HIGH INTENSITY VERSUS ENDURANCE TRAINING: ARE PHYSIOLOGICAL AND BIOMECHANICAL ADAPTATIONS PRESERVED 2 MONTHS FOLLOWING THE COMPLETION OF AN INTENSIVE EXERCISE INTERVENTION

by

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Lay Abstract

In light of the current global prevalence of overweight and obesity, the associated health risks, and the continuing adoption of sedentary lifestyle, this thesis investigated some of the factors that contribute to exercise adherence, directly comparing high-intensity whole body interval training and continuous endurance training. 68 inactive university aged adults (Age: 21.4±3.4 yrs, BMI: 25.6±4.6 kg/m², VO₂peak 40.1±5.7 ml/kg/min) were randomized into one of three groups; a non-exercise control, whole body high intensity training, or continuous endurance training. Aerobic capacity measurements, time to completion trials, muscular endurance, and core strength measures were taken at pre, post and follow up testing sessions. Psychological questionnaires were also administered during exercise as well as throughout the study. Following the intervention both exercise groups demonstrated equivalent improvements in aerobic performance, with only the interval group experiencing improved muscular and core endurance. After the 2-month follow up testing sessions the interval group lost all aerobic and core adaptation, with endurance only experiencing a partial loss. This finding indicates that the interval group did not adhere to exercise at a level that was high enough to preserve the adaptations associated with training. This finding is further supported by the psychological factors measured throughout this study, including acute affect, enjoyment and intentions to engage in future exercise.
Co-Authorship

This thesis presents the work of Tina Siemens in collaboration with Dr. Brendon Gurd.

*High intensity versus endurance training: are physiological and biomechanical adaptations preserved 2 months following the completion of an intensive exercise intervention* is presented according to the guidelines for the Journal of Physiology. Tina Siemens was responsible for reviewing the relevant literature to identify the research question, conduction of the training study, performing the analysis, and drafting the manuscript. All aspects were a collaborative effort between Tina Siemens and Dr. Brendon Gurd. In addition, Dr Mary Jung and Dr. Steve Fischer contributed to the design and drafting of the manuscript.
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List of Abbreviations

ANOVA – analysis of variance
BMI – body mass index
cm - centimetre
CON – control
DMM – dual mode model
END – endurance exercise
FMS – functional movement screen
FS – feeling scale
HIT – high intensity interval training
HR – heart rate
kg – kilogram
km – kilometre
lb - pound
m - metre
mph – miles per hour
NPHS – National population health survey
O₂ – oxygen
PA – physical activity
PACES – physical activity enjoyment scale
PAR – physical activity recall survey
PBC – perceived behavioral control
POST – post-testing
PRE – pre-testing
Rel – relative
**SD** – standard deviation

**TBP** – Theory of Planned Behavior

**VO₂** – volume of oxygen

**VT** – ventilatory threshold

**yrs** – years
Chapter 1

Introduction

1.1 General Introduction

Obesity is an emerging epidemic in both developed and developing countries worldwide and is linked to multiple comorbidities (12, 13, 15, 17, 19). Current estimates indicate that 56% of males and 44% of females 20-39 years of age are considered overweight or obese according to their body mass index (BMI) (18). With only approximately 15% of the Canadian adult population meeting the 150 minutes of moderate to vigorous physical activity per week as recommended by Health Canada, the trend towards increasing rates of overweight and obesity is not surprising (4). Recently published data from Statistic Canada’s National Population Health Survey (NPHS) indicates that participation in physical activity decreased 24% between the ages of 12-15 and 24-27 years with the largest declines seen in men transitioning into post-secondary education (14). This transition into early adulthood marks the most pronounced and disproportionate decrease in the regular participation in physical activity. In a young population becoming inactive is a gateway to a future sedentary lifestyle, which could then lead to becoming overweight/obese. Thus, this period during young adulthood characterizes a critical time to intervene in an attempt to alter the decision-making process regarding physical activity, preventing the adoption of a future sedentary lifestyle.
1.2 HIT: A possible solution?

High intensity interval training is defined as repeated bouts of relatively brief intense exercise interspersed with periods of recovery (11). Due to this broad definition several protocols have been developed. For the purpose of this thesis an adapted version of extremely low volume HIT, which consists of 8 x 20 second intervals of maximal intensity exercise separated by 10 seconds of rest will be used (21). The modified protocol used incorporates whole-body exercise with the same work-to-rest ratio, and our lab has demonstrated that 4 weeks (4 days/week) of this very low-volume HIT protocol improves aerobic capacity to a similar degree as endurance training in recreationally active females (16). Whole body HIT also increases core strength and muscle endurance, adaptations that are not observed following endurance training (16). These additional benefits of whole body HIT may improve functional movement quality and reduce the risk of future injury (5). Furthermore, since the most often stated barrier to regular participation in physical activity is time (10, 20, 24), extremely low volume HIT, requiring only 4 minutes of training 4 days per week, clearly addresses this perceived obstacle to regular participation in physical activity.

1.3 Other factors to consider

Unfortunately, the relative time efficiency of whole body HIT may not be enough to increase exercise adherence in the general population as exercise behavior is determined by a complex decision making process that is influenced by several dynamic factors. The Dual-Mode Model (DMM), an evolutionary perspective proposing that exercise affect is the primary means by which information about critical disruptions of homeostasis enters conscious thought (7-9), speculates that high-intensities of exercise (specifically above ventilatory threshold [VT]) will
elicit negative affect, or feelings of displeasure. In combination with the Hedonic principle, which argues that individuals strive to minimize and avoid pain and displeasure, DMM has been used to suggest that an individual’s affect will predict their future behavior, specifically that negative affect during exercise will result in future avoidance of that activity and reduced exercise adherence (25). While affect has been shown to decrease with increasing intensity, as the DMM would predict (7-9), the more relevant link between exercise affect and long term adherence to physical activity has remained untested.

In addition to exercise affect, exercise intentions, or an individual’s readiness to perform exercise, may also play a key role in determining behavior. The importance of intentions as a proximal determinant of behavior is described in the Theory of Planned Behavior (TBP) (1). Taken in conjunction with the DMM, the TBP would predict that affect experienced during exercise would impact an individual’s attitude towards the exercise performed, and thus their intentions to perform that exercise in the future. More specifically, these theories would suggest that the high intensities associated with HIT, and the resulting negative affect, will result in a negative attitude towards, and decreased intentions to perform, HIT. In contrast to these ideas, time also influences intentions through effects on controlled beliefs and perceived behavioral control (1, 6). Thus the limited time required for HIT may actually improve exercise intentions and potentially adherence.

Adding further complexity to these relationships are the influences of exercise enjoyment and exercise (task) self-efficacy - described as the confidence in one’s ability to complete the exercise task - on exercise intentions. Both enjoyment and task self-efficacy can directly and indirectly influence intentions through altered perceived behavioral control (1, 6). Interestingly, and in contrast to its negative affect, HIT has been reported to be more enjoyable than endurance
exercise (2) and levels of enjoyment of HIT increased across a 4-week training intervention (16). Further, high levels of self-efficacy following 3 weeks of HIT have also been observed (3). These results conflict with the assumptions that the DMM and hedonic theory make based on the acute affective response to exercise and suggest that HIT may be an effective intervention strategy for improving exercise adherence in young adults.

1.4 The Problem

Current physical activity and obesity trends in Canada are alarming. Young adulthood appears to be a critical time for the loss of physical activity (14), and while endurance exercise is effective in improving cardiovascular health (23), and weight management (22), it is reportedly too time consuming (10, 20, 24). In this light, HIT is an attractive alternative because it is time efficient, provides the additional benefit of improved core strength and muscle endurance (16), and requires minimal to no equipment. While past research indicates it’s potential in previously fit females (16), the efficacy of whole body HIT in young inactive, but otherwise healthy adults, remains unknown.

The ability of a short-term HIT intervention to alter exercise adherence in young, inactive adults, has yet to be studied. Importantly, the multi-faceted and apparently contrasting influences of exercise time, affect, enjoyment, task-self efficacy and exercise intentions on exercise adherence following an exercise intervention utilizing either HIT or endurance training have never been examined in concert. Therefore, the overarching purpose of the current thesis was to examine the relationship between acute affect, the factors influencing exercise intentions, exercise intentions themselves, and changes in exercise adherence following an exercise
intervention consisting of either whole-body high intensity interval training or traditional continuous endurance exercise.

For the purpose of this thesis adherence refers to the maintenance of the exercise intervention throughout the follow up period. In an attempt to gain insight into a free-living environment actual behavioral activity was not measured but was instead assumed based on changes in VO2peak at follow up. Specifically, it was assumed that if the intervention was adhered to throughout the 2 month follow up period VO2peak adaptations seen at post testing would be maintained.

1.5 Thesis Organization

This manuscript-style thesis conforms to the regulations as outlined in the Queen’s School of Graduate Studies and Research “General Forms of Theses”. In Chapter 2 the reader will find a detailed review of the literature surrounding HIT training, and the influence of exercise intensity on acute affect, and the associated theories involving future exercise behaviors. Chapter 3 contains the manuscript detailing the study and the impact of exercise intensity on acute affect and it’s impact on exercise adherence in an inactive university aged population. Chapter 4 then provides a discussion of the implications of this research as well as this study’s limitations, and future directions. Finally, several appendices are attached to the end of this document to provide more complete examples of items referred to throughout the thesis.
1.6 References


Chapter 2

Literature Review

2.1 The Global Epidemic – Inactive Lifestyles

Obesity is a global epidemic that is linked to the development of diabetes, hypertension, cardiovascular disease and some cancers (42, 47, 55, 72, 74). Over the past twenty years obesity has become increasingly prevalent with an estimated 56% of Canadian males, and 44% of Canadian females aged 20-39 years currently considered over-weight or obese according to their BMI’s (73). Further, being overweight and/or obese is associated with a 35% and 48% increased risk of development of health problems in males and females, respectively (73). While these statistics are startling, they are not surprising given that approximately 85% of the adult Canadian population does not achieve Health Canada’s recommendations of 150 minutes of moderate-vigorous physical activity per week (8, 13, 16). Accordingly, physical inactivity and its associated co-morbidities are predicted to be the fourth highest risk factor of global mortality as stated by the World Health Organization (89).

Evidence demonstrating the physiological benefits associated with habitual physical activity are convincing (83), with additional evidence supporting a positive impact on psychological health (90). Interestingly, despite the compelling evidence in favor of regular participation in physical activity, adherence rates among adults remain low (16) with a pronounced and persistent reduction in physical activity occurring during the transition into early adulthood (54). More specifically, participation in physical activity decreases 24% between the ages of 12-15 and 24-27 years, with the largest decline in men transitioning to post-secondary education (54). This period of declining physical activity is a critical point in the adoption of an
inactive lifestyle, and once this lifestyle is adopted it becomes increasingly difficult to initiate and adhere to, elevated levels of physical activity (54). Thus, this transition period during which substantial reductions in physical activity reportedly occur, represents a critical time to intervene in an attempt to prevent the dramatic decline in the regular participation in physical activity.

Recent projections estimate that 57.8% of the world’s population will be overweight or obese by 2030 (47), concurrent with substantial increases in health care costs (55). Thus, it is clear that further understandings regarding exercise modalities that improve exercise adherence are necessary, specifically in young adults. While young adults are generally more active than older adults (42), efforts to intervene and increase physical activity levels in young overweight and obese adults have proven difficult (72). The majority of research in this area involves overweight/obese, older (9, 15, 71, 80, 85), and diseased populations (52, 60, 79), with only a few studies examining the responses in inactive but otherwise healthy young adults. This suggests that interventions targeted towards younger adults during the transition into sedentary adulthood are necessary, and may help to prevent the adoption of lifelong inactive lifestyles.

2.2 Traditional Endurance Training

Habitual participation in endurance exercise (END), defined as prolonged bouts of continuous steady-state low-intensity exercise engaged in 3-4 times per week, is associated with significant health benefits (15). Specifically, END reduces the risk of development of metabolic disorders such as type 2 diabetes (74, 83), improves cardiovascular health (64, 80, 83) and aerobic capacity as measured by VO_{2\text{peak}} (the gold standard of aerobic fitness – an important correlate of overall cardiovascular and metabolic health) (83). Correspondingly, END is currently the most commonly recommended form of physical activity by national physical
activity guidelines (12, 13, 66). Despite the known positive health benefits associated with END, most Canadian adults do not adhere to current physical activity guidelines apparently primarily because of a perceived lack of time (37, 77, 81). If time truly is the primary cause of the overwhelmingly inactive lifestyles being led in today’s society, the development, and implementation of less time consuming exercise protocols capable of eliciting similar improvements in aerobic capacity are needed.

2.3 High Intensity Interval Training

High intensity interval training (HIT), repeated bouts of relatively brief intense exercise interspersed with periods of recovery (38), represents a time efficient exercise protocol that can reduce training time commitment. HIT can employ a variety of different work to rest-ratios and exercise modes including cycling, running, and/or swimming interspersed with periods of active recovery, but can also employ dynamic whole body activities such as burpees or jumping jacks.

There is now a wealth of evidence demonstrating that HIT is a time efficient exercise stimulus that reduces total exercise time, while resulting in similar, or superior fitness benefits compared to END (39, 59, 80). Specifically, HIT has been reported to elicit comparable improvements in VO$_2$peak (10, 43, 58, 80), exercise performance (38, 58), VO$_2$ kinetics (10), and reductions in body weight and BMI (79). HIT may therefore represent a viable alternative for individuals who cite “lack of time” as the primary barrier impeding participation in regular exercise.

2.3.1 Whole body high intensity interval training

Due to the broad definition of HIT mentioned above several protocols have been developed. Extremely low volume HIT, requiring only 4 minutes per training session (78), has
been shown to improve both anaerobic capacity and aerobic fitness, as assessed through \( \text{VO}_2 \text{peak} \), when performed on a cycle ergometer (78). Using a modified protocol that utilizes whole-body exercise with the same work-to-rest ratio (20 second intervals separated by 10 seconds of rest), our lab has demonstrated that 4 weeks (4 days/week) of extremely low-volume HIT significantly improves aerobic capacity and muscular endurance in recreationally active females (59). While this study demonstrated that both endurance training and whole body HIT increase \( \text{VO}_2 \text{peak} \) equivalently, whole body HIT also induced increases in upper body and core muscular endurance (59). At present, the functional impact of these additional improvements in muscular endurance remains unknown, however, they may contribute to an improved capacity for joint stability during dynamic movements and potentially reduce risk of future injury.

2.3.2 HIT and Functional Movement Screening

“Functional movements” are large dynamic movements requiring the coordination of several muscles that elicit a coordinated kinetic chain of movement requiring accuracy, stability, mobility and efficiency. These movements form the foundation of movement quality and the framework for movement patterns essential to leading a healthy functional everyday life. The current inactive lifestyle shared by 85% of the Canadian adult population (16) is the largest contributing factor to impaired movement function (51), and therefore the implementation of an exercise intervention designed to improve movement quality may help attenuate the growing health care concern surrounding injury resulting from poor movement quality.

The Functional Movement Screen (FMS) is a simple, quantifiable evaluation tool capable of assessing movement pattern quality in order to demonstrate limitations and/or asymmetries in individuals’ basic movement patterns (18). The FMS consists of seven fundamental movement patterns that require a combination of balance, mobility and stability, placing the individual in
challenging positions (18-20). The performance of these movements reveals weaknesses and compensatory movements, which may predispose individuals to excess stress, work, poor biomechanics and potentially injury (18). Each of the seven movements is scored on a scale from zero to three, with three representing the highest movement quality, to give an overall score out of twenty-one. The scoring methodology is designed to be very broad, only identifying successful completion of the required movement, with or without compensatory allowance, unsuccessful completion, or pain. Although simple, broad scoring promotes inter and intra-rater reliability by trained individuals promoting the accuracy of the evaluation (62).

While some studies demonstrate that an FMS score of 14 or less indicates an increased risk for injury (14, 49, 50), others have found that the FMS score is not predictive of injury (11, 76). These differences may be attributed to the populations studied with professional and collegiate level athletes demonstrating a higher level of risk of injury. Importantly, FMS scores can improve following exercise interventions, which are accompanied by a reduced risk of potential injury in professional football players (48), members of the military (40) and firefighters (21). Given the potential clinical relevance of the FMS as a predictive tool for injury prevention, the impact of improved upper body and core muscular endurance following whole body HIT on functional movement in young inactive adults is of interest.

2.3.3 Detraining

Exercise interventions are known to be associated with adaptive changes in aerobic capacity and performance. Detraining is the partial or complete loss of those training induced adaptations in response to either a significant decrement in the training load, or the cessation of training (88). The literature in this area indicates that the time course in which adaptation is lost following the cessation of training is dependent on several variables including; fitness level prior
to training, age and the length of the training intervention. Coyle et al. found that after confining athletes to 84 days of inactivity following habitual training, VO$_2$peak remained higher than an inactive control group (22). Conversely, research in sedentary young adults indicates that improvements in VO$_2$peak induced by 15 weeks of training were significantly decreased following 7 weeks of detraining (75). There have also been reports indicating that in as little as 2 weeks of inactivity a loss of muscular endurance results (88). Importantly, the amplitude of the detraining response is significantly impacted by the amount of exercise, or an individual’s “exercise adherence”, in the post-training period (44-46). Based on this relationship, the maintenance of training induced improvements in aerobic capacity, exercise performance and muscle endurance in the period following the completion of a training intervention can be used as a proxy for exercise adherence.

2.3.4 A Summary of the Problem

Current physical inactivity and obesity trends in Canada are alarmingly high. According to Kwan et al. young adulthood appears to be a critical time in the adoption of an inactive lifestyle (54), and while endurance exercise is effective in improving cardiovascular health (80), and weight management (79), it is reportedly too time consuming (37, 77, 81). HIT, specifically whole body extremely low volume HIT, is therefore an attractive alternative due to both its time efficiency and its additional impact on muscular endurance (59). However, at present, the efficacy of whole body HIT in young inactive, but otherwise healthy adults remains unknown, and the ability of this protocol to alter exercise adherence in this population has not been studied.

Importantly, although time is the most often stated barrier to regular participation in physical activity (37, 77, 81) factors contributing to exercise adherence are far more complex than lack of time alone. For example, intentions to exercise have been implicated as a potential
mediator of exercise adherence (68). Additionally, affect (how one feels during exercise) may also impact an individuals’ continued participation in physical activity (4, 7, 25-30, 32). The remainder of this literature review will discuss and explore the complexities surrounding exercise behavior with specific attention paid to a few of the current theories surrounding exercise adherence.

2.4 Dual-Mode Model (DMM)

The dual mode model (DMM), first proposed by Ekkekakis (26) is an evolutionary theory that proposes that exercise affect is the primary means by which information about critical disruptions of homeostasis enters conscious thought (25, 26, 31, 36). The DMM speculates that exercise below, at and above ventilatory threshold (VT) consistently elicit changes in affect from positive, variable and negative respectively. It is known that exercising at intensities above VT, an exercise intensity that disrupts both intramuscular and cardiovascular homeostasis is associated with negative affect (1, 27-29, 32, 41, 56, 70, 84). According to DMM VT represents a turning point, which acts as an objective and quantifiable variable that is an indicator of whether exercise will elicit a positive or negative affect. VT reflects one’s ability to maintain exercise.

The dual model refers to both cognitive (motivation, efficacy, personality, etc.) and interoceptive (thermoreceptors, baroreceptors, etc.) influences on the affective response (33, 35, 41). When exercising below VT the interoceptive factors have little to no influence on affective response because homeostasis is not interrupted and cognitive factors have a moderate influence, with exercise generally reported as pleasant (positive affect). In contrast interoceptive factors have increasing influence on affect when individuals exercise above VT because physiological
homeostasis is threatened, which accounts for the consistently reported negative affect for high intensities of exercise (28, 34, 41). Previous research conducted in the area of the intensity-affect relationship have used healthy recreationally active adults (6, 57-59), and therefore this relationship is less clear in inactive populations where differences in cognitive factors and interoceptive sensitivity may alter the intensity-affect relationship.

2.4.1 Exercise and the Affective Response

It has been suggested that a potential relationship exists between affect and exercise adherence, although this hypothesis remains unconfirmed. Specifically, both the DMM and the Hedonic principle have been incorporated to suggest that an individual’s affect will predict their future behavior under the assumption that if an individual experiences negative affect they will find that activity aversive and avoid it in the future (82, 86). While this seems intuitive the measure of affect itself may be flawed. Early research in the area of affective response to exercise operationalized affect using a categorical approach to determine specific emotions associated with exercise (33, 34, 41). This approach reflects the assumption that emotions are unrelated, and organized into distinct categories. Conversely, a dimensional approach can theoretically capture the basic core affective responses to exercise (41). While a categorical method is certainly relevant if trying to distinguish specific emotions, the specificity of this approach may omit measures of distinct affective states. Additionally, due to it’s multi-item assessment structure it is also difficult to measure during exercise. Dimensional measures are single item assessments of basic affect, which can easily be administered multiple times, including during exercise. Initial research in this area only took measures of affect before and after exercise, which, consequently led to the conclusion that acute bouts of exercise lead to consistent improvements in affective states (90). It was not until during exercise measures, and a
dimensional approach was adopted, that a more accurate affective profile was created (30, 36, 41). While most individuals experience a ‘re-bound’ effect post exercise, accounting for the consistently reported positive affect, not everyone reports the same affective responses during exercise. According to the learning theory (86), more immediate responses to exercise will be more predictive of future behavior, and therefore a 'during' exercise measure may be critical to predicting future exercise adherence (30, 41). While affect has been shown to decrease with increasing intensity, as the DMM would predict, the more relevant link to exercise adherence has remained untested, leaving this affect-adherence relationship merely an assumption. With inactivity levels so high amongst the Canadian population it is of importance to challenge/test this notion.

2.4.2 HIT and DMM

When HIT is considered within the context of DMM, its inherent time efficiency is overshadowed by the high intensities of exercise typically required for beneficial adaptations (39). Specifically, the extremely high relative intensities associated with HIT protocols should result in a negative affective response according to DMM (25-31, 33-35, 41, 86). This hypothesis is supported by the affective response to endurance exercise where an inverse relationship exists between exercise intensity and affect (1, 7, 29, 41, 53, 56, 61, 65, 67, 70, 87, 91). There is also evidence that this relationship extends to HIT with greater decreases in affect accompanying increasing intensities with a 1 minute on, 1 minute off protocol (Figure 1), as well as 20 seconds on, 10 second off protocol meant to elicit 170% of peak work rate on a cycle ergometer (unpublished observations). Interestingly, when affect is compared across a training study week 1 affect is highly negative, while this decrease in affect is ameliorated by week 4 (Figure 2). This finding, indicating that individuals may find HIT less aversive following
repeated bouts combined with the commonly held belief that affective benefits require ‘vigorous’ intensity exercise (63), highlights the current controversy/contradictions inherent in the exercise affect literature. Indeed, relatively little is known about the relationships between exercise intensity, affect and subsequent adherence to physical activity following HIT.
Figure 1. The Impact of Interval Intensity on Exercise Affect. Changes in acute affect from baseline (BSL1: 10mins prior; BSL 2: immediately prior to interval 1) during a single bout of exercise performing 1 minute intervals (separated by 1 minute or rest) at 65%, 90% and 120% VO$_2$max at the end of intervals 2, 4, 6 and 8 as well as post exercise (2.5minutes; 10minutes; 20minutes).

* Significant (p<0.05) difference from 120%
† Significant (p<0.05) difference from 65%
‡ Significant (p<0.05) difference from 65% and 90%

Figure 2. Changes in affect from week 1 to week 4 of a HIT intervention. Changes in acute affect from baseline to interval 8 for intervals (1 minute intervals separated by 1 minute of rest) performed at 65%, 90%, and 120% VO$_2$max during the first and last training session of a 4-week training intervention.

* Significant (p<0.05) difference from week 1
† Significant (p<0.05) difference from 90%
‡ Significant (p<0.05) difference from 65% and 90%
2.4.3 Summary

The most commonly cited explanation for lack of regular participation in physical activity is lack of time (37, 77, 81). HIT is a time effective strategy that has been consistently demonstrated to increase VO$_2$peak (10, 39, 43, 58, 80), exercise performance (39, 58) and improve strength (59). If lack of time is in fact the predominant barrier to habitual exercise, HIT offers the solution. However, HIT is also associated with negative affective response during exercise, suggesting that HIT will be avoided (25, 28, 30, 31, 41). It is clear that exercise behavior is a complex issue with several potential mediating factors, including time, affect and a myriad of additional factors that combine to influence an individual’s intention to exercise, another important factor in determining exercise adherence.

2.5 Exercise Intentions

The theory of planned behavior (TPB; Figure 3) is a widely applied expectancy model of attitude and behavior relationships (2). TPB indicates that the most proximal determinant of behavior is intention, which is a person’s readiness to perform a behavior. Intentions are determined by three main factors; 1) attitude reflecting positive or negative evaluation of engagement in the targeted behavior, 2) subjective norms which reflect sense of social pressure to perform the behavior, and 3) perceived behavioral control which reflects the degree of control one perceives she has over the behavior. In turn, each of these three factors are influenced by behavioral beliefs (expectations of the outcomes associated with engaging in the behavior and associated value of those expected outcomes), normative beliefs (perceived expectations of others to perform the targeted behavior and motivation to comply with other’s expectations), and control beliefs (perceptions of factors that may facilitate or inhibit performance of the behavior.
and the strength of each of these factors); respectively. Attitude is theorized to influence intentions, and therefore indirectly behavior, while intentions and perceived behavioral control are indirectly and directly closely associated with exercise behavior (24). Importantly, intentions consistently account for approximately 50% of actual behavior (3), and have been suggested to be one of the best predictors of future exercise (23).

2.5.1 HIT and the Theory of Planned Behavior

The DMM theorizes that as exercise intensity increases, reported affect will decrease. The construct of affect is measured using the feeling scale (FS) and it is possible that the affect experienced during exercise impacts an individual’s attitude towards the exercise performed, and thus their intentions to perform the exercise in the future. Their behaviors are therefore influenced by their attitudes towards the activity, which is in part determined by affect (2, 69). Due to the high intensities of exercise associated with HIT, and the negative affect that individuals experience while engaged in HIT (See Figures 1 and 2), the theory outlined above would predict a negative attitude towards HIT. This negativity would then decrease intentions and consequently future behavior. While it has been demonstrated that increased intensity does lead to lower affect, the hypothesized connection to behavior remains untested.

As previously mentioned, time is the most often stated barrier to regular participation in physical activity (37, 77, 81). As depicted in figure 3, control beliefs account for perceived barriers, which then influence perceived behavioral control (PBC). PBC not only impact intentions, which will then influence behavior, but are also believed to directly influence behavior. In the context of TPB, PBC plays an important role in predicting future behavior because of this dual impact (2, 23). While the intensity of HIT will impact one’s attitude towards exercise via the negative affective response, this is accompanied by a significant
reduction in the time required to complete exercise, which may be more impactful on future behavior through changes in PBC. Additionally the construct of attitude also accounts for enjoyment, as measured by the Physical Activity Enjoyment Scale (PACES) (69). Previous research has indicated that individuals enjoyed and preferred HIT training compared to lower intensity, traditional continuous exercise (6). Figure 2 also suggests that affect can be changed over the course of training, indicating that the initial negativity reported with HIT may be mitigated over the course of training, further highlighting the complexity of this relationship.

In addition to affect and enjoyment, an individual’s confidence, or self-efficacy may also impact their intentions to engage in exercise. Self-efficacy describes an individual’s belief in their ability to organize and execute a course of action required to produce a desired outcome (5, 23). With increased self-efficacy there is a resulting increase in the targeted behavior, and as positive behavioral changes occur, self-efficacy will also increase in a cyclical fashion (23). In the context of exercise, task self-efficacy is described as the confidence in one’s ability to complete the exercise task. In the framework offered by the TPB, task self-efficacy would be an influential factor in PBC, making exercise self-efficacy a potentially important indirect and direct mediator of exercise behavior (Figure 3). While there is debate regarding the theoretical distinction of self-efficacy and PBC (perceiving internal versus external control), these concepts remain part of a multidimensional view of perceived control (17). Preliminary research using interval training demonstrates that, while higher intensities of HIT (1 minute on 1 minute off at 100% vs. 70% of maximal aerobic power) is associated with greater negative affect during exercise, participants reported similar high levels of self-efficacy following training suggesting that participants perceived both intensities of HIT as manageable (9). These results, in conjunction with the higher reported ratings of enjoyment associated with HIT (6), are contrary
to the affective research and suggest that HIT may be an effective intervention strategy that may improve exercise adherence in previously inactive individuals.

Additionally, an individual’s satisfaction of outcomes associated with a behavior is considered behavioral beliefs. In the context of exercise, this satisfaction surrounds the beliefs that being physically active will lead to certain consequences (weight loss, improved attractiveness, etc.). These beliefs then directly impact an individual’s attitudes’ toward that exercise, which then affects intentions and possibly future behaviors (23) (Figure 3).

2.5.2 What we are testing

The DMM indicates that as exercise intensity increases, reported affect will decrease. This affect could then predict future behaviors, as shown in figure 4. While this model appears intuitive, exercise behavior is far more complex incorporating a multitude of factors, including time and enjoyment. Research has indicated that as intensity increases in continuous endurance exercise, affect decreases, however, the notion of adherence has gone widely untested (29, 30, 32). With time being the most commonly stated barrier to regular participation in physical activity, HIT overcomes this obstacle and may therefore ameliorate the predicted negative intensity-affect relationship associated with HIT. Additionally, previous research has indicated that with continued HIT the negative affect reported becomes significantly less negative over the training sessions (Figure 2), and HIT as been reported to be more enjoyable than continuous endurance exercise, (6). Therefore, the purpose of the current thesis was to examine the relationship between acute affect, exercise intentions and exercise adherence following an exercise intervention consisting of either whole-body high intensity interval training or traditional continuous endurance exercise.
Figure 3. The Theory of Planned Behavior. Figure adapted from Croker, Peter, R.E. (2011).

Figure 4. The proposed pathway through which acute exercise affect may influence future exercise behavior.
2.6 Specific Purposes and Hypotheses

In order to examine the relationships between training time, exercise affect, intentions, and exercise adherence, as well as potential changes in functional movement quality, we conducted a training study with an additional 2-month post-training intervention follow-up. Participants were recruited and randomized into one of three groups; a non-exercise control group; continuous endurance, or a whole body high intensity interval-training group. During and following training, participants were asked a series of questionnaires to determine their acute affect, as well as their self-efficacy, and satisfaction as it related to the exercise training. Following the 4-week intervention, participants then experienced a 2-month hiatus, after which time they were invited to return to determine their adherence to exercise.

For the purpose of this thesis adherence refers to the maintenance of the exercise intervention throughout the follow up period. Actual behavioral activity was not measured but was instead indirectly measured through VO$_2$peak at follow up. VO$_2$peak was used as a proxy measure of adherence such that if the intervention was adhered to throughout the 2 month follow up period VO$_2$peak adaptations seen at post testing would be maintained.

*Purpose 1:* To determine the changes in VO$_2$peak, exercise performance, muscular endurance and functional movement following 4 weeks of training utilizing either END or HIT in previously inactive individuals.

*Hypothesis 1:* Endurance and HIT training will induce similar increases in VO$_2$peak and exercise performance with no differences between groups. Whole-body HIT will also induce increases in muscular endurance and improved FMS scores and these adaptations will not be present in the
Purpose 2: To determine if the different intensities of exercise associated to END and HIT elicit different acute affective responses to exercise, and whether these differences in exercise affect influence intentions to exercise following a 4 week exercise intervention.

Hypothesis 2: END exercise will report a higher (less negative) affective response than whole body HIT. Despite this negative affective response, and contrary to the predictions of the Dual-Mode Model we predict that reported intentions will be higher following HIT.

Purpose 3: To determine the impact of END and HIT on exercise intentions, exercise enjoyment, confidence to complete exercise and satisfaction of outcomes in an attempt to elucidate the potential psychological factors that may influence future exercise adherence.

Hypothesis 3: END exercise will report lower intentions, exercise enjoyment, confidence to complete exercise and outcome satisfaction following the 4-week training intervention as compared to HIT, primarily as a result of END’s perceived lengthy time commitment.

Purpose 4: To determine the adherence to exercise during the 2 month follow-up period after training utilizing END and HIT.

Hypothesis 4: HIT will have a higher adherence to exercise than END during the 2 month follow-up period which will be reflected in both the self-reported physical activity recall survey, as well as the maintenance of the training induced improvements in VO_2peak.
2.7 References


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Chapter 3

The impact of affect on exercise adherence in inactive young adults
Introduction

High-intensity interval training (HIT) has long been known to stimulate training adaptations (12). Relatively recently however, the potency of very low dose sprint interval training for improving skeletal muscle mitochondrial content and exercise performance (27), and the similarity of these adaptations to traditional endurance exercise (21) was demonstrated. Since these reports, a significant body of literature has emerged demonstrating the ability of low dose HIT to improve aerobic capacity, exercise performance and a variety of clinically relevant outcomes across a range of populations (22, 26). At present, the message from this burgeoning field of research being translated to the general public is that you can achieve more with less. Case in point, a recent publication in the American College of Sports Medicine’s Health and Fitness Journal emphasized this concept by incorporating the phrase “Maximum Results with Minimal Investment” into its title (28). This message is being disseminated despite the fact that the impact of the high-intensities required to induce adaptations in brief training sessions, on the adoption of, and adherence to HIT in previously inactive individuals, is unknown.

The Theory of Planned Behavior (TPB) describes how exercise intentions are shaped by a myriad of dynamic factors, and how intentions themselves play an important role in determining behavior (1, 13). Within the framework of TPB, the high ratings of perceived exertion (31) and negative affect (feelings of displeasure) (7, 30), associated with the high-intensity component of HIT may decrease exercise intentions and therefore adherence. This negative outcome may be particularly likely in inactive populations (17, 18, 38). Conversely, the relative brevity of many HIT protocols may reduce perceived time required to exercise, the most commonly stated barrier to regular participation in physical activity (20, 35, 37), and potentially provide a solution to this barrier that may facilitate improved exercise intention and therefore
adherence. In addition, several recent reports have observed that HIT is also associated with high levels of exercise enjoyment (5, 31), exercise self-efficacy or confidence to perform exercise (7) and exercise intentions (7, 31). Thus, with the exception of negative within exercise affect, the majority of the available evidence suggests that exercise intention may be equal to or higher following a HIT compared to an END intervention. Importantly, the impact of HIT and END on exercise intentions have not been compared, nor have the relationships between the postulated determinants of exercise intentions and exercise adherence following a structured intervention utilizing either HIT or END been examined.

At present, the briefest HIT protocol available requires less than 4 minutes per training session and consists of 8 20 second intervals separated by 10 seconds of rest (36). When training is performed on a cycle ergometer, this protocol improves aerobic and anaerobic capacity, and skeletal muscle mitochondrial protein content (30, 36). We have also recently demonstrated that when adapted to whole-body aerobic-resistance training this protocol improves both aerobic capacity and muscular endurance (31). In addition to being extremely brief, this protocol also elicits high ratings of perceived exertion and low, or negative, exercise affect (30, 31). Thus, this protocol, being both brief and physically demanding, provides an excellent model to examine the relationships between exercise time, exercise affect, exercise intentions and the impact of these factors on exercise adherence.

While many studies have examined the efficacy of HIT in active young and older/clinical populations, inactive young adults have received much less attention in the HIT literature. Interestingly, the transition into young adulthood is when the most pronounced decreases in regular participation in physical activity occur (29), making young inactive adults an important target for exercise interventions aimed at improving lifelong exercise adherence. Therefore, the
The purpose of this study was to examine exercise adherence following a structured exercise intervention consisting of either HIT or END in young previously inactive adults. More specifically, the relationships between factors proposed to influence exercise intentions (exercise time, affect, enjoyment, task-self efficacy), exercise intentions themselves, and changes in exercise adherence (primarily determined by the maintenance of training induced adaptation at a 2 month post-training follow-up) were examined. We hypothesized that exercise adherence would be greater following HIT compared to END due to improved post-training exercise intentions, despite the more negative affect during training sessions.
Methods

Participants

One hundred forty-two participants were originally screened for participation in the current study with a total of sixty-eight inactive but otherwise healthy university aged students completing all aspects of the study. A flow chart detailing participant recruitment, screening and dropouts is presented in Figure 5, while participant characteristics for all participants completing the study are presented in Table 1. During initial screening, only self-identifying inactive participants, self-reporting less than 150 minutes of moderate to vigorous physical activity per week, and demonstrating a VO$_2$ peak of less than 50 mL·min$^{-1}$·kg$^{-1}$ (men) or 45 mL·min$^{-1}$·kg$^{-1}$ (women) were enrolled into the study. Following screening, participants were randomized into a non-exercise control group, an endurance-training group (END) or a whole body high intensity interval-training group (HIT). The Health Sciences Human Research Ethics Board at Queen’s University approved this study, and all participants provided written informed consent (Appendix A)

Experimental Approach

This was a randomized control study in which males and females were randomized independently. Initially participants were randomized to all three groups however, approximately half way through the study when it became apparent that recruitment targets would not be fully achieved priority was given to participant allocation to the exercise intervention groups.

This study followed an experimental protocol consisting of (i) a familiarization visit; (ii) baseline testing; (iii) a 4-week training intervention; (iv) post-testing, and (v) 2-month follow-up testing. Following randomization, participants completed two days of baseline testing. The non-
exercise control group was instructed to continue with their regular activities throughout the study while participants randomized into one of the experimental groups trained four times per week for four consecutive weeks. END consisted of 30 minutes per training session at 85% of their HRpeak. The HIT group completed eight 20-second intervals separated by 10-second rest periods during each training session with a different exercise being performed on each session of each week. Following the completion of the control/intervention period all participants returned to the lab for two days of post-testing. Participants also reported to the lab two months after post-testing for follow-up testing.

Familiarization Visit (Initial Screening)

All participants reported to the lab for an initial visit during which they were interviewed and completed a 7 day Physical Activity Recall Survey (PAR) (33). Participants reporting less than 150 minutes of physical activity per week were informed of the study protocol both verbally and in writing before signing an informed consent form. Participants then completed an adapted VO2peak test to exhaustion on a treadmill (Sports Art Fitness 6300HR) consisting of three minutes of resting data collection (participant was asked to stand on the treadmill and breathe normally), a five-minute warm-up with the treadmill set to 2.5mph at an incline of 2, followed by an increase of either incline or speed every two minutes to volitional exhaustion. The protocol is outlined in Appendix B. Gas exchange and heart rates were collected throughout the test with a metabolic cart (Moxus AEI Technologies, Pittsburgh, PA). VO2peak and HRpeak were calculated as highest 30-second average during the protocol. Peak O2 pulse was calculated as absolute VO2peak divided by HRpeak. If participants met the inclusion criteria outlined above they were asked to report to the lab again approximately 1 week after familiarization to complete baseline (pre-intervention; PRE) testing.
Baseline (PRE) Testing

Day 1

Upon arrival at the lab on day 1 of PRE, participants were interviewed and completed a 7-day PAR, following which they were asked for a detailed account of their diet from the previous day. Participants then completed the adapted VO$_2$peak treadmill test to exhaustion as described above.

Day 2

Approximately 24 hours after day 1 testing, participations reported to the lab to complete PRE testing. Following arrival participants were escorted to the Queen’s University Biomechanics & Ergonomics lab where they completed the Functional Movement Screen (FMS) and a series of strength tests. The FMS has been described in detail previously (10, 11). Briefly, the participant had reflective markers placed on the acromion process, the head of the 5th metatarsal, L4/L5 lumbar vertebra, T1/T2 thoracic vertebra, the ASIS, and the head of the greater trochanter. Participants then completed seven movements (deep squat, hurdle step, in-line lunge, shoulder mobility test, active straight leg raise, trunk stability push-up and a rotary stability test; for a detailed description of each movement please see Appendix C) each of which was assigned a score between 0 and 3 (0 meaning they were unable to complete the movement; 3 being perfect performance). The scoring was conducted in accordance with “The Functional Movement Screen and Exercise Progressions Manual” (9). Each movement was performed three times with approximately two seconds of rest in between the repetitions. Participants were continually recorded by two video cameras, one sagittally (Canon, Vixia HF M40) placed 3.94m directly in front of the subject, and the other coronally (Canon, FS300), placed 3.81m to the left of the
participant. Scoring was completed using the recordings to ensure the best movement performed was scored (32, 34).

Following the FMS testing participants completed a series of strength exercises including a grip strength test, a modified Biering-Sorensen test (measurement endurance of back extensor muscles; (19), a stationary flexor endurance test (measurement of abdominal muscles endurance (19) a side bridge test (measurement of oblique endurance) (19) and 1 set of push-ups to volitional fatigue at a rate of 30 push-ups per minute. For detailed explanations of these tests please see Appendix D. Immediately following strength testing participants were escorted back to the exercise lab and given approximately ten minutes to rest before completing a 5km time to completion trial at a self-selected speed and 0% incline. Participants were instructed to complete the test as quickly as possible but were given no other temporal, verbal or physiological feedback other than distance completed, which was displayed on the treadmill. Exercise duration was recorded upon completion of each test.

Training Protocol

Training was performed four times per week for four weeks, with each session beginning with a standard warm-up as reported previously (31). END participants exercised on a treadmill at 85% of their HRpeak for 30 minutes. HR (Polar Team2 Pro System; Polar, Lachine, QC), speed and incline were recorded every five minutes throughout each training session. For HIT, participants completed a total of eight 20-second intervals separated by 10-second rest periods, with the session totaling four minutes as we have described previously (31). Briefly, each training day consisted of one of four different whole body exercises; burpee push-ups; mountain climber push-ups; jumping jacks, and squat and thrusts (females starting with 5lb weights with the option of 3lbs, and males starting with 10lbs weights with an 8lbs option). See Appendix E
for a graphical depiction of each of these exercises. The number of completed repetitions was recorded for each interval.

During week one and week four of all four training sessions in the training intervention, participants’ completed psychosocial measures of exercise affect, enjoyment, effort, and confidence. Participants’ acute affect and rate of perceived exertion was assessed when they arrived at the lab, following their warm-up, halfway through their respective training interventions (at 15 minutes for END and immediately following the completion of the 4th interval in HIT), immediately upon completion of exercise and ten-minutes post exercise. After each training session in weeks 1 and 4 participants were also asked to complete measures of confidence to complete exercise, a global measure of affect, intentions to exercise in the future, and their preference of modality of exercise in the future.

*Post- and Follow-up Testing*

Post testing (POST) was completed the week following the completion of training. POST testing days followed the same protocol as PRE testing days with one exception. Following the time to completion trial performed on the second testing day, participants were asked to complete the Physical Activity Enjoyment Scale (PACES) as well as a Satisfaction of Outcomes Questionnaire. Before leaving the lab at the completion of all of the post-testing each participant was given a pamphlet that outlined the Canadian Health Guidelines (8) (Appendix F). No further instructions were provided regarding exercise expectations during the 2-month post control/intervention period. Participants were contacted approximately six weeks later to set up appointments for their final follow-up testing sessions. Follow-up testing followed the same protocol as the PRE and POST and was completed 2 months after POST.
Psychological Measures

Affect. Affect was assessed at varying time points throughout training using two separate measures. Acute affect was measured using the feeling scale, a single-item validated 11-point Likert scale assessing “What number best describes how do you feel right now?” ranging from -5 [Very Bad] to +5 [Very Good] (Appendix G) (24).

Physical Exertion. Self-reported exercise exertion was reported using the perceived rate of exertion (RPE) (Borge Scale: scale ranges from 6 (“extremely light”) to 20 (“extremely hard”) (Appendix H) (6).

Task-Self Efficacy. A measure used to assess confidence in the participant’s abilities to complete 3 different durations of exercise at 3 different intensities. Participants were asked to report their rate of confidence to complete 10, 30 and 60 minutes of light, moderate and vigorous exercise using a 10-point scale (1, not at all confident to 10, extremely confident) (Appendix I).

Intentions. To assess participants’ intentions to add exercise to their weekly schedule they were asked how often they intended to perform exercise per week, as well as the strength of their intentions on a 10-point scale (1 not confident at all and 10 extremely confident) (Appendix J).

Preference. Participants were also asked to report their preference for either END or HIT (Appendix K).

Physical Activity Enjoyment Scale (PACES). This survey reports a participant’s perceived enjoyment. Each item is rated on a 7-point bipolar scale with 4 representing a neutral point in terms of how much the respondent enjoyed the exercise (25)(Appendix L).

Satisfaction of Outcomes. Participant satisfaction with a variety of outcomes was assessed using a 9-point scale ranging from -4 (“very unsatisfied”) to 4 (“very satisfied”) with zero being neutral (Appendix M).
Statistical Analysis

All results are expressed as mean ± standard deviation and the level of significance was established as \( p < 0.05 \). A two-factor (group x time) ANOVA with repeated measures on the second factor was used. When significant, interaction effects were further examined using a Bonferroni post hoc test. Initial power calculations revealed that to demonstrate statistical significance between the three groups, approximately 100 people would be required to detect differences across the intervention and follow-up period for \( \text{VO}_2\text{peak} \). Therefore, given that the final number of participants that were recruited and completed the study was 68, we were underpowered (power = 0.6) and failed to detect a significant interaction effect for \( \text{VO}_2\text{peak} \) and several other outcomes. In light of our lack of statistical power, for the purposes of this thesis, we have continued with Bonferroni post hoc testing where significant main effects of either time or group were present. The repetitive data acquired through the training sessions was analyzed by a paired t-test, as well the magnitude of the training response for \( \text{VO}_2\text{peak} \) was determined by a one-way ANOVA. Data analysis was completed with GraphPad Prism v 5.01 (GraphPad Software, Inc., La Jolla, CA). Statistical significance was accepted at \( p < 0.05 \) unless otherwise noted.
Results

Implementation of exercise intervention

A description of the study, dropouts and final numbers are depicted in Figure 5. No significant change was observed for body weight in any group (Table 1). The attendance of participants’ completion of the training sessions was 99.3%, with a total of 88% completing the entire study. The mean training HR elicited by END was the same in week one and four (168±6, 169±6 respectively), representing an average training HR of ~86.5% HRpeak. There were significant (p<0.05) increases across the training intervention for the HIT group as determined by a paired t-test, with the total repetitions performed per training session increasing from week 1 to week 4 for burpee push-ups (week 1, 39±8; week 4, 43±9), mountain climber push-ups (week 1, 40±8; week 4, 46±8), jumping jacks (week 1, 209±24; week 4, 241±23), and squat and thrusts (week 1, 110±21; week 4, 134±26). The in-training group responses for acute affect and rate of perceived exertion from week 1 are presented in Figure 6A and 6B respectively. Acute affect scores at the end of exercise (i.e. At 30 minutes for END and at the end of interval 8 for HIT) were significantly lower (p<0.05), in the HIT group in week 1 compared to END on day 1 (END 2.3±1.9; HIT -0.5±3.0), day 2 (END 2.4±1.7; HIT -0.1±3.2) and day 4 (END 2.6±1.5; HIT 1.3±3.1), with no significant difference observed on day 3, as determined by a 2 way repeated measures ANOVA with a main effect for group where a Bonferroni post hoc analysis identified the significant differences at the middle and end of the training session. End exercise RPE was significantly higher in HIT than END on all training days of week 1 (day 1, END 12±2; HIT 17±2; day 2, END 13±2; HIT 17±2; day 3, END 13±2; HIT 15±2, day 4, END 13±2; HIT 17±2), as shown by a 2 way repeated measures ANOVA with
a main effect for group where a Bonferroni post hoc analysis identified the significant differences.

Psychological Predictors of Exercise Behavior

Following a 2-way repeated measures ANOVA, a significant effect of group was observed such that perceived enjoyment of exercise was higher (p<0.05) in END and HIT compared to control at POST and Follow-up (Figure 7). A 2-way repeated measures ANOVA was used to analyze all three questions regarding the satisfaction of outcomes with a significant effect of group being observed at POST and Follow-up satisfaction in “change in weight” (Figure 8A), “change in attractiveness” (Figure 8B) and “how clothes fit” (Figure 8C) were all higher (p<0.05) in the END group than the HIT group. During week 4 of the training intervention, and at Follow-up, no differences were observed between END or HIT for confidence to complete 10 or 30 minutes of either light, moderate or vigorous activity or 60 minutes of light or moderate activity (data not shown). However, a significant (p<0.05) main effect of group was observed for confidence to complete 60 minutes of vigorous activity, such that confidence was higher throughout week 4 for END compared to HIT (Figure 9). A significant (p<0.05) main effect of group for intentions to complete exercise (How many times to you intend to exercise per week) was such that intentions were higher for END than HIT throughout week 4 (Figure 10). Following participants final training session 9/28 subjects in END indicated that if given the choice they would prefer to engage in HIT training while 19/28 subjects in HIT expressed a preference for HIT. 12/28 END and 20/28 HIT subjects indicated if the Canadian Health Guidelines stated they could achieve the same health benefits in END and HIT training and would have to engage in HIT more often they would prefer to participant in HIT.
Physiological Indicators of Exercise Adherence

No statistically significant differences in VO$_2$peak were present at PRE. A 2-way repeated measure ANOVA did not reveal a group x time interaction for VO2peak across the study. Despite this lack of significance, Bonferroni post hoc analysis indentified that following training, relative VO$_2$peak increased significantly (p<0.05) in both END and HIT groups (Figure 11A). Although the magnitude of the training response for VO2peak following END (+8.6%) was more than double that observed following HIT (+3.7%) these differences failed to reach significance (p=0.17; Figure 11B) as determined by a one-way ANOVA. At follow-up VO2peak was decreased from POST in both exercise groups but remained elevated (p<0.05) relative to PRE for the END group only (Figure 11A). The decrease in VO2peak from POST to Follow-up was not significantly different between groups (END, -3%; HIT -4%; Figure 11B). No changes were observed within the control group for VO2peak at any time point.

No changes were observed within the control group between any time points for any of the measures of exercise performance examined. A significant interaction effect was observed for the 5 km time to completion test with post hoc analysis revealing that both END and HIT significantly (p>0.05) improved the time required to complete 5km at both POST and follow-up (Figure 12A). A significant interaction was also observed for the maximum number of push-ups with post hoc analysis indicating that push-up performance increased (p<0.05) at POST in HIT (+36%), with this improvement being maintained at Follow-up (Figure 12B). While there was a non-significant increase in the number of push-ups POST following END (+21%; p=0.06) this increase was significant (+33%; p<0.05) at Follow-up (Figure 12B). Despite a non-significant interaction effect post hoc analysis revealed that core endurance was improved (p<0.05) at POST following HIT (Sit up test, +21%, Figure 12C; right side plank test, +29%; left side plank test,
+18%) with these improvements being lost at Follow-up. No change in core endurance was observed in the END group. HIT had no effect on the Biering-Sorensen test of back endurance, while END resulted in a significant (p<0.05) improvement at POST (+27%) that was maintained at Follow-up. No change was observed at any time point for grip strength. Interestingly, despite the changes in core endurance outlined above, no change was observed in the FMS for any group at any time (Figure 13).

Significant interaction effects were observed for total physical activity and both moderate and hard physical activity. Post hoc analysis revealed that total physical activity (PA) increased (p<0.05) in the control group at POST and Follow-up (~190%), while END (~95%) and HIT (~70%) reported increases at follow up only (Figure 14A). While the control group reported increases in both moderate (Follow-up only; Figure 14B) and hard PA, increases in total PA were due primarily to increases in hard PA in the END and HIT groups (Figure 14C).
Figure 5. Flow chart for participants through all aspects of the study.
Table 1. Subject Characteristics.

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Values are mean ± SD. yrs, years; cm, centimeters; kg, kilogram; BMI, body mass index; m, metres; Rel, relative.

Figure 6. Acute affect and rate of perceived exertion for END and HIT protocols.

Group responses for acute affect (A) and rate of perceived exertion (B) for the first training session of week 1 for both the END and HIIT groups.

* Significant (p<0.05) difference between groups.
Figure 7. Post Time-to-completion reports of exercise enjoyment for Control, END and HIT. Reported enjoyment scored according to the physical activity enjoyment scale following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up). * Significant (p<0.05) difference from Control
Figure 8. Self-reported satisfaction of outcomes for END and HIT. Reported satisfaction in changes in weight (A), attractiveness (B), clothes fit (C) accessed following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up).

* Significant (p<0.05) difference between groups.
**Figure 9. Task self-efficacy for END and HIT.** Confidence to complete 60 minutes of vigorous-intensity exercise evaluated following training on day 1, 2, 3, and 4 of training week 4 and 2 months following the completion of training (Follow-up).
*Significant (p<0.05) difference between groups across week 4.

**Figure 10. Exercise intention for END and HIT.** Intentions to exercise evaluated following training on day 1, 2, 3, and 4 of training week 4 and 2 months following the completion of training (Follow-up).
*Significant (p<0.05) difference between groups across week 4.
Figure 11. Changes in aerobic fitness across the intervention for Control, END and HIT. VO$_2$peak at baseline (Pre), following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up) for Control, END, and HIT. Group VO$_2$peak response (A), change in VO$_2$peak from baseline (B), and in individual changes in VO$_2$peak from baseline to post-training for all participants (C-E) are shown.

* Significant (p<0.05) difference from Pre.
† Significant (p<0.05) difference from Post.
Figure 12. Changes in submaximal exercise performance, push-ups and sit-ups for Control, END and HIT. For all groups the performance of the Time-to-Completion (5 km) test (A), maximal number of successful push-ups completed (B), and the time a sit up position could be maintained (C) are shown for baseline (Pre), following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up).

* Significant (p<0.05) difference from Pre.
Figure 13. Effect of Control, END and HIT on functional movement. Functional movement screening scores calculated before training (Pre), following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up) are shown for Control, END, and HIT.
Figure 14. Changes in self-report 7-day physical activity recall for Control, END and HIT. Total physical activity (A), moderate physical activity (B), and hard physical activity (C) self-reported at baseline (Pre), following 4 weeks of training (Post) and 2 months following the completion of training (Follow-up) are shown for Control, END, and HIT.

* Significant (p<0.05) difference from Pre.
Table 2. Summary of Key Findings

<table>
<thead>
<tr>
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<tr>
<td>Exercise Affect</td>
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<td>RPE</td>
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<td></td>
<td>Moderate</td>
<td>Very Hard</td>
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<td>Exercise Intentions</td>
<td>Confidence to Perform</td>
<td>Higher following END</td>
</tr>
<tr>
<td>Post Training</td>
<td>Vigorous Exercise</td>
<td>than HIT</td>
</tr>
<tr>
<td></td>
<td>Satisfaction with Outcomes</td>
<td>Positive</td>
</tr>
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<td></td>
<td>Exercise Enjoyment</td>
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<tr>
<td></td>
<td>Exercise Intentions</td>
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<td>Higher following END</td>
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<td>5km Time Trial</td>
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<td></td>
<td>Physical Activity Recall</td>
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Discussion

The present study examined the impact of extremely low dose HIT and traditional END on within exercise affect, post-training exercise intentions and markers of exercise adherence 2-months following a 4-week intervention. These relationships were examined in a population of young, previously inactive, adults. The major findings of this study were: 1) aerobic capacity (VO$_{2peak}$) was significantly improved in both groups at POST with only END demonstrating maintained benefits at follow-up, 2) while submaximal exercise performance was improved in both exercise groups at POST and at follow-up, only HIT demonstrated improved muscular endurance and core strength at POST. Similar to the VO$_{2peak}$ response, the core strength improvements were lost at follow-up. Combined, the VO$_{2peak}$ and exercise performance results suggest that exercise adherence was lower in the HIT group in the 2 months following the training intervention, 3) acute affect during training sessions in week 1 was significantly lower for HIT than END, and 4) while exercise enjoyment was improved relative to Control in both exercise groups at POST, participants in the END group reported higher levels of satisfaction of outcomes, confidence to perform 60 minutes of vigorous intensity exercise and intentions to perform exercise than the HIT group. These results suggest that inactive but otherwise healthy university aged students will not adhere to this extremely low dose HIT protocol to a greater extent than END. Thus, it would appear that attempts to push this “highly time efficient” protocol on the general public as a means of increasing physical activity may at best be ineffective and could prove counterproductive.
Aerobic capacity, exercise performance and adherence following END and HIT

This study represents one of the first attempts to compare the factors that may influence exercise adherence following a structured exercise intervention consisting of either END or HIT in a young inactive population. HIT is becoming increasingly promoted as a time efficient means of improving aerobic and performance capacity in both scientific (21, 23) and popular press (2, 28, 40). HIT therefore, appears to be an effective alternative mode of exercise directly addressing the commonly stated ‘time’ barrier to regular participation in physical activity. However, despite the pushing of this “more with less” message, there is little to no empirical evidence supporting the efficacy of HIT for improving exercise adherence in inactive populations.

We have previously demonstrated that in recreationally active young adults both HIT and END significantly improved aerobic capacity (31). Similarly, we have shown that VO₂peak and exercise performance are significantly improved following a HIT intervention utilizing cycling exercise in previously inactive individuals (7). In addition to these improved aerobic measures, muscular endurance and core strength are also improved in recreationally active individuals following whole body HIT (31). Consistent with these results, the current study has demonstrated similar improvements in VO₂peak and exercise performance (HIT and END), but a superior effect of HIT on abdominal core strength in previously inactive young adults. Importantly, the improvements in VO₂peak and core strength were completely lost at follow-up in the HIT group. Conversely, improvements in VO₂peak and exercise performance (5 km time to completion test) observed in the END group were partially and completely maintained respectively. It is important to note that improvements observed for the 5km time trial and push-ups performance were also maintained in the HIT group. While HIT reported an increase in
“Hard” physical activity which may have contributed to the sustained 5 km time trial and push-up performance, it appears unlikely that the HIT group adhered to the HIT protocol as performed during the exercise intervention. While the END group also reported increases in “Hard” physical activity, the maintenance of VO$_2$peak in this group suggests that they adhered more closely to the activity performed during the intervention period. It is possible that differences in physical activities between groups across the follow-up period were missed as our PAR only covered the week prior to follow-up testing. Thus, our results appear to indicate that despite the time-efficiency of the HIT protocol, the HIT group appears to have adhered to their interventions physical activity to a lesser degree than the END group.

*The psychological factors measured as they relate to exercise adherence*

The Theory of Planned Behavior (TPB) indicates that the most proximal determinant of behavior is intention (1), which accounts for approximately 50% of actual behavior (3, 4), and has been suggested to be one of the best predictors of future exercise adherence (1). Intentions are determined by three main factors: 1) attitude reflecting positive or negative evaluation of engagement in the targeted behavior, 2) subjective norms which reflects a sense of social pressure to perform the behavior, and 3) perceived behavioral control which reflects the degree of control one perceives they have over the behavior. In turn, each of these three factors are influenced by behavioral beliefs (expectations of the outcomes associated with engaging in the behavior and associated value of those expected outcomes), normative beliefs (perceived expectations of others to perform the targeted behavior and motivation to comply with other’s expectations), and control beliefs (perceptions of factors that may facilitate or inhibit performance of the behavior and the strength of each of these factors); respectively (1, 13). In an attempt to examine the impact of END and HIT on intentions and exercise behavior, we have
measured several factors that are believed to contribute to both behavioral beliefs (Satisfaction of outcomes, exercise affect and exercise enjoyment) and control beliefs (training time and task [exercise] self-efficacy). In addition, we also directly asked participants about their intentions to engage in exercise in the future. The Duel Mode Model (DMM) theorizes that as exercise intensity increases, reported affect will decrease (14, 15), which in the context of TPB would negatively impact attitude, decreasing exercise intentions and consequently negatively impacting future behaviors (1). Consistent with this logic, the negative affect observed while participants were engaged in HIT was associated with both reduced post training exercise intentions and the apparent reduction in exercise adherence discussed above. These results are in agreement with previous research demonstrating a relationship between exercise intensity and negative affect (14-16), and a report that the affective response to exercise can predict adherence to that exercise behavior up to 12 months afterward (39).

Within the context of TPB the construct of attitude also accounts for enjoyment (1), which in the present study is significantly lower at follow up in HIT compared to END. Interestingly, immediately following the four week intervention END and HIT expressed equally high levels of enjoyment, which contradicts a previous report demonstrating higher enjoyment of interval, compared to endurance exercise (5). The high level of enjoyment observed previously was speculated to increase an individual’s likelihood to adhere to HIT. Our results question this assumption, and highlight the need to perform further studies where changes in exercise behavior are actually measure and not just assumed. This is especially important based on the apparent dissociation of exercise adherence and the equally high levels of exercise enjoyment reported post training.
The HIT group also expressed lower rated outcome satisfactions (weight, appearance and fit of clothes) compared to END. Outcome satisfaction is considered a component of behavioral beliefs, and the lower satisfaction reported in the HIT group may also have contributed to the lower intentions reported post training and therefore the apparent failure to adhere to regular exercise. The behavioral beliefs targeted were primarily concerned with self-image and weight. These elements were all rated lower in HIT, implying that these individuals were unsatisfied with the physical results of the intervention thus contributing a negative influence on intentions. In summary, the factors proposed to contribute to behavioral belief (satisfaction of outcomes, exercise affect and exercise enjoyment) tended to be lower following HIT than END, findings that are consistent with reduced exercise intentions and exercise adherence.

Control beliefs are also proposed to contribute to the formation of exercise intentions. Exercise task self-efficacy (confidence in one’s ability to complete an exercise task) is an influential factor in perceived behavioral control (PBC) within the TPB, making exercise self-efficacy a potentially important indirect (through intentions) and direct mediator of exercise behavior. HIT expressed lower self-efficacy than END and, as predicted by TPB, also reported lower intentions to exercise. Time also impacts control beliefs through its actions as a perceived barrier (1, 13), and is the most often stated barrier to regular participation in physical activity (20, 35, 37). Time therefore, acts as a PBC, which should therefore indirectly (through intentions) and directly influence future exercise behavior. The significant reduction in time required to complete the HIT protocol utilized (4 minutes per day) would have been predicted to have a positive influence on future exercise behavior, however, our data do not support this hypothesis. Rather, the lower exercise intentions reported and the apparent lack of adherence in the HIT group suggest that time does not in fact act as the primary barrier to exercise adherence.
When all of these components are examined together within the context of DMM and TPB, it would appear that the predominantly negative results (exercise affect, satisfaction of outcomes, exercise intentions and exercise enjoyment at follow-up) associated with HIT, and the failure of the HIT group to preserve many of the training adaptations at follow-up, do not position whole body HIT as an model of exercise that is more likely that traditional END to be adhered to by the general population.

Conclusion

The need for effective exercise interventions that will be adopted and adhered to by the general population is of critical importance. This study is one of the first attempts to measure actual adherence rates to an exercise intervention amongst a young inactive population. While HIT is an effective means of improving aerobic and performance capacity, muscular endurance, core strength, and addresses the ‘time’ barrier, the affect associated with the intensity, which is necessary to achieve the health benefits, negatively impacts intentions, further reducing exercise behavior and therefore adherence. Further research investigating the complex and dynamic factors associated with exercise adherence are required to gain a comprehensive understanding into exercise adherence within the general population in order to develop effective interventions.
References


Chapter 4

General Discussion

4.1 Summary of Key Findings

Our results indicate that END and HIT induce equivalent improvements in aerobic capacity and exercise performance, with HIT alone providing additional improvements in muscular endurance and core strength. While HIT is a time efficient alternative to END, HIT was not adhered to in the follow-up period as indicated by the complete loss in the training induced increases in aerobic capacity and core strength. DMM would suggest this lack of adherence is due to the negative affect reported during the HIT training sessions, evoking an instinctive avoidance of the exercise when left to individual volition. Consistent with this idea HIT reported lower intentions to engage in physical activity in the future, as well as lower task self-efficacy. All of these individual components combined resulted in a lack of adherence to HIT. Therefore, our results are consistent with the predictions of the behavioral theories DMM and TPB and suggest that exercise adherence is likely to be lower in a previously inactive population introduced to HIT compared to END.

4.2 Study Strengths

To our knowledge this study represents one of the first attempts to compare the various factors that influence exercise adherence following a structured exercise intervention consisting of either END or HIT in a young inactive population. This is important as this study design offers a more integrative approach to the research problem incorporating physiological components, biomechanical aspects, as well as psychological measures. This approach offers a
comprehensive understanding of future exercise behaviors directly comparing HIT to traditional END. Furthermore, having conducted this study in an inactive university aged demographic strengthens the application of these findings as this population represents a distinct transition period where physical activity levels experience dramatic declines (1) making interventions designed to inhibit progression of inactive behavior especially relevant for this demographic.

This was a randomized control study, considered to be the gold standard in study design as it eliminates researcher bias and minimizes the probability of chance results. Additionally, the recruitment process and selection of appropriate candidates were rigorous. We felt it of great importance to ensure the sample population was in fact inactive, and as such the primary researcher personally interviewed each candidate, with both subjective (self-report physical activity recall) and objective measures (VO2peak) being utilized to ensure the participants studied were inactive prior to enrollment. Finally, we believe the time line of this study was well designed and effectively tested the primary hypothesis, as well; the range of measures that were rigorously collected throughout the course of this study provided a comprehensive overview of the complexities of this project.

4.3 Study Limitations

For the nature of this study our sample size was a limiting factor, as was expressed through our lack of power in determining between group differences for the change in VO2peak. A larger sample size may have allowed us to demonstrate differences in the training amplitude between groups. In addition, while the recruitment and selection process for appropriate participants was rigorous, it was heavily dependent upon self-reported measures as were the psychological components of this study. Self-report measures of are known for their subjectivity
and potential inaccuracy, specifically those referring to physical activity (2), where individuals tend to overestimate their participation. While measures were taken to normalize each session, outside influences, outside of the researchers control, may have impacted those psychological measures. We are also limited in our ability to comment on long-term changes in exercise adherence due to the relative brevity of the follow-up period used in the current study design (2 months). To determine the true effects of adherence a longer study design is warranted to ensure the results seen in the current study do in fact extend beyond the 2-month time point. We were also not able to take any invasive measures, such as lactate, blood, or biopsies to determine the specific mechanisms underlying the adaptations observed following HIT and END, which could have acted to provide additional physiological evidence and potential mechanisms associated with adherence. Finally, the HIT protocol chosen was done so because of it’s proven ability to improve aerobic and performance capacity (3), as well as improve endurance and strength. However, due to the nature of the whole-body exercises implemented it is impossible to determine the actual intensity of work that each participant completed.

Several practical issues also limited this study. We did try to consistently measure heart rate in the HIT group, but we experienced several technique issues regarding the hardware and software program making the data inconsistent and incomplete. There are also currently no available surveys to our knowledge that are designed to be utilized with a HIT protocol, limiting the relevant and valid tools at our disposal. In addition we were limited in our resources and could not hire research assistances to support this thesis, which may have restricted the ability of the study to achieve it’s full potential.
4.4 Future Research

There are still several questions that remain to be answered. Exercise behavior is inherently complex with multiple variables, all of which interact to varying degrees, being integrated to produce a final outcome. While the evidence is compellingly in favor of increasing physical activity levels, the majority of individuals do not perform physical activity on a regular basis. The various factors not only need to be studied in isolation to gain a better understanding of their independent effects, but more importantly and of clinical relevance, is what impacts these factors and how to integrate and manipulate our decision making process regarding physical activity. Ultimately, randomized control trails involving various exercise intervention strategies, targeting young inactive but otherwise healthy adults should be pursued to gain valuable insight into this demographic, potentially uncovering an effective alternative that will be adhered to. It is of great social significance to gain an in depth understanding of this particular decision making process in order to relieve our burdened health care system of the associated health costs attributed with an inactive lifestyle.

4.5 Implications for Exercise Prescription

While the scientific community continues to experiment with HIT and disseminate this knowledge to the public, adherence to the protocol is of primary importance, yet rarely objectively measured. This study indicates that while HIT induces similar aerobic and performance benefits compared to END, the high-intensities necessary to attain the associated health benefits may prevent long-term (or even short-term) adherence. Therefore, while HIT addresses the often-stated time barrier, it appears not to be an effective exercise behavioral strategy in inactive university aged adults. It is therefore the opinion of this researcher that HIT
not be prescribed to the general public as it is unlikely to be adhered to long-term due to the high intensity required to attain and maintain the necessary health benefits. Further, it may in fact be more detrimental to long term positive health care outcomes to continue to encourage an inactive population to engage in HIT, given this initial evidence that suggests a lack of adherence, instead of a protocol more likely to be adhered to once initiated.

4.6 MS.c Research Experience

Over the course of my experience in the Gurd Lab (more affectionately known as ‘Club Gurd’) I have learned a multitude of valuable life skills that I will continue to carry with me in my future career. Specifically, within the exercise lab I became skilled in using, calibrating, troubleshooting, and repairing the metabolic carts, while also gaining a great deal of knowledge regarding the testing itself. Academically, I have spent hours reviewing the literature, attempting to synthesize my thoughts, while improving my ability to read, write, and think critically. I also had the privilege of directly collaborating with the Biomechanics lab, which gave me a deeper appreciation for the research they conduct and its practical implications. With a study of this magnitude I learned effective time management techniques, as well as how to successfully communicate with, and supervise numerous participants and research assistants. My experience working with my lab has been invaluable to me from not only an academic standpoint, where I have learned a true appreciation for the acquisition of knowledge, but also from a personal one in which I have gained life long friends and colleagues.
4.7 Conclusions

High intensity interval training, while a time-efficient exercise strategy, produces negative affect within the participant, consequently reducing their intentions to engage in future participation in HIT, which ultimately leads to a lack of adherence and loss of adaptation.
4.8 References


Appendix A

Research Ethics Board – Informed Consent

School of Kinesiology and Health Studies
Physical Education Centre
Kingston, Ontario, Canada, K7L 3N6

Consent to Volunteer for Participation in a Study

TITLE: Effect of exercise training at a variety of intensities on mitochondrial function in young lean and obese adults.

PRINCIPAL INVESTIGATOR: Brendon J. Gurd, PhD
Queen’s University
School of Kinesiology and Health Studies
Kingston, Ontario, K7L 3N6
613-533-6000 ext. 79023
You are being invited to participate in a study examining the influence of different exercise protocols that vary in intensity (difficulty), duration (length) and mode (type) on mitochondrial function (the ability of your muscle to produce energy) and exercise capacity. This study will also compare the effects of these different exercise protocols in young adults who are either lean or overweight. You have been invited to participate in this study because you are a young adult (18-40 years) who is either lean (waist circumference <86 cm) or overweight (waist circumference >94 cm). 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**

Exercise capacity (Fitness) is an important predictor of long term health. More specifically, the ability of your muscle’s mitochondria to produce energy (mitochondrial function) is impaired with obesity and is a predictor of both further weight gain and development of type II diabetes. Further, fat cells also contain mitochondria, and decreased mitochondria in fat is also associated with weight gain and the development of disease. In healthy active populations interval training (repeated bouts of exercise separated by periods of recovery) is a potent, time effective stimuli for increasing mitochondrial function and exercise capacity. In addition, recreational activity is recommended as part of a healthy lifestyle, however its effects on mitochondrial function and exercise capacity are unknown. This study will examine the ability of different exercise training protocols and modes (cycling, running, whole body exercise or recreational games [i.e. sport]) to...
improve mitochondrial function and exercise capacity. We will also ask you a series of questions designed to increase our understanding of what type of exercise you would prefer and/or are likely to perform during your normal daily routine. You will not be able to participate in the study if you have been diagnosed previously with any respiratory, cardiovascular (e.g. High blood pressure, heart conditions), metabolic (e.g. Diabetes), neurological or musculoskeletal disease; or you are currently on medication; or you are a smoker; or you respond to the exercise protocol in an irregular manner (i.e. chest pains, dizziness, shortness of breath, excessive awareness of breathing)

EXPLANATION OF PROCEDURES

Participation

Participation in the study is voluntary. You may refuse to participate or withdraw from the study at any time with no effect on your academic or employment status. Should you chose to participate you will take part in experimental procedures outlines below. These include exercise tests, physiological tests, and one of a selection of exercise training protocols. The investigator will explain to you, in detail how each of these procedures will be conducted in the study in which you have agreed to participate.

Exercise tests:
During each of the exercise tests you will be required to wear a nose-clip (to prevent you from breathing through your nose) and a rubber mouthpiece (similar to breathing through a snorkel or diving mask). This will enable us to measure the volume of air that you breathe in and out, and measure the gas concentration in that air. You may experience some initial discomfort from wearing the nose-clip and mouthpiece. You will also be required to wear a heart rate monitor around your
chest during all tests. You will be asked to perform each of these tests on one occasion before and once occasion following exercise training.

**Incremental exercise test:** This test is performed on either a cycle ergometer (a stationary bike) or a treadmill and is designed to measure your fitness level. During this test the intensity of exercise increases gradually until you are physically unable to continue exercising because the intensity is either too high or too uncomfortable. The test will begin with the exercise intensity being very light and easy (very little resistance). After a few minutes the exercise intensity will gradually and continuously increase until you are unable to continue because of fatigue, or until you wish to stop.

**Low-intensity exercise test:** This test is performed on a cycle ergometer (a stationary bike) or a treadmill, and is designed to measure heart rate and your ability to burn fat during exercise. This test will last for approximately 1 hour and will involve riding or jogging at a low-intensity (slow bike ride or light jog).

**Exercise test of maximal power:** This test is performed on either a cycle ergometer (stationary bike) or a treadmill and is designed to measure your ability to generate high levels of power during exercise. This test will involve either all out cycling or sprinting and will take between 30 and 60 seconds.

**Functional Movement Screen:** This test is designed to test your ability to perform a series of movements (squats, hurdle steps, lunges, shoulder rotations, single leg raises, push-ups and trunk rotations). During each of these movements your stability and mobility will be assessed. This test will take approximately 30 minutes to complete.
Psychological Questionnaires:

On the first visit prior to the VO$_2$peak test, you will be required to fill out a series of questionnaires designed to determine the amount of physical activity you regularly perform and to predict whether or not you will enjoy high intensity exercise. It is expected that these questionnaires will take less than 30 minutes to complete.

In addition, during training sessions of this study you will be asked a series of questions designed to evaluate how you are feeling towards the exercise you are performing.

Finally, following the exercise protocol you will be asked to fill out a series of questionnaires designed to determine how much you enjoyed the exercise and how likely you are to part-take in exercise in the future. These final questionnaires should also take less than 30 minutes to complete.

All results from these questionnaires will be keep private and will be recorded in an anonymous fashion (i.e. by subject number rather that by name).

Physiological tests:

**Blood sample:** Both before and following training you will be asked to have a small sample of blood taken by a registered nurse. You may experience some minor discomfort when this small blood sample is drawn from a vein in your arm. The blood sampling may be painful and minor bruising is possible following venous blood sampling but generally fades within a few days.

**Fat Biopsy:** Before and after training you will be asked to have a small piece of fat tissue removed from your abdomen (directly beside your belly button).
This procedure is referred to as a biopsy. The fat biopsies will be taken by a medical doctor or by an individual trained in the technique under the supervision of a medical doctor. During the biopsy procedure an area of skin on your abdomen will be cleaned with antiseptic (to reduce changes of infections) and frozen with local anaesthetic (similar to freezing experienced during dental procedures) to minimize pain. A small incision will be made in your skin (less than 1 cm) and a needle with then be inserted into your fat layer and a small piece of tissue will be removed. During fat biopsies you may feel slight pressure and/or discomfort in your fat layer but this discomfort will pass very quickly.

Following your biopsies there may be light bruising in the area where the biopsies were taken but this will generally fade within a couple of days. There is also a slight risk of infection following a biopsy but proper sterilization of equipment and cleaning of the sampled area minimizes this risk. If the site of the muscle biopsy becomes more tender and redness and/or swelling develops in the area over the next five to seven days, or if you have any concerns whatsoever you should contact the research person supervising your study immediately and seek medical attention as needed.

**Muscle Biopsy:** Before and after training you will also be asked to have small amounts of muscle removed from your thigh muscle (quadriceps muscle) by means of a needle biopsy. The muscle biopsies will be taken by a medical doctor or by an individual trained in the technique under the supervision of a medical doctor. While you are resting on a bed, an anesthetic will be applied locally to anesthetize the skin over your thigh muscle at the sites where the biopsies will be taken. A small incision (less than 1 cm each) will be made through your skin and into your muscle at points approximately
midway between your hip and knee. Small samples of muscle will be taken from each incision. This procedure is referred to as a biopsy.

There may be some discomfort associated with the biopsy procedure (like someone pressing hard into your muscle) but you should experience no pain. Following the exercise there may be light bruising of the leg muscle but this will generally fade within a couple of days. There is also a slight risk of infection following a biopsy but proper sterilization of equipment and cleaning of the sampled area minimizes this risk. If the site of the muscle biopsy becomes more tender and redness and/or swelling develops in that area over the next five to seven days you should seek medical attention immediately. You should also report this change to the research person supervising your study as soon as possible. Please refer to the Muscle Biopsy Information Sheet for more information regarding this procedure.

Exercise Training Protocols:

Any exercise carries a slight risk of heart attack or may be uncomfortable if you are unfit or not used to exercise. The risk of a cardiac event (heart attack, dysrhythmias etc.) in a mixed subject population (healthy low risk and unhealthy high risk patients together) is approximately 6:10 000, however this risk decreases in a previously healthy (i.e. young, moderately active) population. There may be some minor discomfort during the exercise testing. You may experience increased awareness of breathing, muscle pain and/or fatigue, increased sweating, or a general feeling of fatigue or nausea, all of which are not unexpected consequences of exercise. You are being asked to participate in one of the following exercise training programs. The investigator will explain to you exactly what is involved in
the specific protocol you are being assigned to. Please initial beside the box that is checked.

☐ **Low-intensity exercise training:** This protocol will involve riding a stationary bike for a period of up to 90 minutes at a low intensity similar to a leisurely bike ride. You will be asked to perform this protocol 3 times a week for a period of 6 weeks.

☐ **Moderate-intensity exercise training:** This protocol involves riding a bike or running on a treadmill at a moderate-intensity, for 30 minutes at a given target heart rate. You will be asked to perform this protocol 4 times a week for a period of 4 weeks.

☐ **High-intensity exercise training:** This protocol involves riding a bike at a high-intensity, like an all out sprint, for 1 minutes at a time (called an interval) followed by 2 minutes of rest. This interval will be repeated up to 12 times. Alternatively you may be asked to perform a high-intensity exercise training protocol that involved whole body exercise (burpees, push-ups, squats, jumping jacks) for a maximum of 8 minutes at a time (20 second intervals separated by 10 seconds of rest). You will be asked to perform one of these protocols 3 times a week for a period of 6 weeks.

☐ **Recreational activity:** This training program will require that you report to a gym for an hour to take part in recreational games (basketball, floor hockey, handball, etc). You will be asked to participate in recreational activities 3 to 5 times per week for a period of 6 weeks.

**RISK OF INJURY**
All exercise also carries a small risk of personal injury. Should any such injury occur during your participation in this study you will be initially cared for by the study administrators, all of whom are certified in first aid. Should further assistance be required you will be taken to the university health centre/hospital or emergency as required.

**POTENTIAL BENEFITS OF PARTICIPATION**

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

**CONFIDENTIALITY**

During the course of your participation in this study you will not be required to provide any personal information beyond your name and phone number (for study purposes only). All information obtained during the course of this study, including your name and fitness results, 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. Brendon Gurd and those working within his laboratory. Your identity will not be revealed in any description or publication.

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.
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. I do understand that I am free to deny consent if I so desire, and may withdraw from the study at any time without any effect on my academic or employment status.

Should I have any questions about the study, I know that I can contact Dr. Brendon Gurd (613 533-6000, ext 79023), 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

VO₂Peak Protocol

To measure aerobic capacity a VO₂ maximum test is performed on a treadmill using a modified version of the Bruce Protocol. Heart rate and gas exchange data is collected throughout the entire test. Resting data is collected for 3 minutes prior to warm-up. The warm up is completed at an incline of 2 and speed of 2.5mph. The participant continues on to complete as many of the following stages as possible. The test is terminated when the participant reaches fatigue and can no longer continue at the set workload.

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<td>XI</td>
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Appendix C

Functional Movement Screening

Deep Squat

Purpose:
The squat is a movement needed in most athletic events. It is the ready position and is required for most power movements involving the lower extremities. The deep squat is a test that challenges total body mechanics when performed properly. The deep squat is used to assess bilateral, symmetrical, functional mobility of the hips, knees, and ankles. The dowel held overhead assesses bilateral, symmetrical mobility of the shoulders, as well as the thoracic spine.

Description:
The individual assumes the starting position by placing his/her feet approximately shoulder width apart with the feet aligned in the sagittal plane. The individual then adjusts their hands on the dowel to assume a 90-degree angle of the elbows with the dowel overhead. Next, the dowel is pressed overhead with the shoulders flexed and abducted, and the elbows extended. The individual is then instructed to descend slowly into a squat position. The squat position should be assumed with the heels on the floor, head and chest facing forward and the dowel maximally pressed overhead. The individual may repeat the movement up to three times. If the criteria for a score of III is not achieved, the athlete is then asked to perform the test with a 2 x 6 board under their heels.

Tips for testing:
• When in doubt, score it low.
• Try not to interpret the score while testing.
• Make sure if you have a question to view individual from the side.

Verbal Instructions:
"Hold the dowel with both hands over your head in order for both your shoulders and elbows to maintain a 90 degree angle. Now, press the dowel over your head and hold it there."

"Place your feet in a comfortable position, approximately shoulder width or slightly greater than shoulder width apart. Point your toes forward and keep them pointing forward."

"While maintaining an upright posture, the dowel over your head, and your heels on the floor, descend into a deep squat in order for your thighs to break parallel with the floor." (Score the subject)

"Return to the starting position." (Repeat 3 times if necessary)

Repeat the instructions as stated above using a 2 x 6 beneath the subject’s heels if necessary.
Deep Squat Testing Procedure

III
- Upper torso is parallel with tibia or toward vertical
- Femur below horizontal
- Knees are aligned over feet
- Dowel aligned over feet

II
- Upper torso is parallel with tibia or toward vertical
- Femur is below horizontal
- Knees are aligned over feet
- Dowel is aligned over feet

I
- Tibia and upper torso are not parallel
- Femur is not below horizontal
- Knees are not aligned over feet
- Lumbar flexion is noted

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
Hurdle Step

Purpose:
The hurdle step is designed to challenge the body's proper stride mechanics during a stepping motion. The movement requires proper coordination and stability between the hips and torso during the stepping motion, as well as single leg stance stability. The hurdle step assesses bilateral functional mobility and stability of the hips, knees and ankles.

Description:
The individual assumes the starting position by first placing the feet together and aligning the toes touching the base of the hurdle. The hurdle is then adjusted to the height of the athlete's tibial tuberosity. The dowel is positioned across the shoulders below the neck. The individual is then asked to step over the hurdle and touch their heel to the floor while maintaining the stance leg in an extended position. The moving leg is then returned to the starting position. The hurdle Step should be performed slowly and as many as 3 times bilaterally. If one repetition is completed bilaterally meeting the criteria below a score of III is given.

Tips for testing:
• Score the leg that is stepping over the hurdle.
• Make sure the individual maintains a stable torso.
• Make sure the toes keep in contact with the hurdle during and after each repetition.
• Tell individual not to lock knees during test.
• Maintain proper alignment with the string and the tibial tuberosity.
• When in doubt score low.
• Do not try to interpret the score when testing.

Verbal Instruction:
"Place the Dowel across your shoulders. Now, stand comfortably with your feet together and your toes against the base of the Hurdle."

"While maintaining an upright posture, step over the hurdle without touching the string."

"Touch the floor with your heel and return to the starting position."

Repeat instructions 2 and 3 for the left foot. (Score the subject)

Repeat 3 times per side if necessary.
Hurdle Step Testing Procedure

III
- Hips, knees and ankles remain aligned in the sagittal plane
- Minimal to no movement is noted in lumbar spine
- Dowel and hurdle remain parallel

II
- Alignment is lost between hips, knees and ankles
- Movement is noted in lumbar spine
- Dowel and hurdle do not remain parallel

I
- Contact between foot and hurdle
- Loss of balance is noted

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
In-Line Lunge

Purpose:
This test attempts to place the body in a position that will focus on the stresses simulated during rotational, decelerating and lateral type movements. The in-line lunge is a test that places the lower extremity in a scissored position, challenging the body’s trunk and extremities to resist rotation and maintain proper alignment. This test assesses hip and ankle mobility and stability, quadriceps flexibility and knee stability.

Description:
The tester attains the individual’s tibia length, by either measuring it from the floor to the tibia tuberosity or acquiring it from the height of the string during the hurdle step test. The individual is then asked to place the end of their heel on the end of the board. The previous tibia measurement is then applied from the end of the toes of the foot on the board and a mark is made. The dowel is placed behind the back, touching the head, thoracic spine and sacrum. The hand opposite to the front foot should be the hand grasping the dowel at the cervical spine. The other hand grasps the dowel at the lumbar spine. The individual then steps out on the board placing the heel of the opposite foot at the indicated mark on the board. The individual then lowers the back knee enough to touch the board behind the heel of the front foot and then returns to starting position. The lunge is performed up to three times bilaterally in a slow, controlled fashion. If one repetition is completed successfully, then a three is given.

Tips for testing:
• The front leg identifies the side being scored.
• Dowel remains in contact with head, thoracic spine and sacrum.
• The front heel remains in contact with the board and back heel touches board when returning to starting position.
• When in doubt score low.
• Watch for loss of balance.
• Remain close to individual in case he/she has a loss of balance.

Verbal Instruction:
"Hold the dowel with both hands and position it along your spine with your right hand against the back of your neck and your left hand against your low back."

"Step onto the 2 x 6 with your right foot along the back edge and place your left foot with the heel just past (length of the tibia) the black line (or mark). Point your toes forward and keep them pointing forward."

"While maintaining an upright posture, descend into a lunge, touching your right knee along the black line (or mark) behind your left heel. Maintain contact with the dowel against the head, thoracic spine and sacrum."

"Return to the starting position, making sure to place the right heel flat on the board."

Repeat instructions 1 through 4 with the left side. (Score the subject)
Repeat 3 times per side if necessary
In-Line Lunge Testing Procedure

III
- Dowel contacts remain with L-spine extension
- No torso movement is noted
- Dowel and feet remain in sagittal plane
- Knee touches board behind heel of front foot

II
- Dowel contacts do not remain with L-spine extension
- Movement is noted in torso
- Dowel and feet do not remain in sagittal plane
- Knee does not touch behind heel of front foot

I
- Loss of balance is noted

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
Shoulder Mobility

Purpose:
The shoulder mobility screen assesses bilateral shoulder range of motion, combining internal rotation with adduction and extension, and external rotation with abduction and flexion. It also requires normal scapular mobility and thoracic spine extension.

Description:
The tester first determines the hand length by measuring the distance from the distal wrist crease to the tip of the third digit. The individual begins standing with feet together, and remains in this position throughout the test. The individual is instructed to make a fist with each hand, placing the thumb inside the fist. They are then asked to assume a maximally adducted, extended and internally rotated position with one shoulder, and a maximally abducted, flexed and externally rotated position with the other. During the test the hands should remain in a fist and they should be placed on the back in one smooth motion. The tester then measures the distance between the two closest bony prominences. Perform the shoulder mobility test as many as 3 times bilaterally.

Clearing exam:
There is a clearing exam at the end of the shoulder mobility test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a positive is recorded and a score of zero is given to the entire shoulder mobility test. This clearing exam is necessary because shoulder impingement can sometimes go undetected by shoulder mobility testing alone.

Tips for testing:
• The flexed shoulder identifies the side being scored.
• If the hand measurement is exactly the same as the distance between the two points, then score low.
• The clearing test overrides the score on the rest of the test.
• Make sure individual does not try to “walk” the hands toward each other.

Verbal Instruction:
While in a comfortable standing position, instruct the subject to:

“Make a fist with the thumbs tucked in the fist.”

“In a single motion, place your right fist over your head on to your back and your left fist behind your back, attempting to touch the fists.”

“Do not move your hands closer after their initial placement.” (Measure the distance between the fists. The closest proximity for each)

Repeat instruction 2 with the opposite hand placement. (Score the subject)

Active Shoulder Stability Verbal Instruction:

“Place your right hand on your left shoulder.”

“While maintaining that hand placement, raise your right elbow toward your forehead.”

Ask the subject: “Do you feel any pain?”

Repeat instructions 1 through 3 with the left side. (Score the subject)
Shoulder Mobility Testing Procedure

III
• Fists are within one hand length

II
• Fists are within one and a half hand lengths

I
• Fists are not within one and half hand lengths

The individual places his/her hand on the opposite shoulder and then attempts to point the elbow upward. If there is pain associated with this movement, a score of zero is given. It is recommended that a thorough evaluation of the shoulder be done. This screen should be performed bilaterally. If the individual does receive a positive score, both scores should be documented for future reference.

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
Active Straight Leg Raise

Purpose:
The active straight leg raise tests the ability to disassociate the lower extremity while maintaining stability in the torso. The active straight leg raise test assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg.

Description:
The individual first assumes the starting position by lying supine with the arms in an anatomical position and head flat on the floor. The board is placed under the knees. The tester then identifies mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella, the dowel is then placed at this position perpendicular to the ground. Next, the individual is instructed to lift the test leg with a dorsiflexed ankle and an extended knee. During the test the opposite knee should remain in contact with the board, the toes should remain pointed upward, and the head remain flat on the floor. Once the end range position is achieved, and the malleolus is located past the dowel, then the score is recorded per the criteria. If the malleolus does not pass the dowel then the dowel, is aligned along the medial malleolus of the test leg, perpendicular to the floor and scored per the criteria. The active straight leg raise test should be performed as many as 3 times bilaterally.

Tips for testing:
• The flexed hip identifies the side being scored.
• Make sure leg on floor does not externally rotate at the hip.
• Both knees remain extended and the knee on the extended hip remains touching the board.
• If the dowel resides at exactly the mid-point, score low.

Verbal Instruction:
“Lay on your back with the back of your knees against the 2 x 6, arms at your side, palms facing up, and toes pointing up.”

“Lift the toes of your right foot toward your shin. With your legs remaining straight and toes pointing toward the ceiling/sky, raise your right leg as high as possible, without any movement occurring in left leg.” (Measure lift in relation to opposite leg)

Repeat instruction 2 with the left side. (Score the subject)
Active Straight Leg Raise Testing Procedure

III
- Ankle/Dowel resides between mid-thigh and ASIS

II
- Ankle/Dowel resides between mid-thigh and mid-patella/joint line

I
- Ankle/Dowel resides below mid-patella/joint line
Trunk Stability Push-Up

Purpose:
The trunk stability push-up tests the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. It assesses trunk stability in the sagittal plane while a symmetrical upper-extremity motion is performed.

Description:
The individual assumes a prone position with the feet together. The hands are then placed shoulder width apart at the appropriate position per the criteria. The knees are then fully extended and the ankles are dorsiflexed. The individual is asked to perform one push-up in this position. The body should be lifted as a unit. There should be no lag in the lumbar spine when performing this push-up. If the individual cannot perform a push-up in this position, the hands are lowered to the appropriate position per the criteria.

Clearing exam:
A clearing exam is performed at the end of the trunk stability push-up test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a positive is recorded and a score of four is given to the entire push-up test. This clearing exam is necessary because back pain can sometimes go undetected by movement screening.

Tips for testing:
• Tell them to lift the body as a unit.
• Make sure original hand position is maintained and the hands do not slide down when they prepare to lift.
• Make sure their chest and stomach come off the floor at the same instance.
• When in doubt, score it low.
• The clearing test overrides the test score.

Verbal Instruction:
“Lay on your stomach with your hands positioned shoulder width apart (appropriate hand placement).”
• Males: Thumbs in line with the forehead
• Females: Thumbs in line with the chin.

“Raise your toes toward your shin and place them on the ground. Extend your knees off of the ground.”

“Maintain a rigid torso, raise yourself as one unit with no lag in the low back into a push-up position.”
Repeat 3 times if necessary.
Repeat instructions 1 through 3 with appropriate hand placement if necessary. (Score the subject)

Prone Press-up Verbal Instruction:
While lying on their stomach, instruct the subject to:

“Place both hands (palms down) beneath your shoulders.”
“Press your chest off of the floor by extending your elbows, arching your back as much as possible, keeping your hips in contact with the floor.”

Ask the subject: “Do you feel any pain?” (Score the subject)
Trunk Stability Push-Up Testing Procedure

III
- Males perform 1 repetition with thumbs aligned with the top of the forehead
- Females perform 1 repetition with thumbs aligned with chin

II
- Males perform 1 repetition with thumbs aligned with chin
- Females perform 1 repetition with thumbs aligned with clavicle

I
- Males are unable to perform 1 repetition with hands aligned with chin
- Females are unable to perform 1 repetition with thumbs aligned with clavicle

Spinal extension can be cleared by performing a press-up in the push-up position. If there is pain associated with this motion, a zero is given and a more thorough evaluation should be performed. If the individual does receive a positive score both scores should be documented for future reference.

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
Rotary Stability

Purpose:
This test is a complex movement requiring proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso. The rotary stability test assesses multi-plane trunk stability during a combined upper and lower extremity motion.

Description:
The individual assumes the starting position in quadruped with their shoulders and hips at 90 degrees relative to the torso. The knees are positioned at 90 degrees and the ankles should remain dorsiflexed. The board is then placed between the knees and hands so they are in contact with the board. The individual then flexes the shoulder and extends the same side hip and knee. The leg and hand are only raised enough to clear the floor by approximately 6 inches. The elbow, hand, and knee that are lifted should all remain in line with the board. The torso should also remain in the same plane as the board. The same shoulder is then extended and the knee flexed enough for the elbow and knee to touch. This is performed bilaterally for up to 3 repetitions. If a score of III is not attained, then the individual performs a diagonal pattern using the opposite shoulder and hip in the same manner as described above.

Clearing exam:
A clearing exam is performed at the end of the rotary stability test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a positive is recorded and a score of zero is given to the entire rotary stability test. This clearing exam is necessary because back pain can sometimes go undetected by movement screening.

Tips for testing:
Scoring is identified by the upper extremity movement on the score sheet, but even if someone gets a three, both diagonal patterns must be performed and scored. The information should be noted on the score sheet.
- Make sure the knee and elbow remain over the board and the back remains flat.
- Make sure the elbow and knee touch during the flexion part of the movement.
- Provide cueing to let the individual know that he/she does not need to raise the hip and arm above 6 inches off of the floor.
- When in doubt, score low.

Verbal Instruction:
In a hands and knees position, instruct the subject to:
“Position your shoulders and hips at 90 degrees with your thumbs and knees touching the sides of the 2 x 6.”
“Lift both your right arm and leg off of the ground, pointing the arm forward and leg backward. Next, touch your right elbow and knee over the board. Again, return to the extended position. Perform this movement keeping your back as flat as possible.”

“Return to the starting position.” Repeat instructions 2 and 3 with the left side. If necessary, instruct the subject to use a diagonal pattern of right arm and left leg. Repeat diagonal pattern with left arm and right leg. (Score the subject)

Passive Spinal Flexion Verbal Instruction:
While in a hands and knee position, instruct the subject to:
“While maintaining contact with your hands on the floor, rock back to your heels.”
“Now, lower your chest to your knees, reaching your arms in front of you on the floor.”
Ask the subject “Do you feel any pain?” (Score the subject)
Rotary Stability Testing Procedure

I
- Inability to perform diagonal repetitions

II
- Performs 1 correct diagonal repetition while keeping spine parallel to board
- Knee and elbow touch in line over the board

III
- Performs 1 correct unilateral repetition while keeping spine parallel to board
- Knee and elbow touch in line over the board

Spinal flexion can be cleared by first assuming a quadruped position and then rocking back and touching the buttocks to the heels and the chest to the highs. The hands should remain in front of the body reaching out as far as possible. If there is pain associated with this motion a zero is given. If the individual does receive a positive score both scores should be documented for future reference.

0 - The athlete will receive a score of zero if pain is associated with any portion of this test. A medical professional should perform a thorough evaluation of the painful area.
Appendix D

Strength Assessment Exercises

**Grip Strength.** Both the right and left hand were tested three times, alternating between the two and the average of the three was taken and recorded for analysis.

**Extensor Endurance Test.** The extensor endurance test is a modified Biering-Sorensen test, which has been shown to be a reliable measure of back extensor endurance. Participants laid in a prone position with their lower body fixed to the test board in a cantilevered fashion over the edge of the bench. Subjects supported their upper body with their hands before the exertion. The researcher then held down the participant’s ankles. The participant was then instructed to cross their arms over their chest, so their hands were resting on opposite shoulders and lift their upper body until their upper body was horizontal to the floor. Subjects were instructed to maintain the horizontal position as long as possible while the time was manually recorded in seconds with a stopwatch from the point at which the subject assumed the position.

**Flexor Endurance Test.** The flexor endurance test required subjects to sit on the floor and place the upper body against a support with a 60° angle from the floor. Both knees and hips were flexed at 90°. The participant was instructed to cross their arms over their chest with their hands placed on the opposite shoulders while the research held their feet down. Subjects were then asked to maintain that body position while the supported wedge was pulled back by 10cm to begin the test. Subjects were asked to hold that position for as long as they were able, and the time was manually recorded in seconds with a stopwatch. The test ended when the subject was no longer able to hold the 60° angle or when their back touched the support.

**Side Bridge Test.** The side bridge test consisted of subjects laying on an exercise mat beginning on their right side, with their legs extended. The top foot was placed in front of the lower foot on the mat for support. Subjects were instructed to support themselves by lifting their hips off the mat to maintain a straight line over their full body length, supporting themselves on one elbow and their feet. The other arm was positioned across their chest and placed on the opposite shoulder. The subject was asked to maintain this position for as long as possible while being manually recorded in seconds with a stopwatch. The test ended when the participant was no long able to hold the straight-line position. The same test was then performed on the left side.
**Push-Ups.** Subjects were asked to complete as many push-ups on their toes as possible to a metronome set to 30 beats per minute. Hand placement was at the participant’s discretion. A research counted the number completed and the test ended when the participant could either no longer keep pace with the metronome or were unable to complete a proper push-up. Female participants were then given approximately five minutes and then asked to complete as many modified (on their knees on the exercise mat) push-ups as possible to the same set metronome.
Appendix E

Whole Body High Intensity Interval Training Exercises

Burpee (A); From standing position, subjects crouched before assuming a plank position and performing a push-up (i), returned to their feet, via the crouch position, they then jumped as high as they could (ii). Mountain climber (B); beginning in plank position subjects flexed their knees (one at a time) forward to their elbows four times (iii) followed by a push-up (iv). Jumping Jack (C); from standing position (v) subjects simultaneously jumped both feet out wider than hip width apart and abducted arms above their head (vi). Squat Thrust (D); from standing position holding two dumbbell weights (5 lbs) at shoulder height, subjects completed a squat where their upper thighs contacted an 18 inch high chair (vii), subjects then returned to the starting position while extending their arms over their head (viii).
Appendix F

Canadian Health Guidelines Pamphlet

For Adults Between Ages 18-64:

- 150 minutes of moderate-to-vigorous intensity physical activity, per week, in bouts of 10 minutes or more.
- Additional benefits are seen with 2 days per week of muscle and bone strengthening activities using major muscle groups.
- More physical activity provides better health benefits.

Types of Exercise:

<table>
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<th>Aerobic</th>
<th>Resistance</th>
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<tr>
<td>Brisk walking or Jogging</td>
<td>Push-ups</td>
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<tr>
<td>Bike Riding</td>
<td>Sit-ups</td>
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<tr>
<td>Cross-country skiing</td>
<td>Bench Press</td>
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<tr>
<td>Sports (Soccer, basketball, etc.)</td>
<td>Squats</td>
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<tr>
<td>Dance</td>
<td>Pulldowns</td>
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<tr>
<td>Household chores</td>
<td>Bicep Curls</td>
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How Intense is Enough?

Moderate intensity exercise will cause adults to sweat a little and breathe harder (ex. brisk walking). Vigorous-intensity exercise will cause adults to sweat and be out of breath (ex. jogging).
Physical Activity Guidelines

Being active at least 150 minutes per week can help reduce the risk of:
- Risk of premature death
- Heart disease
- Stroke
- High blood pressure
- Type 2 diabetes
- Osteoporosis
- Obesity

Engaging in physical activity can also lead to increased:
- Fitness
- Strength
- Self-Esteem
- Morale
- Mental Health

Now is the Time!
Go for a walk around the block after dinner, bike or walk to work, join a local exercise group, take up a recreational sport, or just get active with family and friends! Most of all, get out there and have fun!
Appendix G

Feeling Scale (FS)

What number best represents how you feel right now?

-5  -4  -3  -2  -1  0  1  2  3  4  5
Very Bad  Moderately Bad  Somewhat Bad  Somewhat Good  Moderately Good  Very Good
Appendix H

Borge Rating of Perceived Exertion (RPE)

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from below that best describes your level of exertion.

- **6** No exertion at all
- **7** Extremely light
- **8**
- **9** Very light (walking slowly)
- **10**
- **11** Light
- **12**
- **13** Somewhat hard (feels OK to continue)
- **14**
- **15** Hard (heavy)
- **16**
- **17** Very hard (very strenuous and tiring)
- **18**
- **19** Extremely hard (extremely strenuous – typically need to stop)
- **20** Maximal exertion
Appendix I

Task Self-Efficacy

We are going to start asking you questions about your confidence that you can participate in physical activities that are described as light, moderate, and hard. The word “confident” refers to the belief that you have in yourself that you can do something well.

**LIGHT ACTIVITIES**: These are activities when you are moving around, but your heart rate and breathing rate do not increase very much. You probably will not be sweating unless the weather is really hot. You would be able to talk easily through the activity. **Examples**: slow walking, slow dancing, shooting hoops, tossing a Frisbee, slow bike riding, bowling, yoga.

| 1. How confident are you that you can complete **10 minutes** of physical activity at a **light** intensity level three times next week? |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Not at all confident | | | | | | | | | Extremely confident |

| 2. How confident are you that you can complete **30 minutes** of physical activity at a **light** intensity level three times next week? |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Not at all confident | | | | | | | | | Extremely confident |

| 3. How confident are you that you can complete **60 minutes** of physical activity at a **light** intensity level three times next week? |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Not at all confident | | | | | | | | | Extremely confident |
**MODERATE ACTIVITIES**: These are activities when your breathing and heart rate increase. You may start to sweat, your legs might feel a little bit tired and you may feel out of breath. You may also find it hard to talk during the activity. *Examples*: brisk walking, moderate dancing, basketball drill, skiing, fast hiking.

1. How confident are you that you can complete **10 minutes** of physical activity at a **moderate** intensity level three times next week?

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2. How confident are you that you can complete **30 minutes** of physical activity at a **moderate** intensity level three times next week?

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<th>20%</th>
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3. How confident are you that you can complete **60 minutes** of physical activity at a **moderate** intensity level three times next week?

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**VIGOROUS ACTIVITIES**: These are activities when your heart beats very fast, your breathing is fast and you start sweating. You may also feel exhausted and out of breath. Your legs would probably be feeling pretty heavy. It would be very hard to talk during the activity. *Examples*: running, singles tennis match, group fitness classes.

1. How confident are you that you can complete **10 minutes** of physical activity at a **vigorous** intensity level three times next week?

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2. How confident are you that you can complete **30 minutes** of physical activity at a **vigorous** intensity level three times next week?

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3. How confident are you that you can complete **60 minutes** of physical activity at a **vigorous** intensity level three times next week?

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Appendix J
Intentions

Date: __________ RA: __________ PARTICIPANT CODE: __________ Visit #: __________
--------------------------------------------------------------------------------------------

Please indicate in the blank space below the number of days per week that you intend to exercise for at least 30 minutes. Try to be as accurate and honest as possible in your intentions.

I intend to perform exercise ______ times per week (for a minimum of 30 minutes) over the course of the next week.

Please circle the number that best represents the strength of your intentions for performing this exercise (1 – 9).

1               2               3               4               5               6               7               8               9               10
Definitely
will not

Definitely
will
Appendix K

Preference

The following questions ask about your exercise preferences, based on your experience from this study.

If it were entirely up to you, which type of exercise would you choose to do (only circle one)?

a) Endurance training at a moderate intensity level
b) Whole-body interval training at a vigorous intensity level

Canada’s physical activity guidelines state that we can achieve the same health benefits from moderate-intensity exercise as we get from vigorous-intensity exercise, but we have to do it more frequently. In order to elicit the same health benefits, which type of exercise would you choose to do over the next 4 weeks?

a) Endurance training at a moderate intensity level for 30 minutes 5 days a week
b) Whole-body interval training at a vigorous intensity level for 20 minutes 3 days a week
### Physical Activity Enjoyment Scale (PACES)

Please rate how you feel at the moment about the physical activity you have been doing.

<table>
<thead>
<tr>
<th>I enjoy it</th>
<th>I hate it</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I feel bored</th>
<th>I feel interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>I dislike it</th>
<th>I like it</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>I find it pleasurable</th>
<th>I find it unpleasurable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>I’m very absorbed in this activity</th>
<th>I’m not at all absorbed in this activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>It’s not fun at all</th>
<th>It’s a lot of fun</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>I find it energizing</th>
<th>I find it tiring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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<table>
<thead>
<tr>
<th>It makes me depressed</th>
<th>It makes me happy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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<table>
<thead>
<tr>
<th>It is very pleasant unpleasant</th>
<th>It is very</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
<td></td>
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<table>
<thead>
<tr>
<th>I feel good physically while doing it</th>
<th>I feel bad physically while doing it</th>
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<tbody>
<tr>
<td>1 2 3 4 5 6 7</td>
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<tr>
<td>Statement</td>
<td>Rating</td>
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<tr>
<td>It's not very invigorating</td>
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<tr>
<td>It's very invigorating</td>
<td></td>
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<tr>
<td>I am very frustrated by it</td>
<td>1 2 3</td>
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<tr>
<td>I am not at all frustrated by it</td>
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<tr>
<td>It's very gratifying</td>
<td>1 2 3</td>
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<tr>
<td>It's not very gratifying</td>
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<tr>
<td>It's very exhilarating</td>
<td>1 2 3</td>
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<td>It's not very exhilarating</td>
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<tr>
<td>It's not at all stimulating</td>
<td>1 2 3</td>
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<tr>
<td>It's very stimulating</td>
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<tr>
<td>It gives me a strong sense of accomplishment</td>
<td>1 2 3</td>
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<tr>
<td>It does not give me a strong sense of accomplishment at all</td>
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<tr>
<td>It's very refreshing</td>
<td>1 2 3</td>
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<tr>
<td>It's not very refreshing</td>
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<tr>
<td>I felt as though I would rather be doing something else</td>
<td>1 2 3</td>
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<tr>
<td>I felt as though there was nothing else I would rather be doing</td>
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Appendix M

Satisfaction of Outcomes

Instructions:
For the following questions please indicate how satisfied or unsatisfied you are.

1. **Based on this research program only**, how satisfied are you with changes in your weight?

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<th>Very Satisfied</th>
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2. **Based on this research program only**, how satisfied are you with changes in your attractiveness?

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3. **Based on this research program only**, how satisfied are you with changes in how clothes fit you?

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4. Based on this research program only, how satisfied are you with changes in your current health risks? (For example, a health risk is developing Type 2 Diabetes).

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5. Based on this research program only, how satisfied are you with changes in your social life?

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6. Based on this research program only, how satisfied are you with changes in your ability to be physically active?

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7. Based on this research program only, how satisfied are you with how hard you can push yourself during physical activity?

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8. **Based on this research program only**, how satisfied are you with how intensely you can engage in physical activity?

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9. **Based on this research program only**, how satisfied are you with how quickly you can recover from physical activity? (How fast your heart rate and breathing come back to normal?)

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10. **Based on this research program only**, how satisfied are you with how physically strong you are? (How much weight you can lift, how strong you feel during everyday activities)

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