THE ASSOCIATION BETWEEN INCIDENTAL PHYSICAL ACTIVITY AND CARDIORESPIRATORY FITNESS

by

Maria Morgan Craig-Broadwith

A thesis submitted to the School of Kinesiology and Health Studies
In conformity with the requirements for
the degree of Master of Science

Queen’s University
Kingston, Ontario, Canada
(July, 2011)
Copyright ©Maria Morgan Craig-Broadwith, 2011
Abstract

**Objective** The primary objective of this study was two-fold. First, to determine whether incidental physical activity (IPA), which is composed of both light-intensity physical activity (LPA) and sporadic moderate-intensity physical activity (MPA; physical activity accrued in bouts less than 10 minutes), was associated with cardiorespiratory fitness (CRF). Second, to determine whether sporadic MPA was associated with CRF.

**Methods** Participants were abdominally obese (defined as a waist circumference > 102 cm in men and > 88 cm in women), inactive, adult men (N = 24; [mean ± SD] age = 55.5 ± 7.8 years) and women (N = 55; age = 52.3 ± 7.5 years) recruited from Kingston, Canada. Cardiorespiratory fitness was assessed using a graded treadmill test. IPA (activity ≥ 1 metabolic equivalent (MET)) and sporadic MPA (activity ≥ 3 METs accrued in bouts less than 10 minutes) was measured using the SenseWear Pro Armband (SWA). IPA and sporadic MPA were categorized into duration (minutes/day) and expenditure (MET-minutes/day). In secondary analyses, we investigated the association between LPA (activity between 1 – 2.99 METs), sedentary behaviour (SED; activity < 1.0 MET) and CRF.

**Results** Participants accumulated an average of 326.6 ± 127 minutes of IPA per day which was composed of 40.7 ± 17.8 minutes of sporadic MPA and 285.9 ± 118.2 minutes of LPA. Both duration and expenditure of IPA were significantly associated with CRF independent of sex, however, after further control for body mass index and age neither association remained significant (p > 0.05). Sporadic MPA was significantly associated with CRF after control for covariates (p ≤ 0.05). Neither LPA nor SED were associated with CRF after control for covariates (p > 0.05).
Conclusions IPA was not significantly associated with CRF, however, sporadic MPA was an independent predictor of CRF.
Co-Authorship

Morgan Craig-Broadwith was responsible for data acquisition, statistical data analysis, and the writing of the manuscript contained within this thesis. Critical revisions for intellectual content were provided by Dr. Robert Ross.
Acknowledgements

This thesis began like any great story, with a glass of wine and a thought-provoking conversation. Sitting in the kitchen of my best friend’s house, I discussed the benefits of being fit and the associated physiological changes (of which I knew very few at the time) with her father and realized - I really like this stuff. Shortly thereafter I contacted Bob and the rest is history. I owe a lot to that conversation.

To Bob – thank you for your support and guidance over the past two years. I find it hard to believe that we have come to the end of our road together. I have learned so much from you – more than I can ever convey with written word. You took a chance on me, a B.A. psychology major with no science background. While it has not always been easy (many tears shed in the privacy of your office) it has been an amazing experience both academically and personally. I have grown a lot over the past two years and you are largely responsible for my growth as a student, but more so as a person. I have learned to persevere through the challenges that seem insurmountable, to dig deeper, to ask more questions, and to ‘get dirty with the data’ so to speak. Thank you from the bottom of my heart for accepting, challenging, and mentoring me. Here’s to killing a chicken with a cannon.

To past and present colleagues in the lab – Melinda, Jenn, Paula, Dan, Nicole, Amanda, Pam, Shawn, Jackie, and Dave – thank you for your contribution to the ongoing study and to my current thesis. To John and Lauren, the accelerometer warriors – thank you for putting up with those stupid armbands. I appreciate your work and dedication to this study. Ehsan – you are our resident genius. My thesis would not have come to be without your crafty computer programming skills. Thank you for being patient, listening over and over again to both Bob and I (two of the
non-techiest people on the planet), and coming up with a brilliant program to spit out all the variables I needed.

To the students of the lab, I will miss you forever. To Peter – thank you for your jokes and witty remarks. You made my transition to graduate life/work so much easier. James, your infectious laugh and ability to converse about anything made my early mornings/mid-afternoons/evenings so much more bearable. I look forward to future visits in Australia! To the recent addition, Trevor, I am so fortunate to call you a friend. I will miss our regular morning chats revolving around celebrity gossip, your Tim Bit girlfriend, and our crazy families. Ash, your patience, guidance and never-ending support helped to make my thesis a reality. You always had time to lend an ear, look at another output (there were just so many), edit my manuscript, provide encouragement, and best of all be a friend. Thank you, thank you, thank you. I now approach the last individual on my list, but definitely not the least. Diva – you are a true blue friend. We shared so many laughs in the confines of this crazy laboratory and I will forever miss that. Our shared love of alcohol, Edward, food, coffee, and Tim Bits made this experience so much more fun. I look forward to more visits in Vancouver (who knows, maybe we’ll have babies by then).

Granny – your love and encouragement have helped me to accomplish this feat. You mean more to me than you will ever know. You are one heck of a granny – you swear, you enjoy a good Irish beverage every so often, your humour remains unbeaten, and you love me unconditionally. You push me to do more, to continue in my academic pursuits and I would not be here today, completing this MSc without your words of encouragement and motivation.

To Momma and Daddio you are my best friends and the most incredible support systems a gal could ever ask for. Your unwavering belief in my ability is astounding and has helped me many a time to get back on track when I lost faith in myself (which has been more than I like to
admit over the past two years). I love you both so much. Thank you for giving me the gift of life and perhaps, more importantly, the gift to live it.

To Evan, the love of my life and best friend, thank you. I know it’s cheesy, but I could not have done this without you. I simply could not have. You listened, you laughed, you cooked, you hugged, you soothed, you loved – no matter what, no matter when. You are woven into every element of this thesis and I love you with all my heart and being.
Contributions

Morgan Craig-Broadwith assisted in the acquisition of data by initializing and downloading data from the accelerometer upon participant return. In addition, Morgan was fully responsible for the cleaning, management and analysis of the data used in the current thesis. In addition to thesis work, Morgan was involved in magnetic resonance imaging acquisition and analysis, exercise monitoring of participants involved in the current exercise trial, and assisting at participant recruitment meetings.
# Table of Contents

Abstract .......................................................................................................................................................... ii
Co-Authorship ............................................................................................................................................... iv
Acknowledgements ......................................................................................................................................... v
Contributions ................................................................................................................................................ viii
Chapter 1 General Introduction ...................................................................................................................... 1
Chapter 2 Review of the Literature .................................................................................................................. 3
  2.1 The Cardiorespiratory Fitness of our Palaeolithic Ancestors ................................................................. 3
  2.2 Cardiorespiratory Fitness and Health ..................................................................................................... 4
  2.3 Determinants of CRF .............................................................................................................................. 5
    2.3.1 Genetics, Gender & Age ................................................................................................................. 5
    2.3.2 Physical Activity ............................................................................................................................. 6
      2.3.2.1 Defining Physical Activity ....................................................................................................... 6
      2.3.2.2 Measurement of Physical Activity Patterns and Energy Expenditure .................................... 9
        Direct & Indirect Calorimetry .............................................................................................................. 9
        Doubly Labelled-Water ...................................................................................................................... 12
        Self-Report ..................................................................................................................................... 13
        Heart Rate Monitor .......................................................................................................................... 14
        Pedometer ....................................................................................................................................... 15
        Accelerometer ................................................................................................................................. 15
      2.3.2.3 Structured Physical Activity and Cardiorespiratory Fitness .................................................... 16
        The Role of Intensity ......................................................................................................................... 19
        The Role of Dose & Frequency .......................................................................................................... 21
        Summary: Structured PA ................................................................................................................. 21
    2.3.2.4 Incidental Physical Activity and Cardiorespiratory Fitness ....................................................... 22
    2.3.2.5 Limitations of the Waist-Worn Accelerometer ............................................................................ 24
    2.3.2.6 Novel Solutions to Waist-worn Accelerometer Limitations ..................................................... 26
      The SenseWear Pro Armband ............................................................................................................ 26
    2.3.2.7 Sedentary Behaviour and Cardiorespiratory Fitness .................................................................... 34
  2.4 Summary .................................................................................................................................................. 35
Chapter 3 Manuscript
The Association between Incidental Physical Activity and Cardiorespiratory Fitness

3.1 Introduction
3.2 Methods
   3.2.1 Study Sample
   3.2.2 Measurement of Body Composition and Cardiorespiratory Fitness
   3.2.3 Measurement of Physical Activity and Sedentary Behaviour
   3.2.4 Statistical Analysis
3.3 Results
3.4 Discussion

Chapter 4 General Discussion
4.1 Clinical Implications
4.2 Accelerometry
   4.2.1 The SenseWear Pro Armband
   4.2.2 General Thoughts on Accelerometry
4.3 Future Research

Summary and Conclusions

Bibliography

Appendix A Consent Form
Appendix B Medical Questionnaire
Appendix C Screening Form
Appendix D Anthropometric Measurement Protocol
Appendix E Measurement of Cardiorespiratory Fitness Protocol
Appendix F Measurement of Physical Activity
Appendix G Armband Log Sheet
Appendix H Example of Statistical Output
Appendix I Results for Tertiary Analysis
List of Tables

Table 2-1 Tools to assess physical activity patterns/energy expenditure in laboratory and free-living conditions .......................................................................................................................... 11
Table 2-2 Physical activity intensity cut-points developed by Freedson and colleagues.......... 17
Table 2-3 Examples of physiological adaptations associated with improved maximal and submaximal cardiorespiratory fitness .................................................................................. 18
Table 2-4 Parameters measured by SenseWear Pro Armband ............................................. 29
Table 2-5 Ability of the SenseWear Pro Armband to measure energy expenditure ............... 31
Table 2-6 Physiological adaptations associated with detraining and bed rest in relation to cardiorespiratory fitness .................................................................................................... 36
Table 3-1 Participant characteristics and mean duration and expenditure for activity variables .. 44
Table 3-2 Association between incidental physical activity and cardiorespiratory fitness ....... 45
Table 3-3 Association between light-intensity physical activity and sedentary behaviour and cardiorespiratory fitness ................................................................................................. 46
List of Figures

Figure 2-1 Determinants of total daily energy expenditure .................................................. 8
Figure 2-2 Physical activity intensity classification ................................................................. 10
Figure 2-3 Photograph image of SenseWear Pro Armband ....................................................... 28
Figure 3-1 Association between sporadic moderate-intensity physical activity duration and cardiorespiratory fitness ........................................................................................................ 47
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>GT3X Actigraph</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>CRF</td>
<td>Cardiorespiratory fitness</td>
</tr>
<tr>
<td>DLW</td>
<td>Doubly labeled water</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
</tr>
<tr>
<td>HRmax</td>
<td>Heart rate maximum</td>
</tr>
<tr>
<td>IPA</td>
<td>Incidental physical activity</td>
</tr>
<tr>
<td>LPA</td>
<td>Light intensity physical activity</td>
</tr>
<tr>
<td>METs</td>
<td>Metabolic equivalent tasks</td>
</tr>
<tr>
<td>MET-min</td>
<td>Metabolic equivalent task minutes</td>
</tr>
<tr>
<td>NEAT</td>
<td>Non-exercise activity thermogenesis</td>
</tr>
<tr>
<td>PA</td>
<td>Physical activity</td>
</tr>
<tr>
<td>SED</td>
<td>Sedentary behaviour</td>
</tr>
<tr>
<td>SWA</td>
<td>SenseWear Pro Armband</td>
</tr>
<tr>
<td>V0₂Max</td>
<td>Maximal oxygen uptake</td>
</tr>
<tr>
<td>VPA</td>
<td>Vigorous physical activity</td>
</tr>
<tr>
<td>WC</td>
<td>Waist circumference</td>
</tr>
</tbody>
</table>
Chapter 1

General Introduction

Cardiorespiratory fitness (CRF) is defined as the ability of the respiratory, circulatory, and musculoskeletal systems to deliver and utilize oxygen (1). Low CRF is associated with elevated health risk for cardiovascular disease and mortality (2-4). However, improvement in CRF is associated with reduced risk for cardiovascular disease events and all-cause mortality (3). The primary determinants of CRF include genetics (5), sex (6), age (7, 8), and physical activity (PA) (9).

The association between structured PA (moderate-to-vigorous intensity physical activity accumulated in bouts of 10 minutes or more) and CRF is well established (10-14). However, the association between incidental physical activity (IPA; sporadic, unstructured physical activity performed in a free-living condition (e.g. at home and/or work) ≥ 1 MET) and CRF remains less clear. By this definition, IPA encompasses both light-intensity physical activity (LPA; defined as activity between 1 – 2.99 METs), sporadic moderate-intensity physical activity (MPA; defined as activity between 3 – 5.99 METs accrued in bouts less than 10 minutes) and sporadic vigorous PA (VPA; defined as activity ≥ 6 METs accrued in bouts less than 10 minutes).

We have recently reported a significant association between IPA and CRF, however, this association was largely driven by the sporadic MPA (15). This finding is encouraging as it suggests that benefits achieved from PA may occur across a continuum, countering current dogma that states a certain intensity and duration threshold must be achieved and maintained to see improvement in CRF (14). As this is the first study to examine the association between IPA and CRF, replication is warranted. More, the accelerometer employed in the prior study has notable
limitations that may be overcome by a more recently developed device, the SenseWear Pro Armband (SWA; BodyMedia, Pittsburgh, PA). Worn on the upper right arm, the SWA incorporates heat variables and participant characteristics into proprietary algorithms to estimate energy expenditure per minute of wear (16). Due to its placement on the upper arm and measurement of heat parameters this device may better capture upper-body movement and changes in load compared to other waist-worn accelerometers.

It is unclear how sedentary behavior (SED; defined as activity < 1.0 MET) influences CRF. SED comprises approximately 68% of adult Canadians waking hours and is thus, the primary component of waking hour activity (16). Bed rest and detraining studies indicate a clear association between time spent inactive (i.e. bed rest and/or not performing structured PA) and reductions in CRF however, neither activity can be perfectly equated with SED (17, 18). Thus, further study is required to better understand the association between SED and CRF.

A better understanding of the association between IPA, and sporadic MPA and CRF is warranted as a growing proportion of adult Canadians are spending less time in structured PA (19). As improvement in CRF is associated with reduced risk for cardiovascular events and all-cause mortality, determining feasible and maintainable treatment strategies to increase CRF are paramount.

The following literature review (Chapter 2) will define and discuss the determinants of CRF with a primary focus on PA. In the manuscript (Chapter 3) we investigate the association between objectively measured IPA, sporadic MPA, LPA and SED and CRF in a sample of abdominally obese, inactive adult men and women. Chapter 4 includes a summary of our findings and suggested directions for future research.
Chapter 2

Review of the Literature

2.1 The Cardiorespiratory Fitness of our Palaeolithic Ancestors

The current physical activity (PA) level of Canadians is considerably different from that of our Palaeolithic ancestors 10,000 years ago (20, 21). Both the evaluation of skeletal remains and study of present day hunter-gatherer societies provide insight into both the activity patterns and overall health of our ancestors. A large proportion of daily activity during that period was dedicated to hunting and gathering food materials (22). It is estimated that the daily PA energy expenditure of hunter/gatherers was 1240 kilocalories (kcal), considerably more than the 268.5 kcal expended by the present-day sedentary office worker (21, 23). Research has shown that in addition to high levels of PA, our ancestors had cardiorespiratory fitness (CRF) values that were 50% greater than age-matched affluent westerners (maximal oxygen uptake (V\(\text{O}_2\)\(_\text{max}\)) = 57.2 ml/kg/min vs. 37.2 ml/kg/min in males 20-49 years old) (24). Moreover, the incidence of disease in such populations was low (22). Specifically, clinical post-mortem investigations of recent hunter-gatherer societies including the Navajo Indians (25), Solomon Islanders (26), Australian Aborigines (27) and Kalahari San (Bushmen) (28) demonstrated low incidence of coronary artery disease.

It is now well documented that an increase in CRF is associated with a reduction in risk for cardiovascular disease and mortality (3). Thus, one may hypothesize that the low incidence of cardiovascular disease in the aforementioned hunter-gatherer societies may be at least partially attributed to the elevated levels of CRF. The high CRF in these populations can be attributed primarily to the high levels of vigorous-intensity PA. A return to hunter-gatherer lifestyle is not
possible in order to reduce the growing incidence of cardiovascular disease in Canada, however, an adjustment in current PA patterns is paramount for the future health of our country.

The following section will define CRF, its association with health, and its determinants with a primary focus on PA. Subsequently, the association between PA and CRF will be subdivided into the following sections: structured PA and CRF; incidental physical activity (IPA) and CRF; sedentary behaviour (SED) and CRF.

2.2 Cardiorespiratory Fitness and Health

CRF can be defined as the ability of the respiratory, circulatory and the musculoskeletal systems to deliver and utilize oxygen (1). Data from the Aerobics Centre Longitudinal Study and other epidemiological studies indicate that individuals with low CRF are much more likely to develop hypertension (29-31), diabetes (32-34), and metabolic syndrome (35, 36). Conversely, studies have shown that with an improvement in CRF there is a respective improvement in health. A meta-analysis using 33 studies found that in both men and women each one metabolic equivalent (MET; 1 MET is equivalent to 3.5 ml O₂/kg/min) increment in CRF was associated with a 13% and 15% risk reduction in all-cause mortality and cardiovascular disease events, respectively (3). The authors of this meta-analysis further explained that a 1-MET improvement in CRF is associated with a 7-cm, 5-mm Hg, 1-mmol/L and 1-mmol/L decrement in waist circumference, systolic blood pressure, triglyceride level (in men), and fasting plasma glucose, respectively (3). Additionally, one study followed 9777 men aged 20 to 82 years old at baseline who had two CRF assessments over a period of 4.9 years (4). Men were followed to test the hypothesis that a positive change in CRF resulted in reduced mortality risk. Not surprisingly, men who were unfit at both visits had the highest relative risk of mortality. Men who became fit between the first and second visit had almost a 50% risk reduction for cardiovascular disease and
all-cause mortality while men who stayed fit had the lowest risk (4). Similarly, Blair et al. (9) found a reduced rate of mortality with increasing CRF. In summary, these studies demonstrate that an improvement in CRF is associated with a corresponding health benefit.

2.3 Determinants of CRF

2.3.1 Genetics, Gender & Age

The role of genetics on CRF was illustrated through the seminal work of Bouchard and colleagues in the HERITAGE Family Study (5). This study investigated the role that genes play in cardiovascular, metabolic, and hormonal response to aerobic exercise training. Bouchard et al. (5) looked at the response to five months of aerobic training within and between 98 two-generation families of Caucasian descent. They documented a 2.5 variance between families in CRF response to training relative to within-family variance. Genetics were said to account for 47% of the variance in CRF with a significant maternal contribution of 36%. Additionally, monozygotic twin studies have shown considerable between twin-pair differences in response to training relative to the response within a twin-pair (37). The specific genetic characteristics responsible are yet to be elucidated however, the maternal mitochondrial DNA is hypothesized to play a role (5).

Age has also been found to be a significant determinant of CRF (7, 8). Using data from the Baltimore Longitudinal Study of Aging, Fleg et al. (8) reported that age-related decline in CRF was not linear. CRF declined by 3% to 6% per decade for the third and fourth decades of life, however, at 70 years of age this rate increased to 20% per decade (8). Jackson et al. (7) reported similar declines in CRF at 45 years of age in both men and women. Interestingly, they found that a lower body mass index (BMI) and a higher level of PA protected against reductions
in CRF across all ages. Thus, the decline in CRF is not necessarily a result of age and associated muscle mass loss, but also a decline in PA.

Men typically have a greater CRF relative to women as evidenced by a number of studies that have investigated the role of sex on CRF (7, 13). Such differences can be attributed to the morphological and physiological differences between men and women (6). Men typically have a higher percentage of free-fat mass, greater bone-mineral density, an increased number and size of muscle fibres and a lower percentage of fat mass relative to women (6, 38). Additionally, women have a lower blood volume, fewer red blood cells and less haemoglobin thus reducing the oxygen-carrying capacity of the blood. Despite these physiological differences there appears to be little sex difference in the magnitude of CRF improvement following similar training programs (39).

2.3.2 Physical Activity

2.3.2.1 Defining Physical Activity

PA is defined as any movement of the skeletal muscles that results in an increase in oxygen demand and thus, an elevation in energy expenditure above resting metabolism (40). At rest, humans are estimated to consume 3.5 ml O$_2$/kg/min, which is equivalent to approximately 1 kcal/kg/hour (41). More specifically, for each 1 L of oxygen (O$_2$) consumed approximately 5 kcal are expended (42). For example, a 62 kg person at rest would consume approximately 13,020 millilitres (ml) of O$_2$ which is equivalent to 13 L per hour. Therefore, this person would expend approximately 65 kcal per hour at rest.

PA energy expenditure accounts for 10%-30% of total daily energy expenditure while resting metabolic rate and dietary induced thermogenesis account for 60%-75% and 10%-15% of total daily energy expenditure, respectively (43). PA energy expenditure however, is a fairly
broad term and is typically divided into non-exercise activity and exercise thermogenesis (see Figure 2-1).

Levine et al. (44) coined the term non-exercise activity thermogenesis (NEAT) and defines it as “the energy expended for everything that we do that is not sleeping, eating or sports-like exercise”. The variables that influence NEAT are outlined in Figure 2-1. In current literature there are a variety of terms used synonymously with NEAT including incidental, unstructured, non-purposeful, habitual and sporadic physical activity. Such terms can be confusing as the majority of these activities are performed with purpose and possess structure (e.g. cleaning the house, mowing the lawn, putting away groceries). However, this form of activity is not done with the goal or purpose to improve CRF and/or other health outcomes, which perhaps explains the varied and somewhat confusing terminology. For the purposes of this thesis IPA will be used to define all daily activities with an associated energy cost ≥ 1 MET, but excludes activity that meets consensus guidelines (i.e. PA ≥ 3 METs accumulated in ≥ 10 minute bouts). By this definition, IPA includes light-intensity PA (LPA; defined as activity between 1.0 - 2.99 METs), sporadic moderate-intensity PA (MPA; defined as activity between 3 - 5.99 METs accrued in bouts less than 10 minutes) and sporadic vigorous-intensity PA (VPA; defined as activity ≥ 6 METs accrued in bouts less than 10 minutes).
**Figure 2-1** Determinants of total daily energy expenditure

- **Diet-Induced Thermogenesis**
  - Age
  - Weight
  - Meal energy and protein content
  - Lean body mass

- **Resting Metabolic Rate**
  - Height
  - Weight
  - Age
  - Sex
  - Disease
  - Lean body mass
  - Genetics
  - Menstrual cycle

- **Activity Thermogenesis**
  - Occupation
  - Environment
  - Education
  - Genetics, age, sex, body composition

- **Exercise Thermogenesis**
  - Amount of activity + Thermic response to those activities

- **Non-Exercise Activity Thermogenesis**

- **Total Daily Energy Expenditure**
Exercise thermogenesis on the other hand, refers to structured PA that is typically performed with the goal or aim to improve CRF and/or overall health (44). While structured PA typically refers to sport and/or aerobic activity, a number of sports involve fairly long-periods of non-intense activity including golf, bowling, and curling. PA guidelines provide some clarification as to what constitutes structured PA (14, 45). The Canadian PA consensus guidelines recommend 150 minutes per week of moderate-to-vigorous intensity physical activity (≥ 3 METs) accumulated in ≥ 10 minute bouts (45). For the purposes of this document, structured PA will refer to activity as defined by consensus guidelines.

Figure 2-2, provides a clear breakdown of daily activity intensity ranging from very low (sedentary) to very high (vigorous exercise) (46). SED is an important and influential component of total daily energy expenditure (14). The definition of SED remains elusive in current literature however for the purposes of this thesis, sedentary will be defined as behaviours characterized by little physical movement and low energy expenditure (i.e. sitting, watching TV, driving) (46). Low energy expenditure will be defined as any activity < 1 MET.

2.3.2.2 Measurement of Physical Activity Patterns and Energy Expenditure

Direct & Indirect Calorimetry

The majority of studies to investigate the association between structured PA and CRF have done so primarily in the laboratory setting. This is understandable as it allows for rigorous control over the independent variable(s) of interest and potential confounds. Moreover, researchers are able to accurately determine PA energy expenditure via either direct or indirect calorimetry. Direct calorimetry requires the use of an isolated chamber that measures total heat loss from the body via evaporation, radiation, conduction and convection (Table 2-1) (47).
**Figure 2-2** Physical activity intensity classification

**METs** – Metabolic equivalents. This diagram provides information on the cut-points used to differentiate between varying physical activity intensities used for the purposes of this thesis.
<table>
<thead>
<tr>
<th>Tool</th>
<th>Setting Frequently Employed In</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Calorimetry</td>
<td>Laboratory</td>
<td>Accurate, reliable</td>
<td>Expensive, time-consuming, impractical for assessing PA patterns in large population</td>
</tr>
<tr>
<td>Indirect Calorimetry</td>
<td>Laboratory</td>
<td>Accurate, reliable</td>
<td>Invasive, time-consuming, labour intensive</td>
</tr>
<tr>
<td>Self-Report</td>
<td>Free-living Conditions</td>
<td>Inexpensive, applicable in large-scale studies, easy administration</td>
<td>Recall error, social desirability, misclassification of activity</td>
</tr>
<tr>
<td>Doubly Labeled Water</td>
<td>Free-living Conditions</td>
<td>Non-invasive, accurate, reliable, extended wear-time capability</td>
<td>Expensive, unable to discriminate patterns of PA, limited to small-scale studies</td>
</tr>
<tr>
<td>Heart Rate Monitors</td>
<td>Free-living Conditions/Laboratory</td>
<td>Non-invasive, extended wear-time capability, compact</td>
<td>Accuracy, reliability at low/high heart rate</td>
</tr>
<tr>
<td>Motion Sensors</td>
<td>Free-living Conditions</td>
<td>Non-invasive, extended wear-time capability, compact relatively accurate, reliable</td>
<td>Inability to capture incline, often do not account for individual differences</td>
</tr>
</tbody>
</table>
Direct calorimetry is considered the criterion method for measuring energy expenditure, however, access to chambers and the finances required to build and/or operate them often prevent their use in large-scale studies (48). Moreover, while the chamber is often set up to mimic a standard living space with a couch, kitchen, and bathroom, the subject will not necessarily carry out activity in the same manner as in free-living conditions and thus, this form of measurement may not capture true activity patterns (48).

Consequently, indirect calorimetry is more commonly used to determine PA energy expenditure. Indirect calorimetry measures whole-body O₂ consumption and carbon dioxide (CO₂) production which provides information on the specific substrate (i.e. lipid versus carbohydrate) being oxidized (47). Indirect calorimetry can be subdivided into open- and closed-circuit methods. Closed-circuit methods isolate the participant from outside air (49). The respirometer contains pure O₂ and as the participant breathes, the expired CO₂ passes through soda lime (49). O₂ gas volume gradually decreases which provides a measure of O₂ consumption (49). The open-circuit method is posited by Ainslie et al. (49) to be more conducive to the measurement of exercise metabolism. There are two main procedures used in open-circuit calorimetry - the flow-through technique and the Douglas bag method which has been replaced in recent years by the electronic, portable metabolic carts (49). The former, has participants sit under a ventilated hood that has air equivalent to outside air flow through. Airflow and percentage of O₂ and CO₂ are measured precisely. The latter method has participants wear a nose-clip and mouthpiece in which they inhale outside air or its equivalent and exhale into a Douglas bag or Tissot tank (49). A sample of exhaled air is used to determine the O₂ and CO₂ concentrations (49). The more recent addition, the metabolic cart, allow researchers to assess continuous O₂ and CO₂ gas exchange and ventilation (49).
Doubly Labelled-Water

Doubly-labelled water (DLW) is considered the criterion method for measuring energy expenditure in free-living conditions (Table 2-1). This method involves the administration of two stable isotopes (²H and ¹⁸O) which are ingested in the form of water (49). The two isotopes mix with normal hydrogen and oxygen in the body water within a few hours. As ¹⁸O is contained in both CO₂ and H₂O it is lost more rapidly from the body relative to ²H. At the point of study culmination, urine samples provide a measure of the remaining isotopes that, in turn, provide a measure of total energy expenditure over the period of wear (49). This is a relatively non-invasive tool that accurately and reliably assesses total daily energy expenditure in free-living conditions over a period of 14 to 21 days (49). PA energy expenditure is determined by subtracting either measured or estimated resting metabolic rate and dietary-induced thermogenesis from total daily energy expenditure. This method does not provide any information as to the type, intensity, duration, or frequency of the PA performed. Additionally, this tool is not financially feasible for large scale studies. More, the availability of such isotopes waxes and wanes making its use difficult. For these reasons, self-report methods including questionnaire and interview are the most commonly utilized tools to measure PA energy expenditure in free-living conditions.

Self-Report

The use of self-report has until recently, been the primary method for measuring free-living PA patterns (see Table 2-1). While questionnaire and interview methods are more feasible for large scale studies, they are prone to recall bias (47). Recall bias can be further subdivided into differential error and social desirability (50). Differential error occurs due to differences between cases and controls (50). Specifically, cases may have a greater motivation to participate in the study and thus, may better remember past events relative to controls (50). The recall of events or
behaviours that are socially undesirable may be under-reported (50). For example, participants may be less likely to report SED and more likely to report PA. Correlation coefficients between PA energy expenditure as determined by questionnaire and DLW range from 0.42 to 0.74, however, correlation coefficients do not necessarily imply agreement or lack thereof between the two methods (49).

To determine the associated energy expenditure of free-living activities as measured using self-report, the compendium of PA is often relied upon. The compendium lists a plethora of structured and incidental physical activities along with the corresponding MET value (41). Using this list, researchers are able to determine the MET-minutes (METs (for given activity) x duration spent performing that activity) and therefore the associated energy expenditure for free-living activities. While this is a useful and consistent measure of activity expenditure there are a number of limitations to this method. Firstly, the compendium was created utilizing previously published data on activity energy expenditure from a number of different sources (41) and thus, there will be inherent differences in study methodology. Specifically, the MET values listed in the compendium are those derived from relatively health, middle-aged men and women, making generalization to other populations difficult. Moreover, individual characteristics such as mechanical efficiency, body composition, sex, age, weight, and height vary greatly amongst individuals and inevitably influence energy expenditure which the compendium, understandably cannot take into account (43). Therefore, while the compendium marks a step forward in regards to the listing and quantification of PA intensity these limitations make its use questionable.

*Heart Rate Monitor*

The heart rate (HR) monitor can be worn for an extended period of time and provide information on the intensity and duration of physical activity (52). Energy expenditure can be
derived from HR using regression equations developed from individual maximal oxygen uptake data (51). However, HR is influenced by a number of factors other than physical exertion such as emotional stress, heat stress, humidity, temperature, dehydration, pre-existing illness, overall physical fitness, and use of stimulants such as caffeine or nicotine (52-56). Additionally, the association between HR and activity intensity is not linear when performing low-intensity activities (49). This is likely the main reason why 24-hour estimates of energy expenditure from HR may have errors up to 30% in individuals (53, 54, 57).

**Pedometer**

Pedometers are typically worn at the waist and count steps by responding to vertical acceleration (52). While economically feasible tools for large-scale studies, they lack sensitivity as they do not quantify stride length or total body displacement (52). Moreover, they provide little information about the type, frequency, intensity and duration of the PA being performed.

**Accelerometer**

The accelerometer is a compact device that measures body motion (i.e. acceleration) on either 1 (uniaxial), 2 (biaxial), or 3 (triaxial) planes, however, the device is most sensitive to movement in the vertical plane and thus, most accelerometers are uniaxial by default (58). As the accelerometer measures acceleration, the change in velocity with respect to time \( (m/s^2) \), the device is able to capture and quantify PA intensity (58). The theoretical basis underlying the use of accelerometers is that acceleration is directly proportional to muscular force and therefore related to energy expenditure (52). The accelerometer measures body acceleration over a user-defined period of time (e.g. 15 seconds (s), 30 s, or 60s) which is commonly referred to as an epoch (59). For each epoch the accelerometer provides an arbitrary ‘count’ value that corresponds with body acceleration. Calibration studies have been conducted to convert these count values
into physiologically meaningful values (60, 61) and have produced cut-points to differentiate between PA intensity (e.g. LPA vs. MPA).

There have been a number of calibration studies and thus cut-points developed since the accelerometers inception, however, the Freedson cut-points that were developed in 1990s, are arguably the most well-known and utilized cut-points today (Table 2-2) (60). Two years following the publication of the Freedson cut-points, Ekelund and colleagues (62) defined SED as any activity < 100 counts/min. In addition, Freedson et al. (60) developed an energy expenditure prediction equation ((kcal/min = (0.00094 X CPM) + (0.1346 X body mass (kg)) -7.37418)). This cut-point classification system and prediction equation marked a milestone in the field of accelerometry as they provided researchers with a consistent method to quantify physical activity. Yet, there are a number of notable limitations to these cut-points and equation which will be discussed in further detail in section 2.3.2.5.

2.3.2.3 Structured Physical Activity and Cardiorespiratory Fitness

The American College of Sports Medicine suggest that in order to achieve improvement in CRF, a minimum intensity threshold of 40% to 50% of heart rate reserve must be achieved and maintained for 10 minutes or more (14). The physiological adaptations purported to explain the relationship between structured PA and CRF are presented in Table 2-3. Due to the vast number of studies performed to ascertain the relationship between structured PA and CRF, the following section will discuss the role of intensity, duration/dose and frequency of structured PA and CRF separately.
<table>
<thead>
<tr>
<th>Activity Intensity</th>
<th>MET Range</th>
<th>Activity Counts (counts/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive/Light</td>
<td>&lt; 2.99</td>
<td>&lt;1951</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.0 - 5.99</td>
<td>1952 - 5724</td>
</tr>
<tr>
<td>Hard</td>
<td>6.0 - 8.99</td>
<td>5725 - 9498</td>
</tr>
<tr>
<td>Very Hard</td>
<td>&gt; 9.0</td>
<td>&gt;9498</td>
</tr>
</tbody>
</table>

MET – Metabolic equivalent.
### Table 2-3 Examples of physiological adaptations associated with improved maximal and submaximal cardiorespiratory fitness

<table>
<thead>
<tr>
<th>Location</th>
<th>Specific Location</th>
<th>Description of Adaptations</th>
<th>Overall Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central: Circulatory System</td>
<td>Heart:</td>
<td>↑ Stroke volume (65)</td>
<td>↑ Systemic oxygen delivery</td>
</tr>
<tr>
<td></td>
<td>↑ Left ventricle hypertrophy (64)</td>
<td>↑ Cardiac output (65)</td>
<td></td>
</tr>
<tr>
<td>Central:</td>
<td>Lungs:</td>
<td>↑ Ventilatory efficiency</td>
<td>↑ Systemic oxygen delivery</td>
</tr>
<tr>
<td>Respiratory System</td>
<td>↑ Diffusion capacity (66, 67)</td>
<td>↓ Muscle fatigue</td>
<td>↑ Endurance performance</td>
</tr>
<tr>
<td></td>
<td>↑ Strength of respiratory muscles (i.e. diaphragm,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>external intercostal) (68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral:</td>
<td>Vasculature/Blood:</td>
<td>↑ Stroke volume</td>
<td>↑ Systemic oxygen delivery</td>
</tr>
<tr>
<td>Circulatory System</td>
<td>↑ Blood volume (69, 70)</td>
<td>↑ Blood transit time through muscle tissue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑ Capillarization (71, 72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral:</td>
<td>Myocyte:</td>
<td>↑ Oxygen delivery to cell</td>
<td>↑ Ability to utilize oxygen</td>
</tr>
<tr>
<td>Muscular and Skeletal System</td>
<td>↑ Myoglobin (73)</td>
<td>↑ Sensitivity of respiratory control</td>
<td>↑ Time to fatigue</td>
</tr>
<tr>
<td></td>
<td>↑ Size/number of mitochondria (74, 75)</td>
<td>↑ ATP resynthesis</td>
<td>↑ Endurance performance</td>
</tr>
<tr>
<td></td>
<td>↑ Mitochondrial enzymes (76)</td>
<td>↓ Lactate accumulation (78)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lipid:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑ Lipid oxidation (77)</td>
<td>↑ Muscle glycogen sparing (79)</td>
<td></td>
</tr>
</tbody>
</table>
The Role of Intensity

Using a sample of 40 healthy, endurance-trained, male university students Helgerud et al. (12) investigated the role of intensity on CRF. There were four training conditions: long/slow distance running (LSD) consisting of 45 minutes of continuous running at 70% heart rate maximum (HRmax); lactate threshold running (LT) consisting of running for 24 minutes at 85% HRmax; 15/15 interval running with 47 repetitions of 15-second intervals at 90-95% HRmax separated by 15-seconds of active rest at warm-up velocity (70% HRmax); 4x4 interval running consisting of four 4-minute intervals at 90-95% HRmax separated by 3-minutes of active rest (70% HRmax). Energy expenditure was consistent across conditions. There was a significant improvement in CRF from baseline in both the vigorous-intensity interval groups while no significant increase was found in either the LSD or LT conditions. While these results suggest that intensity is an important aspect of exercise induced improvements in CRF it should be noted that these results may be confounded, in part, by baseline CRF. Typically, individuals with an elevated baseline CRF need to work at either an elevated intensity or duration in order to achieve improvement VO$_2$Max (39). Participants in the LSD and LT conditions had a baseline mean VO$_2$Max of 55.8 ml/kg/min and 59.6 ml/kg/min, respectively (12) and thus, it appears that an increased stimulus (i.e. vigorous physical activity) was required in order to elicit a change in VO$_2$Max.

Using a similar study design, Rognmo et al. (63) demonstrated the importance of baseline CRF in men with diagnosed Coronary Artery Disease. Participants in the LSD condition had a 7% improvement in CRF while participants in the vigorous-intensity interval training experienced a 17.9% improvement in VO$_2$Max relative to baseline (63). While the improvements were greater in the vigorous-intensity interval conditions, there was significant improvement in the moderate-
intensity condition (63). Therefore, the findings of Helgerud et al. (12) should be interpreted with caution as a significant improvement in LSD and LT conditions may have been seen with a less fit study sample.

O’Donovan et al. (80) found somewhat conflicting results to those of Helgerud and colleagues (12). The study sample consisted of 42 relatively healthy men aged 30 to 45 years old who did not engage in regular, sustained PA. Participants were divided into three conditions: control; moderate-intensity (60% VO2Max); and vigorous-intensity (80% VO2Max). Caloric expenditure for both conditions was approximately 400 kcal per session, thus sessions in the vigorous-intensity group were of shorter duration. O’Donovan et al. (80) found a significant interaction between monthly VO2Max score and exercise group, suggesting that VO2Max responded differently to moderate- and vigorous-intensity exercise over the period of training. At 24 weeks, however, there was no significant difference in VO2Max between moderate- and vigorous-intensity conditions (80) which suggests that changes in CRF do not differ by intensity.

The findings of Branch et al. (10) are consistent with those of O’Donovan and colleagues (80). The study sample consisted of 18 premenopausal, healthy women aged 20-40 years old who did not engage in regular structured PA. Participants were randomized to one of two conditions: moderate-intensity (40% VO2Max); and vigorous-intensity (80% VO2Max). Exercise training was conducted for 12 weeks in a supervised and progressive manner. Energy expenditure was controlled across conditions at 375 kcal per session. CRF increased significantly from baseline values by 17% in moderate-intensity and 21% in vigorous-intensity, yet the difference between conditions was not significant (10).
The Role of Dose & Frequency

Church et al. (11) conducted a randomized controlled trial to investigate the effects of exercise dose on CRF. The study sample consisted of 464 sedentary, postmenopausal, overweight or obese women. Exercise dose was determined using the National Institute of Health (NIH) public health recommendation which is 30 minutes of MPA most, preferably all days of the week. Participants were randomized to one of 4 conditions: control; 50% of NIH recommendations (4 kcal/kg); 100% of NIH recommendations (8 kcal/kg); 150% of NIH recommendations (12 kcal/kg). Intensity remained constant for each condition at 50% VO\(_2\)Max. Participants exercised 3 to 4 times per week for 6 months. There was a significant effect of dose on CRF such that with increasing dose there was a corresponding improvement in CRF (11). Interestingly, participants in the lowest dose (50% of NIH guidelines) achieved a significant improvement in VO\(_2\)Max relative to the control group indicating that even a low dose of exercise at a moderate-intensity is a sufficient stimulus for CRF improvement (11).

The frequency of PA is associated with improvements in CRF yet this effect has been found to plateau when the frequency of training is increased above 3 days per week (81-83). Additionally, the ACSM states that there is minimal added improvement in CRF with training more than 5 days per week. Conversely, training less than 2 days per week does not generally result in a meaningful improvement in CRF (82, 84).

Summary: Structured PA

The association between structured PA and CRF is unequivocal. While some debate remains as to the best exercise prescription in regards to the intensity, duration or frequency of structured PA there is one overarching commonality of the aforementioned studies – they provide insight into the association between structured PA and CRF only. With only 15% of adult
Canadians meeting the structured PA guidelines (19) the majority of waking hours are composed of either IPA and/or SED. Yet, very little research has been performed to determine the association between either IPA or SED and CRF.

2.3.2.4 Incidental Physical Activity and Cardiorespiratory Fitness

While the association between structured PA and CRF is well-established, the association between IPA and CRF remains less clear. This dearth in the literature can largely be attributed to the lack of objective tools to measure IPA until more recently. Due to the lack of literature in this area, the following sections cannot be divided by intensity, duration and frequency.

IPA and CRF as measured by Self-Report

While there are a number of limitations associated with self-report (Table 2-1) it was, up until recently, the primary tool used to measure free-living PA in large studies. Talbot et al. (13) using questionnaire, conducted one of the few studies to investigate the association between activity performed in free-living conditions and CRF. It should be noted that Talbot et al. (13) did not look specifically at IPA but free-living PA as a whole. Therefore, both structured PA and IPA were examined simultaneously. The study sample consisted of 1116 healthy men and women aged 18 to 94 years old. LPA was defined as any PA < 4 METs, MPA as PA between 5-5.99 METs and VPA as PA > 6 METs (13).

Participants were asked to recall activity over the past 2 years and were given 97 different activities to choose from. Activities were grouped into 9 major domains however domain classification was not provided. Instead, a reference to the Baltimore Longitudinal Study of Aging was provided which lists 14 major activity domains (85). The domains are as follows: personal care, housework, repairs and yard work, shopping, child-care, socializing, entertainment, public services, hobbies and leisure, and sports (85). The 9 domains used out of the 14 listed were not
specified however this list provides insight into the type of activities participants were asked to recall. MET-minutes were derived based on the activity and the time spent performing that activity. CRF was determined using a maximal graded exercise test.

Men had significantly higher MET-minutes in sport and aerobic activities relative to women who performed proportionately more home and leisure activities relative to men (13). Total daily energy expenditure was positively and significantly associated with CRF in both men and women (13). When total daily activity was broken down by intensity no significant association was found between LPA and CRF, however, MPA and VPA were significantly associated with CRF in both men and women (13). This finding is not surprising given the associations found between structured PA and CRF (10-12).

The primary limitation of this study, apart from the use of questionnaire, is the lack of distinction between structured PA and IPA within each intensity. While a clear association exists between MPA and VPA and CRF, one is not able to deduce whether it is the structured PA or IPA driving the respective associations. While many would argue that structured PA is the primary predictor of improvements in CRF and thus responsible for this association, it is important to delineate the independent effect of IPA on CRF. This has been made possible with the relatively recent introduction of a variety of objective measurement tools.

IPA and CRF as measured by Accelerometer

The accelerometer, as previously discussed, provides an objective measurement of free-living PA. McGuire and Ross (15) were the first, to our knowledge, to utilize the GT3X Actigraph (AG; Pensacola, FL) accelerometer to measure the association between IPA and CRF. In short, the AG is a triaxial accelerometer worn at the waist above the right hip. In this study, participants
wore the AG for approximately 7 days, removing only for water-based activities. The Freedson cut-points were employed to define PA intensity (60).

The study sample was composed of 135 abdominally obese, inactive adult men and women (15). Both the duration and intensity of IPA were significantly associated with CRF after controlling for sex, BMI, and average hours of accelerometer wear (15). After control for IPA intensity, however, IPA duration was no longer significantly associated with CRF (15). LPA duration was not significantly associated with CRF after control for covariates however, sporadic MPA duration was significantly associated with CRF (15). McGuire et al. (15) posit that the association between IPA and CRF was driven in large part by the sporadic MPA. Sporadic MPA duration was divided into tertiles and a 1-MET significant difference in CRF between the highest (mean = 33.6 min/day of MPA) and lowest tertile (mean = 6.2 min/day of MPA) was found. Thus, participants who accumulated a greater amount of sporadic MPA had the highest CRF values. These findings counter the current guidelines for two reasons (39). Firstly, the effect of intensity on CRF appears to occur across a continuum and therefore is not restricted to intensities > 45-55% of heart rate reserve. Additionally, it seems that PA performed in bouts of less than 10 minutes is positively associated with CRF. This finding is of current health relevance as a growing proportion of North Americans are spending less time in structured PA (19). Health messaging aimed at increasing IPA may be a more feasible and attractive option to a relatively inactive North American population.

2.3.2.5 Limitations of the Waist-Worn Accelerometer

The limitations of most standard waist-worn accelerometers can be divided into either limitations of the physical device or limitations of the cut-point classification system used to quantify PA intensity.
There are a plethora of accelerometers available on the market making the decision of which device to use difficult. The AG has become one of the best studied and thus, most popular devices on the market (58). Yet, the popularity of this device should not overshadow the inherent limitations of both the AG and other waist-worn accelerometers. Typically, waist-worn accelerometers have limited ability to capture non-locomotor activities such as cycling, weight-lifting and house-hold and outdoor chores (e.g. putting away groceries, raking, shovelling) (86) (39). In addition, the intensity for activities performed on an incline are often under-estimated (87-89). Due to these limitations the duration and intensity of such activities is likely under-reported.

In addition to the number of accelerometers available on the market, there is a wide selection of cut-point classification systems available to quantify 24-hour patterns of PA intensity (60, 61). As mentioned previously, the cut-points developed by Freedon et al. (60) are arguably the most well-known and commonly utilized cut-points. However, Strath et al. (90) in a sample of 10 healthy weight, young adult men and women found the Freedson cut-points to underestimate MPA by 60% relative to values derived via indirect calorimetry. Bassett and colleagues (91) evaluated the Freedson energy expenditure prediction equation in a sample of overweight adults who completed a variety of activities including yard work, housework, family care and conditioning. The correlation coefficient for the Freedson equation with actual oxygen cost as measured by a portable metabolic cart was $r = 0.32$ (91). The underestimation of either duration and/or energy expenditure within a given intensity is perhaps explained by how the cut-points were developed. Freedson et al. (60) utilized a sample of healthy-weight, relatively fit, young adult men and women and had them either walk or run on a treadmill. Both the study sample and the activities performed are not representative of the general population and 24-hour PA.
respectively. Thus, it is likely that the cut-point associated with MPA for a less-fit, more sedentary individual would be considerably lower than for the population utilized by Freedson and colleagues (60) in the calibration study.

Other classification systems have been developed that encompass a greater variety of activities. Swartz et al. (61) developed cut-points for lifestyle based activities using 70 healthy weight, middle-aged adult men and women. Participants performed both dynamic (e.g. walking, running) activity and lifestyle based activities (e.g. yardwork, housework, family care). Strath et al. (90) found the Swartz cut-points to be the best predictors of free-living PA, with no significant differences in the duration of either LPA or MPA relative to measures provided by indirect calorimetry.

All cut-point classification systems however, make the inaccurate yet necessary assumption that exercise intensity and thus, energy expenditure can be determined using biomechanical principles alone. Yet, the intensity that one is performing at is determined by both biomechanical and physiological factors including age, sex, weight, height, lean muscle mass, fitness level, pre-existing health conditions as previously shown in Figure 2-1 (43). Thus, how intensity has been quantified using accelerometer count values alone has likely contributed to either the under- and/or over-estimation of time spent with certain intensities. Therefore, creating a device that overcomes the limitations of most waist-worn accelerometers is necessary in order to achieve a more accurate estimate of energy expenditure.

2.3.2.6 Novel Solutions to Waist-worn Accelerometer Limitations

*The SenseWear Pro Armband*

The SenseWear Pro Armband (SWA; BodyMedia, Pittsburgh, PA), worn on the upper right arm, incorporates measured parameters (accelerometry, heat flux, galvanic skin response,
skin temperature, near-body temperature) and participant characteristics (sex, age, height, weight) into proprietary algorithms to estimate energy expenditure (kcals) and intensity (METs) for each epoch (Figure 2-3) (16). Table 2-4 provides a more detailed overview of the SWA measured parameters. The SWA, unlike the AG, does not have a cut-point classification system(s) to quantify count values and thus, PA intensity. Therefore, activity intensity is determined using the SWA estimated MET output for each epoch. Using a predetermined MET cut-point system as defined in Section 2.3.2.1, time spent within a given intensity can be determined. For example, to calculate average daily time spent in LPA all epochs with a corresponding MET value between 1 and 2.99 are totalled and divided by the number of days worn.

The algorithms utilized in the SWA are constantly evolving (16). Development of the algorithms utilized in the SWA is a fairly intensive and multistage process (16). Data is first collected during clinical studies with laboratory equipment such as metabolic carts and DLW (16). From this raw data, channels are created and stored on the SWA. Mean transverse acceleration and mean heat flux are both examples of what constitutes a channel of which there are 35 in the SWA (V.6.1) (92). These channels provide useful information as to the wearer’s activity and are utilized to determine the context of the wearer. For each context (i.e. walking, running, resting, sleeping, resistance activity (weight-lifting, lower -leg motion), motion caused by external forces (car), and exercise combined with external motion (road biking)) there is an associated algorithm to predict expenditure and intensity (16). By utilizing context-specific algorithms the prediction of energy expenditure/intensity, in theory, should become more accurate.
Figure 2-3 Photograph image of SenseWear Pro Armband

Image property of BodyMedia Inc., 2006
Table 2-4 Parameters measured by SenseWear Pro Armband

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Measurement Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer</td>
<td>• Micro-electro-mechanical sensor</td>
<td>Counts per minute</td>
</tr>
<tr>
<td></td>
<td>• Measures acceleration on transverse and longitudinal planes that results from muscular activity, gravity and other external forces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Gravity is taken into account to determine context of wear (i.e. reclining, sitting, walking, running)</td>
<td></td>
</tr>
<tr>
<td>Heat Flux</td>
<td>• Measurement of heat dissipated (via convection) from the body</td>
<td>Watts/m²</td>
</tr>
<tr>
<td>Skin Temperature</td>
<td>• Measurement of body’s core temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Galvanic Skin Response</td>
<td>• Represents electrical conductivity between two points on wearer’s arm measured via two electrodes integrated on underside of SWA</td>
<td>KW to MW (nSiemens – uSiemens)</td>
</tr>
<tr>
<td></td>
<td>• Skin conductivity influenced by sweat from physical and emotional stimuli</td>
<td></td>
</tr>
</tbody>
</table>
The caveat of this device is that researchers know very little about what channels are used for each algorithm and the weight given to each channel in the determination of energy expenditure and intensity. Thus, while the software associated with the device continues to improve with the incorporation of new/modified algorithms within different populations (i.e. healthy weight, overweight, or obese) researchers still know very little about how the output is derived.

A number of calibration studies have been performed using the SWA and are outlined in Table 2-5. Conducting a comparative analysis of these calibration studies, however, is difficult as most employ different software versions due to the constant evolution of the propriety algorithms. More, the authors of these studies utilize different methods (e.g. Pearson r, Intraclass correlation coefficients, Bland Altman plots) to ascertain whether the SWA is either reliable or valid measure of energy expenditure in relation to the utilized criterion test.

While the Pearson r correlation is a well-recognized and understood test, it merely demonstrates the strength of an association between two measures that may or may not have the same scale of measurement (93). Thus, it is not a good indication of agreement between two measurement devices. Intraclass correlation coefficients (ICC) allow researchers to determine the relationship among variables of a common class (i.e. variables share both their metric and variance) and determine the proportional variance in the dependent variable that is explained by differences between the measurement devices (100). Lastly, the Bland Altman plot allows researchers to determine how well two methods agree in the measurement of a specific variable (e.g. energy expenditure) (101). For each data point (i.e. participant), the mean of the two methods is plotted on the x-axis and the absolute difference between the two methods is plotted
Table 2-5 Ability of the SenseWear Pro Armband to measure energy expenditure

<table>
<thead>
<tr>
<th>First Author</th>
<th>Software Version</th>
<th>Criterion Method</th>
<th>Variable Measured</th>
<th>Pearson $r$</th>
<th>Intraclass Correlation Coefficient</th>
<th>Bland Altman Plot Mean difference [95% Limits of Agreement]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruin (89)</td>
<td>1.0</td>
<td>IC</td>
<td>RMR</td>
<td>$r = 0.76, p&lt;0.01$</td>
<td>-</td>
<td>0.18 [-0.17, 0.20]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r = 0.11, p&gt;0.73$</td>
<td>-</td>
<td>-0.20 [-3.3, 2.5]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r = 0.69, p&lt;0.05$</td>
<td>1.5 [-0.29, 3.25]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r = 0.54, p &lt;0.01$</td>
<td>NG [-1.9, 3.6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r = 0.47, p &lt;0.05$</td>
<td>NG [-6.2, 2.5]</td>
<td></td>
</tr>
<tr>
<td>Jakicic (87)</td>
<td>3.2</td>
<td>IC</td>
<td>PAEE</td>
<td>$r =-0.42, p &lt;0.02$</td>
<td>0.87</td>
<td>0 [-50, 50]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r =-0.48, p &lt;0.05$</td>
<td>0.89</td>
<td>0 [-25, 30]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>$r = 0.14, p &lt;0.59$</td>
<td>0.82</td>
<td>0 [-40, 50]</td>
</tr>
<tr>
<td>King (94)</td>
<td>N/A</td>
<td>IC</td>
<td>PAEE</td>
<td>$r =-0.10, p &lt;0.70$</td>
<td>0.66</td>
<td>0 [-20, 20]</td>
</tr>
<tr>
<td>Papazoglou (95)</td>
<td>4.0</td>
<td>IC</td>
<td>RMR</td>
<td>$r = 0.88, p &lt;0.01$</td>
<td>-</td>
<td>4 [-15, 22]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>0.18</td>
<td>0 [-60, 60]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>0.06</td>
<td>0 [-80, 20]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PAEE</td>
<td>0.03</td>
<td>0 [-100, 20]</td>
<td></td>
</tr>
<tr>
<td>Malavolti (96)</td>
<td>4.0</td>
<td>IC</td>
<td>REE</td>
<td>$r = 0.86, p &lt;0.01$</td>
<td>20 [-645, 188]</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>R</td>
<td>Method</td>
<td>TDEE</td>
<td>PAEE</td>
<td>TDEE - PAEE</td>
<td>PAEE - PAEE</td>
</tr>
<tr>
<td>------------------</td>
<td>---</td>
<td>--------------</td>
<td>------------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>St-Onge (97)</td>
<td>4.0</td>
<td>DLW</td>
<td>TDEE</td>
<td>PAEE</td>
<td>r = 0.74, p &lt;0.01</td>
<td>r = 0.49, p &lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.81</td>
<td>0.46</td>
<td>-100 [-300, 300]</td>
<td>-225 [-720, 241]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(SEE ± 189)</td>
<td>(SEE ±179)</td>
<td>Note: 80% values fell in predefined limits</td>
<td>Note: 83% values fell in 2 SD of mean difference</td>
</tr>
<tr>
<td>Welk (98)</td>
<td>4.0/4.1</td>
<td>IDEEA Monitor</td>
<td>PAEE</td>
<td></td>
<td>r = 0.66</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lie</td>
<td>r = 0.66</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sit</td>
<td>r = 0.51</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stand</td>
<td>r = 0.63</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Walking</td>
<td>r = 0.63</td>
<td>-</td>
</tr>
<tr>
<td>Johannsen (99)</td>
<td>6.1</td>
<td>DLW</td>
<td>TDEE</td>
<td>PAEE</td>
<td>r = 0.68, p &lt;0.01</td>
<td>r = 0.51, p &lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.80</td>
<td>0.63</td>
<td>22.5 [-524.4, 748.8]</td>
<td>-</td>
</tr>
</tbody>
</table>

*Estimated mean difference from Bland Altman Plot as scale or actual value was not provided.
on the y-axis (101). A mean difference between the methods other than zero suggests a systematic bias in measurement (101). The Bland Altman plot allows researchers to visually examine how well the two methods agree using either predetermined and/or 95% limits of agreement (100). How the limits of agreement are determined and thus, the interpretation of how well two measures agree is largely dependent upon the researcher (100). In short, there are limitations to each tool used to assess the agreement between two different measurement devices.

Table 2-5 summarizes the calibration studies and the statistical test(s) used to determine the validity of the SWA. In the measurement of physical activity energy expenditure, the majority of the listed Bland Altman plots reveal mean differences greater or less than zero. This indicates a systematic bias between the SWA and the criterion method used. More, the limits of agreement are fairly large which demonstrate large variability in the SWAs measurement of energy expenditure relative to the criterion method. Upon review of these calibration studies, it is apparent that improvement in the SWA algorithms used to quantify duration and estimate expenditure is necessary.

Few calibration studies have been conducted to compare the SWA with the AG. Welk et al. (98) investigated the ability of the MTI accelerometer, an earlier version of the current AG, and the SWA (V.4.1) in the measurement of energy expenditure over the course of a day. The Freedson cut-point classification system was employed (60). The criterion method employed to measure free-living PA was the Intelligent Device for Estimating Energy Expenditure and Activity (IDEEA) monitor - a portable system consisting of 5 integrated sensors. The details of this device are outlined elsewhere (98). The SWA and MTI yielded values that were within 0.01 and 0.38 METs of those derived from the IDEEA monitor for total energy expenditure, respectively. In the measurement of PA duration, the SWA had a strong correlation with the
IDEAA monit \((r = 0.90)\) and fairly good measurement agreement as indicated by a Bland Altman plot \((98)\). This is, to our knowledge, the only study to compare the SWA and AG in the measurement of energy expenditure. Further study is required to determine the reliability and accuracy of these devices over a longer period of wear.

2.3.2.7 Sedentary Behaviour and Cardiorespiratory Fitness

The study of SED has become a primary research focus in recent years which can be attributed to both the development of better tools to quantify SED and the large increase in time spent SED \((46, 102, 103)\). This includes both occupational and leisure-time sitting which is predominantly composed of screen- and travel-time \((46)\). In the United States time-use surveys found individuals to work an average of 9.2 hours per day with an estimated half of those hours spent sitting \((104)\). Additionally, they accrued 2 hours of television watching or playing video/computer games in the evening \((104)\). Australians were found to sit at work for a mean time of 4.2 hours with an additional 2.9 hours in the evening \((105)\). The risks associated with such a behaviour shift include increased incidence of obesity, metabolic syndrome, diabetes, markers of cardiovascular risk and premature mortality \((106)\). Moreover, increased sitting time, regardless of one’s respective activity level, is associated with elevated health risk \((107)\). While the association between SED and health risk is clear, the direct association between SED and CRF remains unknown. As CRF as independent correlate of cardiovascular disease and mortality, a better understanding of this association is pertinent.

The association between sedentary behaviour and CRF remains to be elucidated. Thus, the physiological mechanisms associated with SED in relation to CRF also remain unknown. Detraining and bed rest studies, however, provide some insight into the possible side effects of
reduced activity levels (17, 18, 108). Three reviews (17, 18, 108) aptly summarize these physiological alterations and are outlined in Table 2-6.

Based upon the findings presented in Table 2-6 it appears that ending a structured PA program and increased bed rest are both associated with fairly dramatic declines in CRF due to changes in cardiovascular function, blood volume, capillarization, and enzymatic and mitochondrial size and number. However, neither of these respective activities can be perfectly equated with SED. Thus, further investigation looking at the direct association between objectively measured SED and CRF is required.

2.4 Summary

CRF is a strong predictor of cardiovascular disease and mortality however, with improvements in CRF there is a corresponding reduction in risk. Determinants of CRF include genetics, sex, and age with PA being the principle modifiable determinant. A plethora of research exists documenting the association between structured PA and CRF however, the associations between IPA, sporadic MPA, LPA, SED and CRF remain less clear. Recent evidence suggests that IPA is associated with CRF however further investigation is required.
Table 2-6 Physiological adaptations associated with detraining and bed rest in relation to cardiorespiratory fitness

<table>
<thead>
<tr>
<th>Location</th>
<th>Characteristic</th>
<th>Detraining (18, 108)</th>
<th>Bed Rest (17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central/Peripheral</td>
<td>Maximal Oxygen Uptake</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Central</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plasma volume</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Stroke volume</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Cardiac output</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Maximal heart rate</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Submaximal heart rate</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Peripheral</td>
<td>Capillarization</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Venous pooling</td>
<td>N/A</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>Mitochondria content/size</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Enzymatic availability</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Respiratory Exchange Ratio</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

N/A – Not applicable
Chapter 3 Manuscript

The Association between Incidental Physical Activity and Cardiorespiratory Fitness
3.1 Introduction

It is well established that structured physical activity (PA; activity ≥ 3 metabolic equivalents (METs) in bouts of 10 minutes or more) is associated with the improvement of cardiorespiratory fitness (CRF) (10, 12, 80). McGuire et al. (15) recently observed that incidental physical activity (IPA; defined as unstructured, sporadic light- and moderate-intensity PA performed in free-living conditions) is positively associated with CRF suggesting that all forms of physical activity carry health benefit (15). This association, however, is believed to be driven by the sporadic moderate-intensity physical activity (MPA; defined as activity ≥ 3 METs accumulated in bouts less than 10 minutes), as McGuire et al. (15) found a significant association between sporadic MPA and CRF, but not between light-intensity physical activity (LPA; defined as activity between 1.0 - 2.99 METs) and CRF. Given the established association of CRF with morbidity and mortality (3), the observations that IPA and sporadic MPA are positively associated with CRF have important clinical and public health implications.

In our prior study, IPA was measured using the GT3X Actigraph (AG) accelerometer worn at the waist (15). The current study utilized the SenseWear Pro Armband (SWA), a relatively novel accelerometer worn on the upper arm. This device utilizes both measured parameters (i.e. acceleration and heat variables) and participant characteristics (i.e. age, height, weight and sex) in the prediction of energy expenditure for each minute of wear (16). A large proportion of household activities require use of the upper-body (e.g. dusting, washing dishes, and putting away groceries) which the SWA may better capture due to its placement on the arm. Moreover, as this device incorporates heat measures it may be more sensitive to changes in load (e.g. carrying groceries). Whether an association between IPA and/or sporadic MPA as measured by the SWA is associated with CRF is unknown.

The primary objective of this study was to determine whether the duration and expenditure of IPA and sporadic MPA, objectively measured using the SWA, was associated with
CRF in a sample of abdominally obese, inactive, adults. Secondary analyses investigated the associations between LPA, sedentary behaviour (SED; defined as activity < 1.0 METs) and CRF.

3.2 Methods

3.2.1 Study Sample

Participants were abdominally obese (waist circumference ≥ 102 cm in men and ≥ 88 cm in women) men (n = 24) and women (n = 55) recruited for participation in an exercise trial (ClinicalTrials.gov Identifier: NCT00955071) at Queen’s University. Additional inclusion criteria included: 2-hour glucose greater than 6.5 mmol/L, body mass index (BMI) between 25.0 to 39.9 kg/m², and no self-reported structured PA more than 1 day/week. Participants self-reported that they were weight stable (±2 kg) for 6 months prior to beginning the study and were non-smokers. Exclusion criteria included: BMI over 40 kg/m², Type I or Type II diabetes, and any impairment that would make PA difficult or unsafe (including history of myocardial infarction, stroke, coronary bypass surgery or angioplasty in the last 6 months). All participants submitted informed written consent (Appendix A), filled out a medical questionnaire (Appendix B), completed a screening form (Appendix C) and received medical clearance by their regular physician before participation in the study. The exercise trial was approved by the Queen’s University Health Sciences Research Ethics Board.

3.2.2 Measurement of Body Composition and Cardiorespiratory Fitness

Weight was measured to the nearest 0.1 kg using the Detecto scale (Webb City, MO) with shoes removed wearing a standard T-shirt and shorts (Appendix D). Standing height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Waist circumference (WC) was measured at the level of the iliac crest using an anthropometric tape (Gulick II) to the nearest 1.0 cm (Appendix D). BMI was determined by using the following formula: weight (kg)/(height (cm)²).
Cardiorespiratory fitness, measured as peak oxygen consumption per unit of time (peak VO$_2$), was measured at baseline using a maximal graded treadmill exercise test (modified Bruce protocol) combined with standard open-circuit spirometry techniques (SensorMedics Corp, Yorba Linda, California) (Appendix E). A Polar Heart Rate monitor (Polar Oy, Kempele, Finland) and the Borg rate of perceived exertion scale were used to measure heart rate and ratings of perceived exertion throughout the test.

3.2.3 Measurement of Physical Activity and Sedentary Behaviour

Free-living PA was measured using the Sensewear Pro Armband (SWA, Pittsburgh, PA). For more details about the SWA please refer to Appendix F. The SWA incorporates measured parameters (accelerometry, heat flux, galvanic skin response, skin temperature, near-body temperature) and participant characteristics (sex, age, height, weight) into proprietary algorithms to estimate energy expenditure (kilocalories) and intensity (METs) in 1-minute epochs.

Participants wore the SWA over the triceps muscle on the right arm at the midpoint between the acromion and olecranon processes for a period of 7 days during the baseline period of the exercise study. In addition, participants were asked to fill out a log sheet indicating the time they woke, went to bed, and if they took the device off for any reason (Appendix G). Data from the SWA was downloaded using Innerview Professional Software Version 6.1 (Innerview; Pittsburgh, PA). A proprietary program was developed using Visual Basic to read and organize raw data for analyses (See Appendix F).

In order for data to be included in analysis participants wear required to wear the SWA for $\geq 10$ hours per day for a minimum of four days including at least one weekend day. Wear time was calculated after extended periods of consecutive zero counts $\geq 30$ minutes and sleep time (determined using both participant logs and visual examination of the data) were excluded. Of the
115 participants who wore the SWA at baseline, 95 met the wear-time requirements and were included in analyses.

Activity intensity was defined using the following MET cut-points: SED < 1.0 MET; IPA ≥ 1.0 MET; LPA 1.0 - 2.99 METs; MPA 3.0 – 5.99 METs; and vigorous-intensity physical activity (VPA) ≥ 6.0 METs. However, 62% of the participants did not accumulate any VPA and the remaining participants had less than three minutes per day. Therefore, all PA ≥ 3.0 METs was classified as MPA.

Activity accumulated during each day of monitoring was quantified as: 1) average duration, in minutes per day (min/day) expressed as a percentage of total wear-time for IPA, sporadic MPA, LPA and SED, 2) average expenditure, in MET-minutes expressed as a percentage total MET-minutes for IPA, sporadic MPA, LPA and SED. MET-minutes were derived by totaling all MET values per minute of wear within the given intensity range (e.g. LPA is between 1-2.99 METs) and dividing by the number of days worn to get MET-minutes per day. Of the 95 participants who met wear-time requirements, 16 met the consensus recommendation of 30 minutes of MPA per day accumulated in 10 minute bouts or more and were therefore removed from analyses. Of the remaining 79 participants, 54% did not accrue any bouted MPA (i.e. consecutive counts of MPA equal to 10 minutes in length) and the remaining participants did not meet consensus PA guidelines. Therefore, all MPA was classified as sporadic.

3.2.4 Statistical Analysis

The Predictive Analytics Software (PASW, SPSS Inc., Chicago, Illinois) was used for all statistical analyses. Shapiro-Wilk tests were performed to ensure that all variables were normally distributed. LPA and SED duration were logarithmically transformed owing to non-normal distributions. Sex differences in descriptive characteristics and PA variables were determined
using Independent Student’s T-tests. Analyses were collapsed across sex as no sex interaction was found between the associations of any of the PA or SED variables and CRF.

The association between the duration and expenditure of IPA and CRF was explored using linear regression models wherein either IPA expenditure or IPA duration was the independent variable and CRF was the dependent variable. Four adjusted models were also conducted: 1) control for sex, 2) control for sex and BMI, 3) control for sex, BMI, and age. Multicollinearity tests were performed for all models. Due to multicollinarity, linear regression analysis to determine the relationship between IPA duration and CRF, independent of IPA expenditure and vice versa was not performed. Similar models were used to determine the association between sporadic MPA duration and expenditure and CRF however, an additional model was performed that controlled for sex, BMI, age, and related PA variables. To further examine the relationship between sporadic MPA and CRF, participants were divided into tertiles based on mean sporadic MPA duration. Differences in CRF across tertiles were determined using a univariate analysis of covariance (ANCOVA) with a post-hoc tukey test. A univariate linear trend test was used to characterize the difference in CRF across MPA tertiles.

In secondary analyses, similar regression models were employed to determine the association between LPA, SED and CRF. An additional model was performed for the association between LPA and CRF that controlled for sex, BMI, age, and related PA variables. There was one exception, however, no model was performed to examine the relationship between SED expenditure and CRF.

Power calculations were determined using the primary outcome. With our sample of 79 participants we estimated that we had 80% power to detect a correlation of 0.35 with an alpha level of $p < 0.05$. 

42
3.3 Results

Participant characteristics are provided in **Table 3-1**. Participants accumulated an average of 326.6 ± 127 minutes of IPA per day which was composed of 40.7±17.8 minutes of MPA and 285.9±118.2 minutes of LPA. Time spent in SED was 601.4±120.7 minutes per day.

Primary analysis revealed that IPA duration was significantly associated with CRF (**Table 3-2**). This association remained significant after statistical control for sex (p < 0.05), but not after further control for BMI and age (p > 0.05). Observations for IPA expenditure were similar (**Table 2**). Sporadic MPA duration was positively associated with CRF and remained significant after control for sex, BMI, age and LPA duration (p < 0.05, **Table 3-2**). Independent of sex, BMI, and age, and LPA duration, for every one unit standard deviation change in sporadic MPA duration (17.0 min/d) there was a corresponding increase in CRF by 0.36 standard deviations (1.5 ml O₂/kg/min). Similar results were found for sporadic MPA expenditure and CRF (p ≤ 0.05; **Table 3-2**). Independent of covariates, for every one unit standard deviation change in sporadic MPA expenditure (70.0 MET-min/d) there was a corresponding increase in CRF by 0.12 standard deviations (0.5 ml O₂/kg/min).

**Figure 3-1** depicts the relationship between differences in CRF across tertiles of sporadic MPA duration. The mean difference in CRF within the highest sporadic MPA tertile was significantly greater than mean CRF in the lowest tertile (p ≤ 0.05). Furthermore, a significant linear trend (p < 0.05) was observed across tertiles of increasing sporadic MPA duration.

Secondary analyses revealed that LPA duration was positively associated with CRF (**Table 3-3**) however this association did not remain significant after control for covariates (p > 0.05). Results for LPA expenditure were similar (**Table 3-3**). SED duration was negatively associated with CRF (**Table 3-3**) however this association did not remain significant after control for covariates (p > 0.05).
### Table 3-1
Participant characteristics and mean duration and expenditure for activity variables

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Observations (n = 79)</th>
<th>Males (n = 24)</th>
<th>Females (n = 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53.5 (7.7)</td>
<td>55.5 (7.8)</td>
<td>52.3 (7.5)</td>
</tr>
<tr>
<td>BMI</td>
<td>33.6 (4.5)</td>
<td>34.3 (3.9)</td>
<td>33.3 (4.6)</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>112.0 (11.0)</td>
<td>119.0 (9.3)</td>
<td>109.0 (10.3)*</td>
</tr>
<tr>
<td>VO₂Max (ml O²/kg/min)</td>
<td>26.4 (4.3)</td>
<td>30.5 (3.4)</td>
<td>24.6 (3.2)*</td>
</tr>
<tr>
<td>VO₂Max (METs)</td>
<td>7.6 (1.2)</td>
<td>8.7 (1.0)</td>
<td>7.0 (0.92)*</td>
</tr>
</tbody>
</table>

#### Duration (min/d)

<table>
<thead>
<tr>
<th></th>
<th>Mean (hrs/d)</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPA</td>
<td>326.6 (127.0)</td>
<td>368.8 (153.2)</td>
<td>308.2 (110.3)</td>
</tr>
<tr>
<td>SED</td>
<td>601.4 (120.7)</td>
<td>576.8 (135.6)</td>
<td>612.2 (113.3)</td>
</tr>
<tr>
<td>MPA</td>
<td>40.7 (17.8)</td>
<td>42.3 (16.7)</td>
<td>40.0 (18.4)</td>
</tr>
<tr>
<td>LPA</td>
<td>285.9 (118.2)</td>
<td>326.4 (146.4)</td>
<td>268.2 (99.9)</td>
</tr>
</tbody>
</table>

#### Expenditure (MET-min/d)

<table>
<thead>
<tr>
<th></th>
<th>Mean (MET-min/d)</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPA</td>
<td>659.7 (231.3)</td>
<td>707.8 (247.7)</td>
<td>638.7 (222.8)</td>
</tr>
<tr>
<td>MPA</td>
<td>154.8 (70.0)</td>
<td>159.8 (64.4)</td>
<td>153.0 (72.2)</td>
</tr>
<tr>
<td>LPA</td>
<td>504.8 (188.7)</td>
<td>547.9 (216.2)</td>
<td>486.0 (174)</td>
</tr>
</tbody>
</table>

**BMI** – Body mass index, **IPA** – Incidental physical activity, **LPA** – light-intensity physical activity, **METs** – Metabolic equivalents, **MPA** – moderate-intensity physical activity, **SED** – Sedentary behaviour, **VO₂Max** – Maximal oxygen uptake.

Data is presented as a group mean (SD)

*Indicates significant sex difference, \( p < 0.05 \).
### Table 3-2 Association between incidental physical activity and cardiorespiratory fitness

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>p value</th>
<th>95% CI [Lower, Upper]</th>
<th>R(^2) Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta (SE)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPA Duration (min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.14 (0.04)</td>
<td>0.00</td>
<td>0.07, 0.20</td>
<td>0.17</td>
</tr>
<tr>
<td>2</td>
<td>0.10 (0.28)</td>
<td>0.00</td>
<td>0.05, 0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>3</td>
<td>0.05 (0.03)</td>
<td>0.09</td>
<td>0.0, 0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>-0.01 (0.03)</td>
<td>0.85</td>
<td>-0.06, 0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>IPA Expenditure (MET-min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.12 (0.04)</td>
<td>0.00</td>
<td>0.04, 0.20</td>
<td>0.11</td>
</tr>
<tr>
<td>2</td>
<td>0.10 (0.03)</td>
<td>0.00</td>
<td>0.04, 0.16</td>
<td>0.07</td>
</tr>
<tr>
<td>3</td>
<td>0.05 (0.03)</td>
<td>0.14</td>
<td>-0.46, -0.13</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>0.00 (0.03)</td>
<td>0.89</td>
<td>-0.05, 0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>MPA Duration (min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.65 (0.25)</td>
<td>0.01</td>
<td>0.16, 1.2</td>
<td>0.08</td>
</tr>
<tr>
<td>2</td>
<td>0.60 (0.19)</td>
<td>0.00</td>
<td>0.22, 0.97</td>
<td>0.07</td>
</tr>
<tr>
<td>3</td>
<td>0.44 (0.17)</td>
<td>0.01</td>
<td>0.10, 0.79</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>0.30 (0.16)</td>
<td>0.06</td>
<td>-0.01, 0.60</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>0.36 (0.17)</td>
<td>0.03</td>
<td>0.03, 0.69</td>
<td>0.02</td>
</tr>
<tr>
<td>MPA Expenditure (MET-min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.18 (0.10)</td>
<td>0.07</td>
<td>-0.02, 0.39</td>
<td>0.04</td>
</tr>
<tr>
<td>2</td>
<td>0.18 (0.08)</td>
<td>0.02</td>
<td>0.03, 0.33</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>0.16 (0.07)</td>
<td>0.02</td>
<td>0.02, 0.29</td>
<td>0.03</td>
</tr>
<tr>
<td>4</td>
<td>0.12 (0.06)</td>
<td>0.06</td>
<td>0.00, 0.24</td>
<td>0.02</td>
</tr>
<tr>
<td>5</td>
<td>0.12 (0.06)</td>
<td>0.05</td>
<td>0.00, 0.24</td>
<td>0.02</td>
</tr>
</tbody>
</table>

CI – Confidence interval, IPA – Incidental physical activity, MPA – Moderate-intensity physical activity. R\(^2\) Change – Variance explained in cardiorespiratory fitness by independent variable of interest (IPA or MPA).  
Model 1: Unadjusted  
Model 2: Control for sex  
Model 3: Control for sex, BMI  
Model 4: Control for sex, BMI, age  
Model 5: Control for sex, BMI, age, LPA duration (for MPA duration and CRF), LPA expenditure (for MPA expenditure and CRF)
### Table 3-3 Association between light-intensity physical activity and sedentary behaviour and cardiorespiratory fitness

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients Beta (SE)</th>
<th>p value</th>
<th>95% CI [Lower, Upper]</th>
<th>R² Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPA Duration (log min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>9.6 (2.7)</td>
<td>0.00</td>
<td>4.1, 14.9</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>6.9 (2.1)</td>
<td>0.00</td>
<td>2.6, 11.1</td>
<td>0.07</td>
</tr>
<tr>
<td>3</td>
<td>2.7 (2.3)</td>
<td>0.25</td>
<td>-1.9, 7.4</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>-0.92 (2.1)</td>
<td>0.67</td>
<td>-5.2, 3.4</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>-2.5 (2.2)</td>
<td>0.26</td>
<td>-6.9, 1.9</td>
<td>0.01</td>
</tr>
<tr>
<td>LPA Expenditure (MET-min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.12 (0.05)</td>
<td>0.01</td>
<td>0.03, 0.21</td>
<td>0.08</td>
</tr>
<tr>
<td>2</td>
<td>0.09 (0.04)</td>
<td>0.01</td>
<td>0.02, 0.16</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>0.02 (0.04)</td>
<td>0.59</td>
<td>-0.05, 0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>-0.03 (0.03)</td>
<td>0.39</td>
<td>-0.09, 0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>-0.03 (0.03)</td>
<td>0.36</td>
<td>-0.09, 0.03</td>
<td>0.00</td>
</tr>
<tr>
<td>SED Duration (log min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-1.2 (0.33)</td>
<td>0.00</td>
<td>-1.9, -0.56</td>
<td>0.15</td>
</tr>
<tr>
<td>2</td>
<td>-0.89 (0.26)</td>
<td>0.00</td>
<td>-1.4, -0.37</td>
<td>0.08</td>
</tr>
<tr>
<td>3</td>
<td>-0.40 (0.29)</td>
<td>0.16</td>
<td>-0.97, 0.19</td>
<td>0.01</td>
</tr>
<tr>
<td>4</td>
<td>0.03 (0.26)</td>
<td>0.90</td>
<td>-0.49, 0.56</td>
<td>0.00</td>
</tr>
</tbody>
</table>

CI – Confidence interval, LPA – Light-intensity physical activity, SED – Sedentary behaviour, R² Change – Variance explained in cardiorespiratory fitness by independent variable of interest (LPA or SED).

Model 1: Unadjusted
Model 2: Control for sex
Model 3: Control for sex, BMI
Model 4: Control for sex, BMI, age
Model 5: Control for sex, BMI, age, MPA duration (for LPA duration and CRF) or MPA expenditure (for LPA expenditure and CRF)
Figure 3-1 Association between sporadic moderate-intensity physical activity duration and cardiorespiratory fitness

METs – Metabolic equivalents.
Participants were separated into tertiles according to mean sporadic moderate-intensity physical activity duration. Tertile 1: N = 26, CRF = 7.24 METs. Tertile 2: N = 27, CRF = 7.38 METs. Tertile 3: N = 26, CRF = 8.03 METs.
Data is presented as mean and the standard error of the mean.
* Tertile 3 is significantly different from Tertile 1 (p ≤ 0.05)
† Tertile 3 is significantly different from Tertile 2 (p ≤ 0.05)
3.4 Discussion

In this study we did not find an association between either the duration or expenditure of IPA and CRF, however, we found sporadic MPA to be an independent predictor of CRF. This finding suggests that PA accrued in bouts of less than 10 minutes can have health benefit which has both clinical and public health implications as CRF is an independent predictor of morbidity and mortality.

The non-significant association between IPA and CRF counters the recently published finding by McGuire et al. (15) who found a significant and positive association between IPA and CRF. This association, however, was largely driven by the sporadic MPA which had a significant and positive association with CRF while no association was found between LPA and CRF (15). Similar associations between sporadic MPA, LPA and CRF were documented in the current study.

The incongruence between the current and prior study in regards to the association between IPA and CRF is likely explained by the differences in study sample size. Yet, differences in the accelerometer used to objectively quantify PA variables may also partially explain the discrepant findings. McGuire et al. (15) utilized the GT3X Actigraph (AG; Pensacola, FL), a triaxial, waist-worn accelerometer, to measure 24-hour patterns of activity. The AG is limited in its measurement of upper-body movement, and non-ambulatory activities (58). More, how activity intensity is quantified in the AG is inherently different from the SWA. Specifically, cut-point classification systems have been developed for the AG that equate count values, which are representative of body acceleration over a period of time, with a MET value (60, 61). Thus, only body acceleration is utilized to differentiate between various activity intensities. Conversely, the SWA utilizes proprietary algorithms that incorporate acceleration, heat variables and individual characteristics to estimate METs for a given period of time (16). Therefore both physiological and biomechanical factors are included in the determination of intensity quantification.
To determine whether sample size or device differences influenced the association between IPA and CRF we performed a tertiary analysis (data presented in Appendix I) in a subsample of participants (n=59) who wore both the AG and the SWA at baseline. We did find a significant difference in the measurement of IPA and sporadic MPA duration between the AG and SWA which suggests device differences in activity intensity quantification. However, we did not find a significant association between IPA, as measured by either the AG or SWA, and CRF. Therefore, with a reduced sample size we found a similar association between IPA, as measured by the AG, and CRF as was found in the current study. Thus, despite frank differences in the methodology employed to determine PA (SWA vs. AG), it is more likely the difference in sample size between the current and prior study that explains the lack of significant association found between IPA and CRF. We would expect that with an increase in sample size we would see a similar association between IPA and CRF as found previously.

MPA duration and expenditure were both independent predictors of CRF. These findings challenge the current dogma that states improvement in CRF can only be achieved by participation in structured PA (39). In contrast, our findings suggest that sporadic, unstructured MPA performed in free-living conditions may be associated with significant health benefit. Furthermore, we noted a 1-MET difference between the highest and lowest tertile of sporadic MPA duration which may be associated with substantial reductions in health risk. A recent meta-analysis found that for each 1-MET increment in CRF there was a corresponding 13% and 15% risk reduction in all-cause mortality and cardiovascular disease, respectively (3). In addition, we found a 0.5-MET difference between the highest and middle tertile which may confer a 6.5% and 7.5% reduction in risk for all-cause mortality and cardiovascular disease, respectively. However, as this study was cross-sectional in design we are unable to infer causality regarding the association between sporadic MPA and CRF. Thus, we suggest a prospective study design to examine the association between sporadic MPA and CRF.
This is the first study, to our knowledge, to investigate the direct association between SED and CRF. In univariate analysis, SED was significantly and negatively associated with CRF, however, this association did not remain significant after control for covariates. SED accounted for 65% of waking hour activity which is similar to the national average of 68% (19). SED is significantly associated with increased risk for premature mortality and thus, finding strategies to reduce SED are imperative (106). As prior research has documented a negative correlation between SED and IPA (109) perhaps substituting IPA for SED may be a feasible approach to reducing SED and its associated risks. Further study is required to clearly elucidate the association between SED and CRF in a larger sample.

A large proportion of participants found the size of the device and its placement on the arm fairly cumbersome. Some experienced technical problems with the device buzzing and low battery life. Due to these disturbances many participants removed and returned the device. If batteries were removed for an extended period of time without replacement data was sometimes lost. These factors contributed to data loss and thus, a reduced sample size. The more recent SWA model is more compact and may be a more attractive tool for both researchers and participants. Moreover, placement on the wrist may be less invasive and should be further explored.

In summary, we were unable to confirm that IPA is an independent predictor of CRF in abdominally obese adults. However, we did note a significant association between the expenditure and duration of sporadic MPA and CRF suggesting that MPA accrued in bouts less than 10 minutes is associated with health benefit. Thus, all forms of MPA should be promoted to improve CRF, a known predictor of cardiovascular disease and mortality. Further study is required with a larger, more heterogeneous sample to better understand the association between IPA and CRF.
Chapter 4

General Discussion

4.1 Clinical Implications

We were unable to replicate the findings of McGuire et al. (15) wherein a significant association was observed between IPA and CRF. As we suggest, this difference may be explained in large measure by differences in sample size. However, the notion that this association may not exist altogether should not be discounted. Regardless, further research is required using a larger, more heterogeneous sample to better understand the association between IPA and CRF.

We did find a positive association found between sporadic MPA and CRF which is of both clinical and public health relevance. Sporadic MPA encompasses activities (e.g. stair climbing, raking, and push lawn mowing) that are performed on a fairly regular basis and are thus, part of one’s respective daily routine. As such activities are already a fairly interwoven component of daily activity, maintaining and/or adding on to such activities is likely more feasible than initiating a structured exercise program. This would be of greatest relevance to either overweight or obese individuals unable to engage in a structured exercise program due to other health complications or injury. It is noteworthy however; that sporadic MPA is not a replacement for structured PA. Thus, we must be cautious in over-stating the benefits of such activity as such statements may be easily misconstrued by a public seeking information to minimize physical activity. Developing and implementing a concise public health message that incorporates the current findings in addition to the promoting the necessity of structured PA is challenging yet, necessary.

While incorporating, maintaining or increasing sporadic MPA is likely to benefit overall health, specifically CRF, it will most likely not result in weight loss. For a large proportion of North Americans weight loss is the only marker of health success. Using weight loss as an
indicator of success is not necessarily negative as excess fat, specifically trunk fat, is associated with increased risk for insulin resistance and other comorbidities (110). Yet health benefit can be achieved without weight loss. However, such health benefits are not necessarily visible and thus, quantifiable by the general public without physician and/or health practitioner follow-up (e.g. measuring changes in insulin sensitivity following an increase in PA). Therefore, some individuals may feel that such activity (i.e. sporadic MPA) is of little health benefit and may make little effort to incorporate, maintain or increase such activity. Thus, while public health message misinterpretation is a concern as discussed above, I believe the greatest public health hurdle will be to promote the less-visible benefits of sporadic MPA.

4.2 Accelerometry

4.2.1 The SenseWear Pro Armband

The SWA differentiates itself from other accelerometers due to its incorporation of heat parameters in the estimation of METs. With the inclusion of heat parameters it may have been more sensitive to differences in energy efficiency amongst our participants relative to the AG. With increasing body fatness there is a reduction in energy efficiency (111). Stated differently, the greater one’s body fatness the greater the energy required to perform a given task. Our current study sample, composed of abdominally obese, unfit men and women may have been less energy efficient at performing certain household tasks. In addition, the SWA is worn on the upper arm which may have improved the measurement of household activities that are more stationary such as carrying and putting away groceries, dusting or vacuuming. These two factors may explain the elevated time spent in MPA as measured by the SWA relative to the AG as documented in the tertiary analysis (Appendix I). Further testing should be performed in free-living conditions using the SWA and AG in addition to a portable metabolic cart to determine which device is most accurate in the quantification of activity intensity.
The SWA provides raw data for all measured parameters however, the weight given to each parameter in the prediction of energy expenditure is proprietary. In addition, there is no standard cut-point classification system for the SWA as there is for other waist-worn accelerometers. A cut-point classification system could be developed using the acceleration counts for each minute of wear however, it is unclear how the heat parameters could be incorporated in such a classification system. In addition, the SWA is a cumbersome device that is fairly obvious to the outside observer. If the wearer is noticeably overweight or obese the outside observer may assume that they are wearing the device due to health concerns, which may not be the case. Thus, the wearer may become embarrassed or uncomfortable wearing such an obvious device. The more recently developed SWA is more compact and may be a more attractive option for individuals interested in quantifying 24-hour PA.

4.2.2 General Thoughts on Accelerometry

While researchers are now better able to measure and quantify 24-hour PA, the accuracy and reliability of accelerometers remains relatively questionable. The majority of accelerometers are limited in their ability to measure static (e.g. cycling) and complex (e.g. raking, weight-lifting) movements in addition to low intensity activities (e.g. reading, writing, screen-time). As these are predominant components of free-living PA, researchers may not be getting an accurate picture of 24-hour PA patterns. Further calibration studies are required using portable metabolic carts in order to improve accelerometer measurement ability. Moreover, due to the vast number of cut-point classification systems for different populations (e.g. lean, obese, children, adult) and energy expenditure prediction equations, comparing results across different studies is difficult. Guidelines as to which cut-point classification system to use depending on the study population of interest would be useful and necessary for a more accurate measure of energy expenditure. Stated differently, if a study were investigating free-living PA in both lean/fit and lean/unfit sample,
different cut-points could be employed for each group. Even with improvements in the cut-points however, it is unlikely that we will ever be able to accurately and reliably measure PA patterns for each individual person.

In regards to the field of accelerometry as a whole, we have merely skimmed the surface. With the never-ending technological advances, the capability of these devices will continue to grow. This is an exciting and constantly evolving field of research which holds great promise for the objective measure of a behaviour that has a strong association with a wide range of health outcomes.

4.3 Future Research

Canada is a culturally diverse nation that in 2009 welcomed 252,179 immigrants from over 177 countries (112). Thus, our study sample of primarily Caucasian adult men and women is not representative of the ever-changing Canadian population. This is important to note as different cultures and/or ethnicities have varying perspectives on PA. For example, people of Pakistani and Indian origin are less likely to engage in structured PA for a variety of reasons including lack of time, fear and shame (more commonly experienced by women), lack of culturally sensitive facilities and climate conditions (113). While lack of time and climate conditions are shared reasons with other cultures/ethnicities for not engaging in structured PA, there appear to be very specific cultural barriers to structured PA (113). Low participation in structured PA may, in turn, alter participation in IPA. Thus, not only is future research required in a more heterogeneous sample to examine the association between IPA and CRF, but research to determine possible solutions to the aforementioned barriers.

Additionally, it is unknown whether the physiological mechanisms responsible for the increased CRF in participants with the greatest amount of sporadic MPA are similar to those achieved via structured PA. In other words, does MPA performed at home which is more sporadic
and unstructured in nature invoke the same physiological adaptations as structured PA? Investigating the potential physiological mechanisms accounting for this association would be of great interest and should be performed in future investigations.
Summary and Conclusions

The benefits of structured PA remain unequivocal. With regular participation in structured PA there is a corresponding improvement in CRF. Recent findings suggest that IPA, which encompasses both LPA and sporadic MPA that does not meet with consensus PA guidelines, is positively associated with CRF. This association was driven in large part by the sporadically accumulated MPA. The current study did not find a significant association between IPA and CRF after control for covariates, however, we did note a significant and positive association between sporadic MPA and CRF. The incongruence between the current and prior study findings in regards to the association between IPA and CRF may be partially attributed to differences in study sample size. The positive association between sporadic MPA and CRF is meaningful as it suggests that benefit can be achieved through all forms of MPA. While these findings do not negate the importance of structured PA, they do provide an alternative and/or additional PA option for individuals unable or unwilling to perform structured PA. Further study is required in a more heterogeneous study sample to better understand the association between IPA, and sporadic MPA and CRF.
Bibliography


Appendix A
Consent Form
CONSENT TO VOLUNTEER FOR PARTICIPATION IN A STUDY

TITLE: Dose-response effects of exercise on abdominal obesity and risk factors for cardiovascular disease in women and men

PRINCIPAL INVESTIGATOR: Robert M.J. Ross, Ph.D.
Queen’s University
School of Kinesiology and Health Studies/ Medicine, Division of Endocrinology and Metabolism
Kingston, Ontario, K7L 3N6
(613) 533-6583

CO-INVESTIGATORS:
Robert Hudson, M.D., Ph.D., FRCPC
Kingston General Hospital
Medicine, Division of Endocrinology and Metabolism
Kingston, Ontario, K7L 3N6
(613) 533-2973

Miu Lam, Ph.D.
Queen’s University
Department of Community Health and Epidemiology
Kingston, Ontario, K7L 3N6
You are invited to participate in a research study on the influence of different doses (amounts) of exercise on abdominal fat and related health risk. The following brief is intended to provide you with the details you should be aware of prior to your consent as a participant in this study. Please read the following information carefully and feel free to ask any question that you may have.

BACKGROUND INFORMATION
Obesity is a major risk factor for disease and a public health problem. Recent information suggests that body fat located in the upper body region (abdominal fat) conveys a very strong health risk. Exercise is thought to be a good treatment option for reducing both abdominal fat and cardiovascular risk factors (e.g., blood fats (cholesterol), blood sugar and blood pressure). However, the specific exercise strategy or program required to achieve optimal benefit continues to be the source of considerable debate. At present, health professionals are unsure of the specific type, amount, pattern, and intensity of exercise that provides optimal health benefits. Therefore, you are invited to participate in a study to assess the relationships between exercise dose (how much) and intensity (how hard) on abdominal fat, and cardiovascular risk factors (e.g., blood sugar and fats). The results of the study may have important implications for development of public health messages and clinical guidelines for prevention and treatment of obesity and associated health risks through exercise.

EXPLANATION OF PROCEDURES
Pre-participation screening
You will be required to complete a medical questionnaire and make an appointment with your family physician prior to participation in this study. Your physician will also complete a medical questionnaire and may perform a medical examination on you. If your family physician charges you for completion of this exam, an invoice can be faxed to the Project Coordinator 613-533-2580 for payment or, the study investigators will reimburse you fully. In addition to the medical exam, you will have a fasting blood test to measure your blood fat and sugar levels. We will also measure your waist circumference. These measures are explained in further detail on pages four (4) and five (5) of this form.

Study Protocol
The exercise study will be approximately 7 months in duration. The 6-month exercise period will begin and end with a 1 to 2 week weight maintenance period. By volunteering to participate in this study, your name will be selected by chance and placed into one of the following four groups: (1) Control - no exercise, (2) Low volume-Low intensity exercise, (3) High volume-Low intensity exercise, (4) Low volume-High intensity exercise. You will have a 1 in 4 chance of being placed in one of the four study groups. You will not be able to choose which group you will be in.

The follow-up study will take place during Months 7-13. During this part of the study, you will be asked to continue the same exercise routine that you followed for the first six months. The reason for the 6-month follow-up is to find out whether you have been able to maintain the exercise level prescribed at start of the study.

**Expectations**

You will be expected to:

1. Accept your group assignment
2. Participate fully in your assigned groups for the duration of the study
3. Keep all testing appointments
4. Provide accurate answers on all questionnaires

You can expect:

1. Full disclosure of all procedures required for participation in this study
2. To be treated fairly and with respect
3. Any information that is disclosed will be private and confidential
4. No one will be coerced or forced to do anything they wish not to do
5. To have all your questions answered fully and as promptly as possible
6. To not be penalized for choosing to withdraw from the study for any reason

**Control Group:** For the entire study the men and women in this group will consume a healthful diet. Thus there will be no weight loss or exercise.

**Low volume-Low intensity group:** As a participant in this exercise group you will be asked to perform walking type exercise on a motorized treadmill for around 30 minutes, 5 times per week, at about 50% of your maximum fitness level (e.g., low-to-moderate paced walking) for the duration of the 6 month treatment period. During each exercise session we will measure your
heart rate every 5 minutes using an automated heart rate monitor. All of your exercise sessions will be by appointment and performed under supervision of a trained professional within our laboratory at Queen’s.

**High volume-Low intensity group:** As a participant in the aerobic exercise group you will be asked to perform walking type exercise on a motorized treadmill for around 60 minutes, 5 times per week, at about 50% of your cardiovascular fitness level (e.g., low-to-moderate paced walking) for the duration of the 6 month treatment period. During each exercise session we will measure your heart rate every 5 minutes using an automated heart rate monitor. All of your exercise sessions will be by appointment and performed under supervision within our laboratory at Queen’s.

**Low volume-High intensity group:** As a participant in the aerobic exercise group you will be asked to perform walking and/or jogging type exercise on a motorized treadmill for around 30 minutes, 5 times per week, at about 75% of your cardiovascular fitness level (e.g., brisk walking) for the duration of the 6 month treatment period. During each exercise session we will measure your heart rate every 5 minutes using an automated heart rate monitor. All of your exercise sessions will be by appointment and performed under supervision within our laboratory at Queen’s.

**Diet Program:** All participants in each group will eat the same type of foods. The diet will consist of regular foods that you will buy and prepare yourself. All aspects of the diet plan will be explained to you by a nutritionist. The session will take place at the beginning of the study, with several additional sessions planned throughout to help you follow the diet plan. If someone else shops for your food or prepares your meals, or if you share those tasks with someone else, that person is invited to meet with the nutritionist as well. You will be required to record the food you eat each day for the duration of the study. All of your meetings with the nutritionist will be in Dr. Ross’s laboratory within the School of Kinesiology & Health Studies at Queen’s. At the beginning of the study, using the diet records that you complete, the number of calories required to maintain your body weight will be determined. During the study the nutritionist will work with you to help you to maintain this caloric (number of calories) intake. In other words, the nutritionist will help you eat an amount of food that would normally maintain your body weight. Thus any weight loss you experience will be the result of an increase in exercise.
Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a method for creating pictures of body structures or organs. MRI gives pictures (images) in slices comparable to those produced by x-ray tomography (e.g., CT scan). One of the primary advantages of MRI is that it does not use x-rays or other forms of radiation. Instead, a large magnet, a radio transmitter/receiver and a computer are used to gather information from the body, and to produce pictures of internal anatomy. No harmful effects have been associated with MRI under existing conditions of use. However, if you feel claustrophobic during the scan you can end the test immediately.

As mentioned, the MRI procedure is very similar to a scanner examination. You will be placed on a table and moved smoothly into the scanner. A loud-speaker within the magnet makes it possible for you to keep in constant contact with the staff. At all times the operator can see and hear you and if you need help or have questions, you can be removed from the machine if necessary. The whole procedure takes about 30 minutes and will be performed by appointment at Kingston General Hospital once at the beginning of the study and one at the end of the exercise study (week 24).

Anthropometry (Skinfolds and Circumferences)

Many circumference measurements will be taken at numerous places on your body. These measurements can be used to derive estimates of body composition. Skinfold callipers (skinfold thickness) will be measured at 4 different places on your body. Circumferences measurements using a measuring tape will also be obtained at different places on the body. These measurements require about 45 minutes to complete and will be obtained at Dr. Ross’s laboratory within the School of Kinesiology & Health Studies at Queen’s.

We will collect these measurements five times throughout the study: at the beginning (week 0), then after two months (week 8), four months (week 16), at the end of the exercise training period (week 24), and at follow-up (week 48, six months after the end of the exercise training period).

Assessment of Cardiovascular Fitness

We will measure your cardiovascular fitness (endurance) using a treadmill (VO₂) test. The test will begin at a level you can easily accomplish and will be advanced in stages, depending on your
capacity to do so. We may stop the test at any time because of signs of fatigue or you may stop
the test because of personal feelings of fatigue or discomfort.

The treadmill test involves risks comparable to any strenuous exercise situation. They include
very rare instances of abnormal blood pressure, fainting, disorders of the heartbeat, and heart
attack. Every effort will be made to minimize your risk by preliminary medical examination and
observation during the test. A Research Assistant at Hotel Dieu Hospital, with a trained
paramedic or medical doctor on-site, will conduct your fitness test. You will perform the exercise
test 6 times: at the beginning (Week 0), after one month (week 4), after two months (week 8),
after four months (week 16), at the end of the exercise training period (week 24), and at follow-up
(week 48, six months after the end of the exercise training period).

Assessment of Daily Physical Activity
How physically active you are throughout the day will be measured by two small devices known
as accelerometers: one is worn on your arm (armband) and one is worn on your hip (Actigraph).
The armband involves wearing a monitor that is worn on your upper right arm that will track the
amount of energy you burn and the amount of physical activity that you perform. The Actigraph
is a small unit that you wear on your belt at the level of your hip and this device also measures the
amount of physical activity that you perform. You will wear these monitors during all of your
waking hours and will remove the monitor when you sleep or participate in water activities such
as showering, bathing, or swimming. You will wear this device for 7 consecutive days at 0, 8, 16,
and 24 weeks.

Laboratory measurements (blood glucose (sugar) and lipid (fat) tests)
The measurement of how much sugar and fat are in your blood will be done at Dr. Ross’s
laboratory within the School of Kinesiology & Health Studies at Queen’s. To determine your
ability to manage blood sugar you will be asked to perform an Oral Glucose Tolerance Test. You
will be asked to arrive at the lab in the morning after an overnight fast (no eating after 7pm the
night before). The first step of this test will be the insertion of a saline lock into a vein in your
arm. This allows the nurse to take blood at different times without having to re-puncture each
time. She will then remove about 30 ml (3 tablespoons) of blood. The only risk from this
procedure is possible local pain and bruising at the time of the blood test. In addition, you will
be asked to drink a fluid that contains 75 grams of sugar (like an orange drink). At 30-minute
intervals for 2 hours after drinking the sugar solution, a small amount of blood will be taken (through the saline lock) for the purpose of measuring the amount of sugar in the blood. This test will be performed four times during the study: at week 0, after four months (week 16), at the end of the exercise period (week 24) and at the end of the follow-up (week 48).

**Summary of Appointments and Time Requirements**

All appointments will be scheduled at a time that is convenient for you. For the testing you will be required to make six 45-minute appointments at the Hotel Dieu Hospital to complete the cardiovascular fitness (VO$_2$max). We will also arrange two 30-minute appointments to complete the MRI (Kingston General Hospital). The other testing will be done at Dr. Ross’s laboratory in the School of Kinesiology & Health Studies at Queen’s. This includes: four 2.5-hour appointments for the oral glucose tolerance test and blood lipid/cholesterol tests (fasting blood draw); and five 45-minute anthropometric measurement appointments. In addition, we will ask you to make appointments for dietary counselling and for exercise (if you are randomized into one of the exercise groups). The total time commitment for all testing appointments and exercise sessions over the total 13-month study will be between 86 and 149 hours.

**Time commitment per participant**

<table>
<thead>
<tr>
<th>Measure/Task</th>
<th>Time per session</th>
<th>Number of sessions</th>
<th>Total time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropometrics</td>
<td>1 hr</td>
<td>5</td>
<td>5 hr</td>
</tr>
<tr>
<td>Fitness (VO$_2$) test</td>
<td>1 hr</td>
<td>6</td>
<td>6 hr</td>
</tr>
<tr>
<td>OGGT</td>
<td>2.5 hr</td>
<td>4</td>
<td>10 hr</td>
</tr>
<tr>
<td>MRI</td>
<td>0.75 hr</td>
<td>2</td>
<td>1.5 hr</td>
</tr>
<tr>
<td>Dietary Counsel</td>
<td>0.5-1 hr</td>
<td>6-12</td>
<td>3-6 hr</td>
</tr>
<tr>
<td>Exercise</td>
<td>0.5-1 hr</td>
<td>120</td>
<td>60-120 hr</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>86-149 hours</strong></td>
</tr>
</tbody>
</table>

**Benefits of Participation**

You will gain no direct benefit through participation in this study.

**Risks of Participation**

Participation may involve some risks. The known risks are:

Insertion of a catheter in your arm or hand vein may cause bruising, bleeding, soreness or infection.
For MRI, there are certain conditions that would exclude you from participating in this study. These include cardiac pacer, aneurysm clip, cochlear implant, intra-uterine device (IUD), shrapnel, neurostimulators or other metal devices. Metal objects present in the body could be moved by the large magnet involved in the MRI, and such movement could cause serious injury. Fear of closed spaces (claustrophobia) is also a reason you would be excluded from the study. No serious biological effects have been reported from being in a magnet. If you experience a fear of the confined space while in the magnet, you can terminate the study. Trained personnel are always in attendance during these studies.

The exercise test may cause muscle soreness or fatigue. In any individual, there is a minute risk of a heart attack or death from the exercise test. A trained paramedic or medical doctor will be on-site. If you develop chest pain, the test will be stopped immediately.

Risk of Wearing the Activity Monitor: Some people may experience mild skin irritation at the site where the activity monitor is worn. One cause of skin irritation has already been identified in people who wear the armband for extensive periods of time (i.e., more than 24 hours). Specifically, the build-up of sweat that can be trapped between the skin and the armband can cause pink pustules or pimples to appear. This condition is named miliaria, or prickly heat. This condition is common and occurs in 10% to 25% of people (10 to 25 out of 100 people) that wear the armband. To help to prevent this condition you should clean your arm using rubbing alcohol before putting on the activity monitor. Also, you should use soap and water to clean the elastic strap that attaches the monitor to your arm before each use. You should also wipe off the monitor using rubbing alcohol and allow this to dry before putting it on your arm.

You should inform the investigators if you have participated in any other research study during the previous year. This will help to ensure that you have not been exposed to a procedure in another study that may influence your ability or eligibility to participate in this one. You should understand that this study is a research study and may not be of direct benefit to you. If requested, a report will be generated for your medical record, which will include any information important for your medical care.

**CONFIDENTIALITY**
All information obtained during the course of this study is strictly confidential and your anonymity will be protected at all times. Your information will be kept in locked files and will be
available only to Dr. Robert Ross and those working within his laboratory. Your identity will not be revealed in any description or publication.

In the event you that you are injured as a result of the study procedures, medical care will be provided to you until resolution of the medical problem. By signing this consent form, you do not waive your legal rights nor release the investigator(s) and sponsors from their legal and professional responsibilities.

Financial remuneration ($100) for parking, gas, and other costs associated with participation in the study will be provided to you.

**VOLUNTARY CONSENT**

I have been given an opportunity to ask any questions concerning the procedures. All of my questions regarding the research project have been satisfactorily answered. I understand that my test results are considered confidential and will never be released in a form that is traceable to me, with the exception of my family physician or myself. I understand that all my lab results will be sent to my family physician. I do understand that

I am free to deny consent if I so desire, and may withdraw from the study at any time without prejudicing current or future medical care.

Should I have any questions about the study, I know that I can contact any of the following: Dr. Robert Ross (613 533-6583), Dr. Jean Coté, Head, School of Kinesiology and Health Studies (613 533-6601), or Dr. Albert Clark, Chair, Queen’s Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (613 533-6081). A copy of this consent form will be provided me for my records. My signature below means that I freely agreed to participate in this study.

__________________________________  __________________
Volunteer’s Signature                  Date:
STATEMENT OF INVESTIGATOR

I, or one of my colleagues, have carefully explained to the subject the nature of the above research study. I certify that, to the best of my knowledge, the subject understands clearly the nature of the study and demands, benefits, and risks involved to participants in this study.

__________________________________  __________________
Principal Investigator’s Signature     Date
Appendix B
Medical Questionnaire
MEDICAL QUESTIONNAIRE FOR RESEARCH STUDY

DOSE-RESPONSE EFFECTS OF EXERCISE ON ABDOMINAL OBESITY AND RISK FACTORS FOR CARDIOVASCULAR DISEASE IN WOMEN AND MEN
To the study participant: Please answer all questions in sections 1 and 2 of this form. Have your family doctor fill out section 3.

To the physician: Please fill out section 3 of this form (pages 4-6). Completing this form may not require a medical re-evaluation of your patient. If the results of recent tests are readily available that might prove useful to study personnel while dealing with the participant, please include that information in this questionnaire.

Please return sections 1 to 3 to the Project Manager via fax at (613)533-2580 along with an invoice for any costs associated with completing the form.
SECTION 1: PERSONAL DATA (please print)

Name: _______________________________________

Date of Birth: ______________________________________

Date: ______________________________________

SECTION 2: MEDICAL HISTORY

A. Has your doctor ever said you have heart trouble?

B. Do you get pains, pressure or tightness in your chest?

C. Do you often feel faint or experience dizziness?

D. Has your doctor ever told you that you have high blood pressure?

E. Is there a good reason, not mentioned above, why you should avoid exercise?

F. Have you ever had blood taken?

G. Have you ever had any negative experiences with a blood draw?
   If yes, please describe:
   _______________________________________________________
   _______________________________________________________

H. Do you have any allergies (i.e. latex, medications, etc)?
   _______________________________________________________
   _______________________________________________________

I. Do you have diabetes?  YES ☐  NO ☐
If yes, please indicate: Type I Diabetes ☐ Type II Diabetes ☐ Unsure ☐

☐ Diet Controlled ☐ Oral Diabetic Medication ☐ Insulin Required

J. Do you have, or have you ever had, problems with any of the following?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Heart or blood vessels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Nerves or brain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Breathing or lungs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv. Hormones, thyroid, or diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. Muscles, joints, or bones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vi. Other (please list)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

K. Please list any serious injuries suffered, or surgeries you have had:

L. If you have had surgery, was any metal (e.g., pins or screws) left in your body?

M. Are you presently taking any medications? If yes, please list.

N. Are you presently undergoing physiotherapy, or any other sort of treatment? If yes, please list.

I hereby authorize the my family physician to complete Section 3 of this medical questionnaire and to fax or send to the SERENA exercise study researchers at Queen’s University.

__________________________________________
Signature

__________________________________________
Witness

SECTION 3: MEDICAL REFERRAL

Physician: The applicant is considering participation in a research study that is investigating the effects of exercise dose (amount) on abdominal obesity and related cardiovascular disease risk factors. A brief summary of the study objectives is provided (see pages 8-10). As a participant in this study, your patient would undergo a cardiorespiratory fitness appraisal (see explanation on page 7) and a number of other tests to assess body composition and metabolic health risk. We will forward any test results to you with your patient’s consent.

Should you have any questions regarding the participation of your patient in this project, please contact Robert Ross Ph.D., School of Kinesiology and Health Studies, Queen’s University (613-533-6583). Please return completed sections 1 to 3 to the Project Manager via fax at (613-533-2580) along with an invoice for any costs associated with completing this form.

1. Review of Systems - please include diagnoses.

   a) Cardiovascular

   b) Respiratory

   c) Neurological

   d) Gastrointestinal
II. Physical Examination

Blood Pressure: _____________  Pulse: _____________

Cardiovascular:

Respiratory:

Head and Neck:

MSK:
Abdomen:

12-lead ECG (not mandatory)

Neurological:

III. Laboratory findings (not mandatory) Date of Test(s): ______

Hb ____________ WBC ____________ Plts ____________

Total Cholesterol ____________ HDL ____________ Chol:HDL ratio ____________

LDL ____________ Triglycerides ____________ Uric Acid ____________

TSH ____________ Glucose ____________ fasting □ random □

75 g OGTT @ 120 min ____________

IV. Additional abnormalities of which you are aware

____________________________________________________________________

____________________________________________________________________

V. Current medications and doses

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________
VI. On the basis of your knowledge and medical evaluation of the applicant, you would recommend (mark the appropriate answer):

____ Participation in a fitness appraisal supervised by a physical education graduate, or
____ Participation in a fitness appraisal only when a physician or paramedic is present, or
____ Participation in a fitness appraisal is not recommended

*Note:* An explanation of the fitness appraisal protocol, as well as absolute and relative contraindications to exercise testing, is provided on page 7 of this form.

Physician’s Name: __________________________________________

Physician’s Signature: ________________________________________

Date: __________________________

Phone Number: ________________________________

Address:

________________________________________________________________
________________________________________________________________
________________________________________________________________

Thank you very much for your help. We hope that this study and its results will be beneficial to you and your patient.
Appraisal of Cardiorespiratory Fitness (VO\textsubscript{2}max)

Cardiorespiratory fitness is assessed using a maximal oxygen uptake (VO\textsubscript{2}max) test, which is routinely employed within the laboratory of the study investigators. The treadmill test begins at a level the study participant can easily accomplish (comfortable walking pace with no incline) and is slowly increased in intensity (by increasing treadmill incline) until the participant reaches volitional fatigue. We may stop the test at any time because of signs of fatigue or the subject may stop the test because of personal feelings of fatigue or discomfort.

The maximal oxygen uptake test involves risks comparable to very strenuous aerobic exercise. Every effort is made to minimize the risk by preliminary medical examination and close observation during the test by physical education graduate students and a physician.

**American College of Sports Medicine Contraindications to Exercise Testing**

**Absolute Contraindications**
A recent change in the resting ECG suggesting infarction or other acute cardiac events
Recent complicated myocardial infarction
Unstable angina
Uncontrolled ventricular dysrhythmia
Uncontrolled atrial dysrhythmia that compromises cardiac function
Third-degree A-V block
Acute congestive heart failure
Severe aortic stenosis
Suspected or know dissecting aneurysm
Active or suspected myocarditis or pericarditis
Thrombophlebitis or intracardiac thrombi
Recent systemic or pulmonary embolus
Acute infection
Significant emotion distress (psychosis)
**Relative Contraindications**

Resting diastolic blood pressure >120 mm Hg or systolic blood pressure >200 mm Hg.

Moderate valvular heart disease

Known electrolyte abnormalities (hypokalemia, hypomagnesemia)

Fixed-rate pacemaker (rarely used)

Frequent of complex ventricular ectopy

Ventricular aneurysm

Cardiomyopathy, including hypertrophic cardiomyopathy

Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxoedema)

Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)

Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise

Advanced or complicated pregnancy
Appendix C

Screening Form
SERENA Screening Appointment Data Collection Form

ID: _____ Date (dd-mmm-yyyy): _____-____-_______ Evaluator: _____

Age: _____ Birth date (dd-mmm-yyyy): _____-____-_______ Gender: M   F

Fasted for 12 hours?       Yes   No
Inactive yesterday?        Yes   No
Consent form returned?     Yes   No
MRI screening complete?    Yes   No

Medical questionnaire (part 1 and 2) complete?    Yes   No

Standing Height: ________cm       Body Mass: ________kg       BMI:_____

Physicians Name: ________________________________

Physician Contact Information: ________________________________

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________

Participant will drop off Medical to their Doctor
We will fax Medical Forms

Notes:_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

_________________________
Appendix D
Anthropometric Measurement Protocol
Anthropometry

List of Measured Variables (intra- and inter-measure error)

Weight and Height

Weight (0.2 kg; 0.2kg)
Standing Height (0.2 cm; 0.2 cm)

Circumferences

Waist (iliac crest, mid-point, last rib) (1.0 cm; 1.0 cm)

Measurement Procedures:

WEIGHT AND HEIGHT

Weight (kg): measured on the Detecto scale with shoes removed, wearing the ‘Greys’ clothing provided.

Standing Height (cm): measured with shoes removed, standing with heels close to the wall, feet together, eyes looking straight ahead, back, and buttocks touching the back rest of the stadiometer. The head may or may not touch the back rest, depending on the size of the participant. I.E. Some participants may have to lean back in order to have the head touch; this would result in an inaccurate height measurement. Instruct participant to stand tall and take a normal breath in, record measurement given on dial.

WAIST CIRCUMFERENCE MEASUREMENT

For waist circumference, position the tape directly around the body part so that the inferior edge of the tape is at the level of the landmarked point. Ensure there is no clothing under tape.

a) GENERAL WAIST PROCEDURE

NOTE: It is mandatory that all assessors first view the WC measurement video prior to collecting any WC data.

1. Clear the client’s abdomen of all clothing and accessories. If you find resistance to the suggestion to fully remove shirt, roll up the shirt to allow free access to measurement sites and hold in place with a clip (i.e. hair clip).
2. Position the client with feet shoulder width apart and arms crossed over the chest in a relaxed manner.
3. Take a position to the right side of the client’s body on one knee.
4. Position the tape directly around the abdomen so that the inferior edge of the tape is at the level of the landmarked point. Use a cross-handed technique to bring the zero line of the tape in line with the measuring aspect of the tape. Ensure that the measuring tape is positioned in a horizontal plane around the abdomen. Apply tension to the tape to ensure it is snug, without causing indentation to the skin. Walk around the participant to ensure the tape is straight all around the abdomen. Alternatively, if a mirror is available – use this to ensure proper tape alignment.
5. At the end of a normal expiration, take the measurement.

**WAIST – ILIAC CREST** - top of the iliac crest. To find this landmark, palpate the upper right hipbone and draw a line where you locate the uppermost lateral border of the iliac crest.

**WAIST – LAST RIB** – bottom of rib cage on right side. To find this landmark, palpate the lower right rib cage and draw a line where you locate the lowest lateral border of the ribs.

**WAIST – MIDPOINT BETWEEN ILIAC CREST AND LAST RIB** – midpoint between the bottom of the rib cage and the top of the iliac crest (use the landmarks from the previous two waist circumference measures to locate this).
Appendix E
Measurement of Cardiorespiratory Fitness Protocol
List of Measured Variables

Maximal oxygen consumption (L/min)
Maximal oxygen consumption per kg body weight (L/kg/min)

Measurement Devices

- Sensor Medics Vmax29 Metabolic Cart (VMax)
- Laptop computer
- Treadmill
- Calibration gas tanks (with sufficient gas)
- Polar HR monitor
- USB stick

Measurement Procedures

Cardiorespiratory fitness tests will be performed at Hotel Dieu Hospital. The VMax system must be turned on 30 minutes in advance of attempting system calibration. Calibration will take 30 minutes on average. Thus, the first scheduled test for that day should be at least 1 hour after the Research Assistant arrives. We will schedule 45 minutes per participant. The participants will change into an athletic shirt and shorts, and wear a pair of comfortable shoes suitable for brisk walking or jogging (they should be reminded to bring all items on the day of the test). We give them a Polar heart rate monitor to wear so we can record heart rates every 20 seconds throughout the test. Ideally the test should last between 8-12 minutes, beginning with a relatively brisk pace at level grade, increasing grade to 5% at the 3rd minute, and then further increasing the grade by 2% every 2 minutes thereafter. If after 2 minutes at the maximal incline of 15% the subject has not reached exhaustion, the speed must increase (generally by 0.2 mph). Heart rates are observed and recorded on the VO₂ Data Collection Sheet by a Research Assistant, who will hold a receiver watch while standing close to the participant. Breath-by-breath analysis of respiratory gases is also recorded throughout the test.

Criteria for a successful VO₂max test
There are a number of popular criteria in the literature which are to be used to assess whether the participant being tested has actually achieved VO$_2$max.

- Plateau in VO$_2$ (oxygen uptake) with increasing work rate (increasing treadmill incline, speed or both). For our purposes we will define plateau in VO$_2$ as $\Delta$VO$_2$ < 0.05 L/min at VO$_2$peak and the data point 40 seconds above or below, with increases in external work
  - **Note:** This criteria is often criticized as it has been shown that approximately 50% of individuals undergoing VO$_2$max testing never reach a true plateau.
- RQ > 1.10: This suggests non-metabolic production of CO$_2$ and reliance on anaerobic metabolism.
- Heart rate (beats per minute or bpm) exceeding age predicted max HR (220-age) minus 12bpm. For example, for a 20 year old, the HR to be exceeded = 188 bpm (220-20 -12)
- Borg scale=10. This gives the perception of effort by the participant during the test.

**A successful test should meet at least 3 of the above criteria.**

**Familiarization**

Measuring changes in aerobic capacity requires a comparison of maximal performance on a graded exercise test. For people who have never been on a treadmill and are unaccustomed to pushing themselves physically, obtaining meaningful results can prove difficult. The warm-up for these individuals should be long enough for them to feel comfortable. The more they comprehend the test and what is required of them, the better the participants will respond when encouraged to exercise “to fatigue” during the test.

The following is the step-by-step process of operating the Vmax machine and other computers used in our laboratory for data collection and analysis of this test:
Appendix F
Measurement of Physical Activity
Accelerometry Protocol

Measurement Device
SenseWear Pro Armband™ (Body Media, Pittsburgh, PA)

List of Required Demographic Variables
- Age (yrs.)
- Weight (kg)
- Height (m)
- Sex
- Handedness
- Smoking status

List of Measured Parameters
- Acceleration on transverse and longitudinal axes
- Heat flux (W/m²)
- Skin temperature (°C)
- Near-body temperature (°C)
- Galvanic skin response (nSiemens)

List of Channels (Data Output)
- Transverse acceleration – peaks
- Longitudinal acceleration – peaks
- Skin temperature – average
- Galvanic skin response – average
- Transverse acceleration – average
- Longitudinal acceleration – average
- Near-body temperature – average
- Transverse acceleration – mean absolute difference
- Longitudinal acceleration – mean absolute difference
- Step counter
- Activity type (lying down, sleep, sedentary, moderate, vigorous, very vigorous)

**List of Estimated Variables**
- Total Energy Expenditure (kilocalories)
- Intensity (METs)

Measurement Procedures

*Preparing the Armband*

1. Insert an AAA battery into the armband, attach elastic/Velcro strap to device (placed around the participant’s arm to secure Armband).
2. Connect the armband to the computer via the USB cable. Windows will detect the hardware.
3. Double click the armband icon on your desktop to open the SenseWear Software (Innerview Professional Software, Version 6.1).
4. Click Configure Armband at the top of the screen.
5. Click Retrieve Configuration.
6. Click Participant Info. Enter in age, weight, height, sex, handedness, smoking status of participant about to wear the Armband.
7. Click Apply at the bottom of window.
8. Detach the armband from the USB cable. The Armband is now ready for data collection.
9. There is no on/off button on your armband. When the monitor makes secure contact with the body, it automatically performs a “turning on” sequence. This may take up to five minutes for some people, depending on the body state. The sequence is as follows:

   **Welcome**: Four distinct notes (do-de-do-deet) ascending in tone. This sound indicates that the Armband has made contact with the skin.

   **Warming up**: Two second vibration. A series of light vibrations will be felt as it settles.

   **Ready**: Three notes (de-de-deet). This sound indicates that the armband is collecting data.

Note: If, after five minutes, the “turning on” sequence is not heard, press and hold the Timestamp button (see picture below) until the “ready” sound is heard (this means that the armband is working properly).
Preparing the Participant

1. There are no guidelines the participant needs to follow prior to getting the accelerometer.
2. The armband is designed to be worn on the back of the upper right arm (the tricep muscle), with the electronic sensors touching the skin (see photograph under ‘measurement device’ section).
3. Slide the armband onto the right arm of the participant with the Timestamp button facing up. Adjust the strap so that it fits on the arm comfortably then secure the strap to reduce movement.
4. The participant will be asked to wear the armband for a 7-day period and to remove it only for water activities (e.g., swimming, showering). If the participant finds it uncomfortable to wear to bed they may take it off. It is most important to wear it during waking hours. If it is removed for sleep it should be put on at wake-up and removed immediately prior to going to sleep.
5. Ensure that the participant is aware that the sensors must maintain continuous contact with the skin and that the strap should always be tight enough to prevent the Armband from sliding off the arm. The Armband may beep and/or vibrate if the sensors are not in contact with the skin. If buzzing continues, the participant should remove the Armband wipe the sensors and arm clean and place the device back on the arm. The participant should also check the battery life by clicking on the Timestamp button. If a red light appears under the battery icon the participant should remove the AAA battery and replace with a fully charged and/or new AAA battery within a 30 second time frame. This time frame is important as data may be lost if not replaced quickly enough. In the instance that the device does not respond by buzzing or beeping to the Timestamp button, the participant will be instructed to contact the lab via email or telephone and asked to bring the Armband back in.
6. The participant will be informed that the device is not harmful and will not interfere with any other medical device.
7. If the armband is removed, the participant will be instructed to record what time(s) and why the Armband was removed on the log sheet. The participant will also be instructed to record wake-up and sleep-start times on the log sheet.
8. Lastly, participants should be informed that although the device is durable they should be careful in handling it.

Data Management

Acquiring and Downloading Data

1. Obtain armband from participant.
2. Connect the USB dongle. Double click the armband icon on your desktop to open the SenseWear® Innerview Professional (V.6.1) software and connect the Armband to the computer via USB cable.
3. Click the Retrieve Armband Data button.
4. Click Via USB Cable.
5. Click Retrieve. A pop-up will inform you if the data has been retrieved successfully.
6. Name and save file in the following format:
a. Participant Number/time of wear (baseline (V00) or 24 weeks (V24))/start day number (Monday is ‘1’, Tuesday ‘2’, Wednesday ‘3’, Thursday ‘4’, Friday ‘5’, Saturday ‘6’, Sunday ‘7’). The start day of wear can by looking at the first epoch of recorded wear and locate the corresponding date from the raw excel file.

b. An example would be S012_V00_1 for a participant who wore the Armband at baseline and started on a Monday.

7. Save it to the folder ‘Armband’ which is in the ‘SERENA PA data’ folder. Export the file to excel (there is an ‘Export’ button at the bottom of the screen. The file will be saved with the same file name as the summary data file but will have .xls at the end. The raw and excel file will be saved in the same location (see example of raw excel file below).

8. Detach strap from armband and wash it in non-allergenic detergent. Hang to dry.

9. Wipe back of armband (the part touching skin) with a cloth dampened with warm water and non-allergenic detergent. After it dries, wipe it with a cloth dampened with 70% isopropyl alcohol to disinfect. Allow it to dry for at least 5 minutes.

Note: Data is deleted from the armband after it has been retrieved so ensure that the file has been saved.

Program Development

An in-house software program was developed by the Cardiometabolic and Lifestyle Research Unit’s programmer to read the raw data from the excel file. The program Visual Basic Application for Excel Version 6 (Microsoft, 1991) was used which is a third generation event driven programming language and integrated development environment. Two programs were developed utilizing this tool. The first will be referred to as the Epoch Development Program and the second will be referred to as the Armband Program.

Epoch Development Program

1. Each minute of wear is referred to as an epoch. For the Armband Program to work, each epoch requires a specific number. These numbers are to provide a specific epoch number for sleep start and stop time for each day of wear, a requirement in order for the Armband Program to work (information on how sleep start and stop is determined using the epoch numbers is discussed in the following section). For example, the first minute of wear the excel file (i.e. epoch) would be labelled ‘1’.

2. During periods of non-wear the Armband does not provide an epoch or a zero count however the Epoch Development Program registers the elapsed time based on the
date and time of Armband removal and replacement on the arm. For such periods the program automatically includes the period of non-wear into the epoch number total. For example, if a participant takes the Armband off at 11:31 PM which corresponds with an epoch number of ‘560’ and replaces the armband the following day at 6:30 AM the program will automatically add in the 419 missing minutes and thus, the next epoch number will be ‘979’.

Sleep Start and Stop Time Procedure

1. To determine the epoch number associated with sleep start and stop time a graduate student or research associate will visually inspect the raw data along with the log sheet completed by the participant. Sleep start and stop epoch values will be entered directly into the Armband Program. For each day of Armband wear the participant ID Number, visit (V00) along with epoch numbers for sleep start and stop time for each day of wear will be entered.

2. Visual inspection of the data is as follows:
   a. The first epoch on the raw excel file (typically the first minute on the first day of Armband wear) will typically be considered the sleep stop time for the first day. Oftentimes the Armband will register and initialize from the research associate’s touch when demonstrating how to use the device to the participant during their instruction session. Visual inspection of the data will clearly show whether this is the case as the second epoch would be on the following day (indicating the participant actually began wearing the Armband the following day). In this case, the epoch number for the first day sleep stop time will be considerably higher than ‘1’ and more likely around ‘1500’.
   b. Sleep stop time on following days of wear will be indicated when there are at least 10 consecutive count values (located in the columns associated with the transverse and longitudinal axes) with epoch value > 50. The research associate/graduate student is to record the corresponding epoch number for sleep stop time in the Armband Program (as displayed below).
c. After recording sleep stop time, the research associate/graduate student will scroll down the file while paying close to attention to the acceleration counts in the transverse and longitudinal axes along with the date and time. Sleep start time is indicated when there are at least 10 consecutive counts < 50. While the participant may display some restlessness prior to falling asleep, this rule generally allows for a fairly accurate assessment of true sleep start time. If the participant however, takes the Armband off at night the last epoch number for that day of wear will be recorded as sleep start time. The research associate/graduate student is to record the corresponding epoch number for sleep start time in the Armband Program (as displayed in the figure above).

d. The above processes for determining sleep stop and start time should continue for each day of recorded wear and the corresponding epoch numbers should be entered in the Armband Program.

e. This process will be completed for each participant.

Armband Program

1. After pressing the ‘Load’ button on the main Armband page (displayed on the previous page in Section 2.b), the following screen will appear:

```
Accelerometry Data

Data  Settings  Bouts

Input files Directory:
C:\Documents and Settings\jeroschan\My Documents\Accelerometry\Morgan\Data

Database File:
C:\Documents and Settings\jeroschan\My Documents\Accelerometry\Morgan\test.mdb

Max length of off time:
30

Activity
Vector

Load Data
Separation
```

2. In the first line the file location which contains the raw excel files must be copied and pasted.
3. The second line requires the file location where the output will be saved.
4. Max length of time should always read ‘30’ and ‘Vector’ should be selected.
5. ‘Load Data’ will load the raw excel file into a first draft access file.
6. ‘Separation’ then determines waking hours for each participant using the sleep stop and start times.

7. Click on the ‘Settings’ tab. The following screen should appear:

![Accelerometry Data](image)

8. Keep the wear-time requirements as already provided. Prior to clicking on ‘Day Separation’ click on the ‘Bouts’ tab which is discussed in detail below. Click on ‘Day Separation’ which determines if participants met wear time requirements (> 10 hrs of wear/day for at least 4 days which had to include 3 weekday days and 1 weekend day). This step also completes calculations for mean duration and intensity within each category (sedentary, light, moderate and vigorous).

9. Clicking on ‘Categories’ is not always necessary. It depends on whether you are planning to look at bouted activity. For the purposes of the current thesis, bouted activity was used to determine which participants met with consensus guidelines. If bouted activity is necessary, click on the ‘Bouts’ tab prior to clicking ‘Categories’. This following screen should appear:
10. The ‘METs Range’ indicate the MET cut-points for sedentary, light, moderate, and vigorous activity can be adjusted depending on the needs of the research.
11. The ‘Bout Time’ can also be adjusted depending on the length of bouts for each intensity.
12. After completing bout time information, click on ‘Categories’ to complete the process.
13. All data output will be provided in an Access File.
14. For SPSS purposes data will be exported to Excel and finally, exported to SPSS.

Data Checking

A number of checks will be carried out to ensure that the reliability and validity of both the Epoch Development Program and the Armband Program.

Epoch Development Program Checks:

1. The programmer will perform a logical check to ensure that the algorithm developed is taking into account participant differences and measuring what it purports to measure.
2. A graduate student/research associated will at random select a raw excel file that has undergone the Epoch Development Program.
3. The research associate/graduate student will scroll through the raw excel file looking for large jumps in the epoch numbers. For example, a jump in the epoch number from ‘899’ to ‘1400’. To ensure that the program has correctly added in the missing time,
the research associate/graduate student would look at the corresponding stop/start
time of Armband wear to determine the actual minutes of elapsed time. For this
example, there would have been a total of 501 minutes of elapsed time. In the case
that this is incorrect, additional participants will be checked. If errors are still found,
the graduate student will converse with the programmer, inspect the code and
determine where the bug may be within the script.
4. Such checks will continue until a number of participants are found to have correct
epoch numbers for start/stop time.

Armband Program Checks:

1. Following completion of the program, the programmer will check for bugs in the
code by assessing 2-3 randomly selected raw files. Presence of a bug is indicated by a
pop up window which often provides information on the location of the error in
coding. The programmer will also perform a logical check to ensure that the program
is taking into account participant differences and measuring what it purports to
measure.
2. If no bugs are detected by the programmer, the program is given to the research
associate/graduate student for further inspection.
3. Firstly, the raw excel file for one participant will be randomly selected. Based upon
the participant’s sleep start/stop times the graduate student will manually go through
the participant’s excel file and divide the raw data into corresponding days of wear by
inserting 2-3 new rows. This will allow for clear visual inspection of each individual
day of wear.
   a. For each day of wear the METs column will be sorted, ascending from
      smallest to highest MET values. As already mentioned the METs value
      corresponds with the intensity of the activity performed for each minute of
      wear (or epoch).
   b. Using the sorted MET values, the following totals will be determined:
      i. Total METs for sedentary, light-, moderate-, vigorous-intensity activity for each day
         of wear.
      ii. Sedentary activity daily METs will be determined by adding all epochs with a
          corresponding MET value < 1.
      iii. Light-intensity activity daily METs will be determined by adding all epochs with a
           corresponding MET value between 1 – 2.99.
      iv. Moderate-intensity activity daily METs will be determined by adding all epochs with a
          corresponding MET value between 3 – 5.99.
      v. Vigorous-intensity activity daily METs will be determined by adding all epochs with a
          corresponding MET value ≥ 6.
   c. Finally, the average daily METs for each intensity (sedentary, light, moderate,
      vigorous) will be determined by totaling all the respective MET values and
      dividing by the number of days worn.
   d. These values will then be compared with those provided by the program. If
      values do not correspond with one another, further checking will be
performed. If problems still occur, the graduate student/research associate will meet with the programmer to determine where the problem is in the code.

**Important Notes**
- If a red light appears above “memory” on your armband, the armband is full. Retrieve your data.
- If a red light appears above “battery” on your armband, the battery in your armband is low. Replace immediately.
- If either of the above situations occur the armband may beep/buzz a lot.
- When the weather is cooler (below 10 degrees) the batteries drain much more quickly so each battery can only be used for 1 week (1 participant).
- For assistance, send email to internationalsupport@bodymedia.com or call +1 (412) 288-9901, option #2.
Appendix G
Armband Log Sheet
<table>
<thead>
<tr>
<th></th>
<th>Day One</th>
<th>Day Two</th>
<th>Day Three</th>
<th>Day Four</th>
<th>Day Five</th>
<th>Day Six</th>
<th>Day Seven</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Awake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Asleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor Off</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
</tr>
<tr>
<td>Why?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitor Off</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
</tr>
<tr>
<td>Why?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise Time</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
<td><strong>:</strong> to</td>
</tr>
<tr>
<td>Any problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Please explain.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The armband should be worn on the back of the upper right arm with the button at the top. The sensors on the armband must be touching the skin to work properly (it will sing when you strap it on to let you know it has detected your skin). Please ensure that the elastic is snug. The armband will make singing noises on and off all day if the strap is not tight enough.

The armband should be worn at all times for the next 7 days and nights except during water-based activities. If you are not comfortable wearing the armband to bed or if you try to wear it to bed and it disrupts your sleep, do not feel obligated to wear it. It is most important to wear it during your waking hours. If it is removed for sleep please put it on as soon as you wake up and remove it immediately prior to going to sleep.

If you perform any activities that cause heavy sweating please wipe the back of the armband with a damp cloth and dry it so that the sensors maintain good contact with the skin.
Appendix H
Example of Statistical Output
Test for Normality – Duration and Intensity Variables

Tests of Normality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kolmogorov-Smirnov</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
</tr>
<tr>
<td>PercentSedMetsPerDay</td>
<td>.050</td>
<td>80</td>
</tr>
<tr>
<td>PercentLFAmetsPerDay</td>
<td>.101</td>
<td>80</td>
</tr>
<tr>
<td>PercentMVFAmetsPerDay</td>
<td>.057</td>
<td>80</td>
</tr>
<tr>
<td>PercentFAMetsPerDay</td>
<td>.077</td>
<td>80</td>
</tr>
<tr>
<td>PercentSedTimePerDay</td>
<td>.149</td>
<td>80</td>
</tr>
<tr>
<td>PercentFATimePerDay</td>
<td>.136</td>
<td>79</td>
</tr>
<tr>
<td>PercentMVFASTimePerDay</td>
<td>.091</td>
<td>80</td>
</tr>
<tr>
<td>PercentFATimePerDay</td>
<td>.146</td>
<td>79</td>
</tr>
</tbody>
</table>

* Lilliefors Significance Correction

This is a lower bound of the true significance.

PercentSedMetsPerDay

Histogram

- Mean = 43.96
- Std. Dev. = 12.014
- N = 80
Test for Gender Interaction

Regression

[DataSet1] E:\Data Output\MGB_dataSet_May31.sav

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2maxkg</td>
<td>26.594</td>
<td>4.2426</td>
<td>30</td>
</tr>
<tr>
<td>Gender</td>
<td>1.32</td>
<td>4.68</td>
<td>79</td>
</tr>
<tr>
<td>LogIPA</td>
<td>1.5181</td>
<td>1.5670</td>
<td>79</td>
</tr>
<tr>
<td>LogIPA Dur</td>
<td>1.9303</td>
<td>7.6564</td>
<td>79</td>
</tr>
</tbody>
</table>

Correlations

<table>
<thead>
<tr>
<th></th>
<th>VO2maxkg</th>
<th>Gender</th>
<th>LogIPA</th>
<th>LogIPA Dur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>.623</td>
<td>.403</td>
<td>.680</td>
</tr>
<tr>
<td></td>
<td>.623</td>
<td>1.000</td>
<td>.117</td>
<td>.574</td>
</tr>
<tr>
<td></td>
<td>.403</td>
<td>.117</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.680</td>
<td>.574</td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>Sig (1-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.000</td>
<td>.154</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>.000</td>
<td>.000</td>
<td></td>
<td>.000</td>
</tr>
</tbody>
</table>

N

<table>
<thead>
<tr>
<th></th>
<th>VO2maxkg</th>
<th>Gender</th>
<th>LogIPA</th>
<th>LogIPA Dur</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2maxkg</td>
<td>80</td>
<td>79</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td>Gender</td>
<td>79</td>
<td>79</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>LogIPA</td>
<td>79</td>
<td>70</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td>LogIPA Dur</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
</tbody>
</table>

Variables Entered/Removed

<table>
<thead>
<tr>
<th>Model</th>
<th>Variables Entered</th>
<th>Variables Removed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gender</td>
<td>.</td>
<td>Enter</td>
</tr>
<tr>
<td>2</td>
<td>LogIPA</td>
<td>.</td>
<td>Enter</td>
</tr>
<tr>
<td>3</td>
<td>Log IPA Duration Xgender</td>
<td>.</td>
<td>Enter</td>
</tr>
</tbody>
</table>

a. All requested variables entered.

b. Dependent Variable: VO2maxkg
## Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig F Change</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.623*</td>
<td>.398</td>
<td>.369</td>
<td>.3396</td>
<td>.188</td>
<td>40.252</td>
<td>1</td>
<td>76</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.709*</td>
<td>.499</td>
<td>.488</td>
<td>.3427</td>
<td>.111</td>
<td>23.055</td>
<td>1</td>
<td>75</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.701*</td>
<td>.503</td>
<td>.493</td>
<td>.3517</td>
<td>.104</td>
<td>26.022</td>
<td>1</td>
<td>74</td>
<td>.000</td>
<td></td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), Gender
b. Predictors: (Constant), Gender, LogPA
c. Predictors: (Constant), Gender, LogPA, LogPA:Duration:Gender
d. Dependent Variable: VO2max

## ANOVA

<table>
<thead>
<tr>
<th>Model</th>
<th>Source of Variation</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regression</td>
<td>1</td>
<td>523.267</td>
<td>48.202</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>76</td>
<td>11.153</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>77</td>
<td>1599.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Regression</td>
<td>2</td>
<td>365.791</td>
<td>37.349</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>75</td>
<td>9.258</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>77</td>
<td>723.055</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Regression</td>
<td>3</td>
<td>232.273</td>
<td>24.842</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>74</td>
<td>8.313</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>77</td>
<td>310.583</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Predictors: (Constant), Gender
b. Predictors: (Constant), Gender, LogPA
c. Predictors: (Constant), Gender, LogPA, LogPA:Duration:Gender
d. Dependent Variable: VO2max

## Coefficients

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig</th>
<th>95.0% Confidence Interval for B</th>
<th>Correlations</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Beta</td>
<td></td>
<td></td>
<td></td>
<td>Correlations</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>191.147</td>
<td>1.135</td>
<td>84.366</td>
<td>.000</td>
<td>16.939</td>
<td>21.430</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>5.853</td>
<td>.813</td>
<td>72.836</td>
<td>.000</td>
<td>-4.024</td>
<td>7.820</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.023</td>
<td>8.947</td>
<td>.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9.450</td>
<td>.040</td>
<td>4.624</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>(Constant)</td>
<td>-1.411</td>
<td>10.274</td>
<td>-1.37</td>
<td>.171</td>
<td>-21.092</td>
<td>19.261</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>10.879</td>
<td>7.965</td>
<td>1.200</td>
<td>1.554</td>
<td>-4.034</td>
<td>25.792</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>511</td>
<td>2.056</td>
<td>.043</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.21</td>
<td>27.328</td>
<td>.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LogPA</td>
<td>13.035</td>
<td>8.727</td>
<td>1.51</td>
<td>4.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>511</td>
<td>2.056</td>
<td>.043</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LogPA:Duration:Gender</td>
<td>-2.874</td>
<td>4.099</td>
<td>-663</td>
<td>750</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.568</td>
<td>15.43</td>
<td>.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: VO2max

112
Regression: IPA duration (expressed as a percentage of wear-time) and CRF control for gender, BMI and age

Regression

Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2mLkg</td>
<td>26.410</td>
<td>4.2703</td>
<td>79</td>
</tr>
<tr>
<td>Gender</td>
<td>1.3 0</td>
<td>0.463</td>
<td>78</td>
</tr>
<tr>
<td>BMI</td>
<td>33.6202</td>
<td>4.42921</td>
<td>78</td>
</tr>
<tr>
<td>Age</td>
<td>53.46</td>
<td>7.878</td>
<td>78</td>
</tr>
<tr>
<td>LogIPA</td>
<td>1.6168</td>
<td>0.15717</td>
<td>79</td>
</tr>
</tbody>
</table>

Correlations

<table>
<thead>
<tr>
<th></th>
<th>VO2mLkg</th>
<th>Gender</th>
<th>BMI</th>
<th>Age</th>
<th>LogIPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>0.649</td>
<td>0.294</td>
<td>-0.194</td>
<td>0.388</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.000</td>
<td>0.102</td>
<td>1.000</td>
<td>-0.075</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
<td>0.000</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.102</td>
<td>0.172</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.075</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.100</td>
</tr>
<tr>
<td>Sig. (1-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N

<table>
<thead>
<tr>
<th></th>
<th>VO2mLkg</th>
<th>Gender</th>
<th>BMI</th>
<th>Age</th>
<th>LogIPA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
</tbody>
</table>

Variables Entered/Removed

<table>
<thead>
<tr>
<th>Model</th>
<th>Variables Entered</th>
<th>Variables Removed</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gender</td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td>2</td>
<td>BMI</td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td>3</td>
<td>Age</td>
<td></td>
<td>Enter</td>
</tr>
<tr>
<td>4</td>
<td>LogIPA</td>
<td></td>
<td>Enter</td>
</tr>
</tbody>
</table>

a. All requested variables entered.
b. Dependent variable: VO2mLkg
### Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std Error of the Estimate</th>
<th>Change Statistics</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.648a*</td>
<td>.421</td>
<td>.414</td>
<td>3.2966</td>
<td>421</td>
<td>56.054</td>
</tr>
<tr>
<td>2</td>
<td>.744b</td>
<td>.553</td>
<td>.541</td>
<td>2.6828</td>
<td>.132</td>
<td>22.555</td>
</tr>
<tr>
<td>3</td>
<td>.820c</td>
<td>.673</td>
<td>.670</td>
<td>2.4914</td>
<td>.120</td>
<td>27.472</td>
</tr>
<tr>
<td>4</td>
<td>.890d</td>
<td>.773</td>
<td>.735</td>
<td>2.0804</td>
<td>.000</td>
<td>0.003</td>
</tr>
</tbody>
</table>

a. Predictors (Constant), Gender  
b. Predictors (Constant), Gender, BMI  
c. Predictors (Constant), Gender, BMI, Age  
d. Predictors (Constant), Gender, BMI, Age, LogPA  
e. Dependent Variable: VO2max

### ANOVA

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regression</td>
<td>559.218</td>
<td>1</td>
<td>559.218</td>
<td>55.054</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>1021.31</td>
<td>77</td>
<td>13.580</td>
<td>55.054</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1422.53</td>
<td>78</td>
<td>18.589</td>
<td>55.054</td>
</tr>
<tr>
<td>2</td>
<td>Regression</td>
<td>768.389</td>
<td>2</td>
<td>384.195</td>
<td>48.977</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>936.044</td>
<td>78</td>
<td>12.039</td>
<td>48.977</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1422.43</td>
<td>78</td>
<td>18.589</td>
<td>48.977</td>
</tr>
<tr>
<td>3</td>
<td>Regression</td>
<td>956.929</td>
<td>3</td>
<td>318.976</td>
<td>51.384</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>465.632</td>
<td>75</td>
<td>6.227</td>
<td>51.384</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1422.56</td>
<td>78</td>
<td>18.589</td>
<td>51.384</td>
</tr>
<tr>
<td>4</td>
<td>Regression</td>
<td>959.849</td>
<td>4</td>
<td>239.712</td>
<td>39.027</td>
</tr>
<tr>
<td></td>
<td>Residual</td>
<td>465.652</td>
<td>74</td>
<td>6.221</td>
<td>39.027</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1422.50</td>
<td>78</td>
<td>18.589</td>
<td>39.027</td>
</tr>
</tbody>
</table>

a. Predictors (Constant), Gender  
b. Predictors (Constant), Gender, BMI  
c. Predictors (Constant), Gender, BMI, Age  
d. Predictors (Constant), Gender, BMI, Age, LogPA  
e. Dependent Variable: VO2max

### Coefficients

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
<th>95.0% Confidence Interval for B</th>
<th>Correlations</th>
<th>Collinearity Statistics</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std Error</td>
<td>Beta</td>
<td>Sig.</td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td>Tolerance</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>10.02</td>
<td>.800</td>
<td>.000</td>
<td>14.01</td>
<td>20.04</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>5.969</td>
<td>.849</td>
<td>4.077</td>
<td>4.301</td>
<td>7.651</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>(Constant)</td>
<td>25.971</td>
<td>2.586</td>
<td>11.545</td>
<td>24.001</td>
<td>26.914</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>6.323</td>
<td>.711</td>
<td>8.698</td>
<td>5.010</td>
<td>8.398</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>-.357</td>
<td>.365</td>
<td>-.970</td>
<td>-.510</td>
<td>-.203</td>
<td>.047</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>(Constant)</td>
<td>40.774</td>
<td>3.041</td>
<td>13.400</td>
<td>40.171</td>
<td>41.322</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>6.026</td>
<td>.751</td>
<td>11.116</td>
<td>5.685</td>
<td>6.367</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>-.304</td>
<td>.368</td>
<td>-.823</td>
<td>-.513</td>
<td>-.255</td>
<td>.034</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-.195</td>
<td>.037</td>
<td>-.524</td>
<td>-.271</td>
<td>-.122</td>
<td>.049</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>(Constant)</td>
<td>41.082</td>
<td>3.045</td>
<td>13.400</td>
<td>40.171</td>
<td>41.322</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>6.456</td>
<td>.751</td>
<td>11.116</td>
<td>6.014</td>
<td>6.986</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>-.304</td>
<td>.368</td>
<td>-.823</td>
<td>-.513</td>
<td>-.255</td>
<td>.034</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-.197</td>
<td>.040</td>
<td>-.524</td>
<td>-.271</td>
<td>-.122</td>
<td>.049</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LogPA</td>
<td>-.132</td>
<td>.225</td>
<td>-.590</td>
<td>.000</td>
<td>.000</td>
<td>.004</td>
<td></td>
</tr>
</tbody>
</table>

a. Dependent Variable: VO2max
Appendix I

Results for Tertiary Analysis
Appendix I – Table 1. Participant characteristics for comparative analysis between the GT3X Actigraph and SenseWear Pro Armband

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>AG (N=59)</th>
<th>SWA (N=59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>53.5 (8.0)</td>
<td>53.5 (8.0)</td>
</tr>
<tr>
<td>BMI</td>
<td>33.1 (4.5)</td>
<td>33.1 (4.5)</td>
</tr>
<tr>
<td>Waist Circumference</td>
<td>111.0 (11.1)</td>
<td>111.0 (11.1)</td>
</tr>
<tr>
<td>V02Max (ml/kg/min)</td>
<td>26.4 (4.1)</td>
<td>26.4 (4.1)</td>
</tr>
<tr>
<td>IPA (min/d)</td>
<td>300.1 (79.1)</td>
<td>331.6 (127.0)*</td>
</tr>
<tr>
<td>MPA (min/d)</td>
<td>16.6 (9.5)</td>
<td>40.7 (17.9)*</td>
</tr>
<tr>
<td>LPA (min/d)</td>
<td>283.5 (77.0)</td>
<td>290.9 (120.0)</td>
</tr>
</tbody>
</table>


Data are presented as group mean (SD)

*Indicates significant pair-wise difference, p < 0.05.

Appendix I – Table 2. Association between incidental physical activity and cardiorespiratory fitness as measured by the SenseWear Pro Armband and GT3X Actigraph

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>p value</th>
<th>95% CI [Lower, Upper]</th>
<th>R² change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWA - IPA duration (log min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12.1 (3.2)</td>
<td>0.00</td>
<td>5.7, 18.7</td>
<td>0.19</td>
</tr>
<tr>
<td>2</td>
<td>10.4 (2.4)</td>
<td>0.00</td>
<td>5.6, 15.3</td>
<td>0.14</td>
</tr>
<tr>
<td>3</td>
<td>6.9 (2.9)</td>
<td>0.02</td>
<td>1.2, 12.6</td>
<td>0.04</td>
</tr>
<tr>
<td>4</td>
<td>0.45 (3.0)</td>
<td>0.88</td>
<td>-5.6, 6.5</td>
<td>0.00</td>
</tr>
<tr>
<td>AG - IPA duration (log min/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.94 (5.0)</td>
<td>0.85</td>
<td>-9.0, 11.0</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>7.7 (3.9)</td>
<td>0.05</td>
<td>-0.13, 15.5</td>
<td>0.04</td>
</tr>
<tr>
<td>3</td>
<td>6.1 (3.5)</td>
<td>0.09</td>
<td>-0.91, 13.1</td>
<td>0.02</td>
</tr>
<tr>
<td>4</td>
<td>4.2 (3.0)</td>
<td>0.17</td>
<td>-1.9, 10.3</td>
<td>0.01</td>
</tr>
</tbody>
</table>

AG – GT3X Actigraph, CI – Confidence interval, IPA – Incidental physical activity, R² Change – Variance explained in cardiorespiratory fitness by independent variable of interest (IPA).

SWA – SenseWear Pro Armband
Model 1: Unadjusted
Model 2: Control for sex
Model 3: Control for sex, BMI
Model 4: Control for sex, BMI, age