, & Rempel, M. (1990). Determination of esophageal insertion length based on standing and sitting height. Journal of Applied Physiology, 69(1), 376-9.

Nadel, E., Metchell, J., & Stolwijk, J. (1971). Control of local and total sweating during exercise transients. International Journal of Biometeorology, 15, 80-87.

Nadel, E., Pandolf, K., Roberts, M., & Stolwijk. (1974). Mechanisms of thermal acclimation to exercise and heat. Journal of Applied Physiology, 37(4), 515-20.

Nordhamn, K., Sodergren, E., Olsson, E., Karlstrom, B., Vessby, B., & Berglund, L. (2000). Reliability of anthropometric measurements in overweight and lean subjects: consequences for correlations between anthropometric and other variables. International Journal of Obesity and Related Metabolic Disorders, 24(5), 652-7.

Paffenbarger, R., Hyde, R., Wing, A., & Hsieh, C. (1986). Physical activity, all-cause mortality, and longevity of college alumni. New England Journal of Medicine, 314, 605-13.

Pate, R., Pratt, M., Blair, S., Haskell, W., Macera, C., Bouchard, C., Buchner, D., Ettinger, W., Heath, G., King, A., Krista, A., Leon, A., Marcus, B., Morris, J., Paffenbarger, R. Jr., Patrick, K., Pollock, M., Rippe, J., Sallis, J., & Wilmore, J. (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. Journal of the American Medical Association, 1(273), 402-7.

Pollock, M., Gaesser, G., Butcher, J., Despres, J., Dishman, R., Franklin, B., & Ewing Garber, C. (1998). The American College of Sports Medicine Position Stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in health adults. Medicine and Science in Sports and Exercise, 30(6), 975-91.

Roberts, M., Wenger, C., Stolwijk, J., & Nadel, E. (1977). Skin blood flow and sweating changes following exercise training and heat acclimation. Journal of Applied Physiology, 43(1), 133-7.

Santiago, M., Alexander, J., Stull, G., Serfrass, R., Hayday, A., & Leon, A. (1987). Physiological responses of sedentary women to a 20-week conditioning program of walking and jogging. Scandanavian Journal of Sports Science, 9, 33-9.

Sawka, M. N., Wenger, C. B., & Pandolf, K. B. (1996). Thermoregulatory responses to acute exercise-heat stress and heat acclimation. In M. Fregley & C. Blatteis (Eds.), Handbook of Physiology (pp. 157-185). New York: Oxford University Press.

Seals, D., Hagber, J., Hurley, B., Ehsani, A., & Holloszy, J. (1984). Endurance training in older men and women. Cariovascular responses to exercise. Journal of Applied Physiology, 57, 1024-9.

Shvartz, E., Bhattacharya, A., Sperinde, S. J., Brock, P. J., Sciaraffa, D., & Van Beaumont, W. (1979). Sweating responses during heat acclimatization and moderate conditioning. Journal of Applied Physiology, 46(4), 675-680.

Stephenson, L., & Kolka, M. (1999). Esophageal temperature threshold for sweating decreases before ovulation in premenopausal women. Journal of Applied Physiology, 86(1), 22-8.

Strydom, N. B. & Williams, C.G. (1969). Effect of physical conditioning on state of heat acclimatization of Bantu laborers. Journal of Applied Physiology, 27(2), 262-65.

Strydom, N. B., Wyndham, C. H., Williams, C. G., Morrison, J. F., Bredell, G. A. G., Benade, A. J. S., & Von Rahden, M. (1966). Acclimatization to humid heat and the role of physical conditioning. Journal of Applied Physiology, 21(1), 636-42.

Tabata, I., Nishimura, M., Kouzaki, M., Hirai, Y., Ogita, F., Miychi, M., & Amamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and V02max. Medicine and Science in Sports and Exercise, 28, 1327-30.

Tankersley, C. G., Nicholas, W. C., Deaver, D. R., Mikita, D., & Kenney, W. L. (1992). Estrogen replacement in middle-aged women: thermoregulatory responses to exercise in the heat. Journal of Applied Physiology, 73(4), 1238-45.

Wenger, H.,& Bell, G. (1986). The interactions of intensity, frequency, and duration of exercise training in altering cardiorespiratory fitness. Sports Medicine, 3, 346-56.

US Department of Health and Human Services. (1996). Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services, National Center for Chronic Disease Prevention and Health Promotion.

Appendix A
Informed Consent

Purpose of the Study

Researchers from the Faculty of Physical Education and Recreation Studies would like you to participate in a University of Manitoba research study designed to learn more about exercise and heat regulation. The purpose of this study is to determine the effects of a moderate intensity exercise program on one's heat tolerance.

Subjects

Only healthy males under the age of 40 who are sedentary, or who do not regularly exercise will be accepted into the study. Participants will be asked to complete a medical screening questionnaire and a survey on their activity level to ensure the above criteria are met.

Methods and Procedures

Participation involves a bike test and a heat exercise test at the beginning of study, and then again approximately 12 weeks later. The bike test consists of riding the bike for approximately eight to twelve minutes, until the point of absolute physical fatigue. Investigators will measure your heart rate with a heart rate monitor, and collect the air you breathe out. This requires you to wear a mask over your mouth and nose, with a tube connected to a machine. If you feel undue discomfort, the test will be terminated, simply by informing the investigator. Prior to this test your height and weight will be measured, and five skinfold measurements will be taken. These measurements allow investigators to estimate the amount of fat under your skin.

The heat exercise test consists of exercising on a stationary bike at a medium intensity in a warm chamber for approximately 30 minutes. A small wire will be inserted through your nostril to the level of your heart to measure core temperature, small thermometers will be taped to your skin to measure skin temperature, and a sensor will be clipped on your finger to measure blood flow and heart rate. You will also be required to wear the face mask again to collect the air you exhale. There will also be a small cup taped to the base of your neck to monitor sweating. You will be given ample time to get used to each measurement device before the actual exercise test. Instrumentation generally takes 30 minutes, and then you spend approximately 30 – 45 minutes inside the warm chamber. These are routine procedures and should not give you any pain or discomfort. If you feel undue discomfort, the test will be terminated, simply by informing the investigator.

After the first bike and heat exercise test, you will be randomly assigned to one of two groups. One group will be asked to immediately begin a 12 week moderate intensity exercise program, led by a qualified instructor. The training program will involve biking, walking, stairclimbing, and other safe and enjoyable activities. Participants are expected to progress to exercising at a medium intensity for approximately four to five hours per week. Participants in this group will be permitted do some exercise on their own, but must attend at least two organized training sessions on campus with an investigator each week. Participants in the other group are expected to continue their current lifestyle for 12 weeks at which time they will also be assisted to begin a regular training program. All participants will be asked to keep a log book of their activity.

Risks

It is highly unlikely that injury or illness will result from participating in any portion of this study. All tests are commonly done in the laboratory. Qualified personnel will review medical questionnaires, and only those for whom physical activity is appropriate will be accepted as participants. Qualified personnel will conduct all tests. Should you feel discomfort at any time during a test, the test will be stopped simply by informing an investigator.

Benefits

By participating in this study, you can learn how to incorporate physical activity into your lifestyle, and reap all of the benefits that come along with that. Individuals in the group that does not exercise in the first 12 weeks will be given an opportunity for exercise counseling with qualified personnel at the end of the study, and thus will receive the same education as the exercise group.

Consent to Participate

I understand that my participation is completely voluntary, and I can withdraw at any time without question or prejudice by simply informing one of the investigators.

I have read the description of the study and understand the measurements and procedures involved.

I understand that all information collected during the course of this study will be kept strictly confidential.

I understand that I am free to question any of the investigators at any time throughout the duration of the study.

I understand that participation in this research study is done at my own risk and I hereby release the University of Manitoba, their agents, officers, and employees from any liability with respect to any damage or injury, including death, that I may suffer during participation in the study.

My signature indicates that I agree to participate in the study.

(your printed name)	(your signature)	(date)
(witness' printed name)	(witness' signature)	(date)

Casie Shields, Msc. Student
Faculty of Physical Education and Recreation Studies
Studies
University of Manitoba
632-2888

Dr. E. Ready
Faculty of Physical Education and Recreation
Studies
University of Manitoba
474-8641

Dr. Gordon Giesbrecht
Faculty of Physical Education and Recreation Studies
University of Manitoba
474-8646

Appendix B

Medical Screening Questionnaire/Revised Par-Q

Name:____________________ Date:__________________
Date of Birth:_______________

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor? Yes No (circle one)

2. Do you feel pain in your chest when you do physical activity? Yes No (circle one)

3. In the past month, have you had chest pain when you were not doing physical activity? Yes No (circle one)

4. Do you lose your balance because of dizziness or do you ever lose consciousness? Yes No (circle one)

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity? Yes No (circle one)

6. Have you ever been diagnosed with diabetes? Yes No (circle one)

7. Do you take any medications? Yes No (circle one)
If yes, please list all the medications subscribed (name and dose)

____
____
____
____

8. Do you know of any reason why you should not do physical activity?
Yes No (circle one)
If yes, explain.

____
____
____

9. List any physical activities that you have participated in regularly in the past six months.

____
____
____
____
____

Appendix C
Seven Day Physical Activity Recall

1. On average, how many hours did you sleep each night during the last 5 weeknights (Sunday-Thursday)? ________hours

2. On average, how many hours did you sleep each night last Friday and Saturday nights? _______hours

The following questions ask about your physical activity during the past seven days, that is, the last five weekdays, and the last weekend. The questions are not going to deal with light activities such as slow walking, light housework, or non-strenuous sports such as archery. Please see attached page for a list which shows examples of what we consider moderate, hard, and very hard activities.

3. First lets consider moderate activities. What activities do you do and how many total hours did you spend during the last 5 weekdays doing these moderate activities or others like them? __________ hours (to nearest half hour)

4. Last Saturday and Sunday, how many hours did you spend on moderate activities and what did you do? __________ hours (to nearest half hour)
(Probe: can you think of any other activities that fall into this category?)

5. Now lets look at hard activity. What activities do you do and how many total hours did you spend during the last 5 weekdays doing these hard activities or others like them? __________ hours (to nearest half hour)

6. Last Saturday and Sunday, how many hours did you spend on hard activities and what did you do? __________ hours (to nearest half hour)
(Probe: can you think of any other activities that fall into this category?)

7. Now lets look at very hard activity. What activities do you do and how many total hours did you spend during the last 5 weekdays doing these very hard activities or others like them? __________ hours (to nearest half hour)

8. Last Saturday and Sunday, how many hours did you spend on very hard activities and what did you do? __________ hours (to nearest half hour)
(Probe: can you think of any other activities that fall into this category?)

9. Compared with your physical activity over the past 3 months, last week's physical activity was more, less, or about the same?

More Less About the same (circle one)

Interviewer: Please list any activities reported by the subject that you don't know how to classify. (Activity, Duration on weekday, Duration on weekend)

Moderate Activities

Occupational tasks:
Delivering mail or patrolling on foot, house painting, truck driving (making deliveries and carrying light objects)

Household tasks:
Sweeping and mopping, raking/mowing the lawn, cleaning windows, auto repair

Sports activities (actual playing time):
Brisk walk, volleyball, ping pong, biking for leisure, general dancing, hunting, badminton, basketball (shooting hoops), bowling, softball/baseball

Hard Activities

Occupational tasks:
Heavy carpentry, construction, physical labor

Household tasks:
Scrubbing floors, shoveling snow

Sports activities (actual playing time):
Doubles tennis, disco, square, or folk dancing, general skating

Very Hard Activities

Occupational tasks:
Digging, chopping, carrying heavy loads, very hard physical labor

Sports activities (actual playing time):
Jogging, swimming, soccer, racquetball, singles tennis, rapid skating

Calculating Energy Expenditure

Activity	Hours	Sleep	moderate	hard	very hard	light
Weekday	120 - [(5*____=	_____) +	_____ +	_____ +	_____] =	_____
Weekend	48 - [2*____=	_____) +	_____ +	_____ +	_____] =	_____
Sum		_____	_____	_____	_____	_____
*METS		1	4	6	10	1.5
energy expenditure: activity level/wk		_____ +	_____ +	_____ +	_____ +	_____

energy expenditure:
kcal/kg/day = _____/7 = _____

energy expenditure:
kcal/day _____ * _____(kg) = _____

Appendix D
Log Book of Physical Activity

Name:______________________ Week of ____________to_____________

	Activity	Duration (minutes)	Heart rate (bpm) (10 minutes)	Heart rate (final)
Mon	____________	____________	____________	____________
Mon	____________	____________	____________	____________
Mon	____________	____________	____________	____________
Mon	____________	____________	____________	____________
Mon	____________	____________	____________	____________
Tues	____________	____________	____________	____________
Tues	____________	____________	____________	____________
Tues	____________	____________	____________	____________
Tues	____________	____________	____________	____________
Tues	____________	____________	____________	____________
Wed	____________	____________	____________	____________
Wed	____________	____________	____________	____________
Wed	____________	____________	____________	____________
Wed	____________	____________	____________	____________
Wed	____________	____________	____________	____________
Thurs	____________	____________	____________	____________
Thurs	____________	____________	____________	____________
Thurs	____________	____________	____________	____________
Thurs	____________	____________	____________	____________

	Activity	Duration (minutes)	Heart rate (bpm) (10 minutes)	Heart rate (final)
Fri				
Fri				
Fri				
Fri				
Fri				
Sat				
Sat				
Sat				
Sat				
Sat				
Sun				
Sun				
Sun				
Sun				
Sun				