HIGH INTENSITY FUNCTIONAL INTERVAL TRAINING FOR OLDER ADULTS

A Thesis Submitted to the College of
Graduate and Postdoctoral Studies
In Partial Fulfillment of the Requirements
For the Degree of Master of Sciences
In the College of Medicine
University of Saskatchewan
Saskatoon

By

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ABSTRACT

Purpose:

The purpose of this study was to examine the effects of 6 weeks of high intensity functional interval training (HIFIT) compared with high intensity resistance training (HIRT) on muscle strength/endurance, functional performance, and aerobic capacity, exercise confidence and level of enjoyment, as exercise interventions for promoting health among older adults.

Method:

A group randomized trial study design was implemented to complete either the HIFIT or the HIRT training program. Twenty older adults trained and completed either HIFIT (n=12, age = 62.9 ± 5.0), or HIRT (n=8, age = 61.1 ± 3.8). Following a 2 weeks adaptation phase, the participants trained for 6-weeks, 3 times per week, for 30 minutes each session. Both groups performed 6 sets of 5 minutes of combined exercise and rest periods. Three within interval movements were performed: strength, faster body weight power, and sprint like movements. The HIFIT group trained using multi-modal exercises and executed the strength, power, and sprint movements; whereas, HIRT group trained using only the strength, and power movements for whole body resistance training. Testing involved VO_2max, body composition with dual energy x-ray absorptiometry, functional performance (i.e. Timed up and Go (TUG), Stair Climb Power (SCPT), 30 second Sit to Stand (STS), Fast Gait Speed (FGS), incremental shuttle walk test (ISWT)); and strength measurements such as 3 repetition maximum (RM) deadlift, 4RM bench press, and 80% of 4RM bench press endurance. Exercise confidence and enjoyment level was surveyed by answering the Exercise Self-Efficacy Scale (EXSE) and Physical Activity Enjoyment Scale (PACES) questionnaires.

Results:

Over the 6-weeks training period, both HIFIT and HIRT groups revealed significant increases in muscle strength when performing the 3RM deadlift (p=0.00) and 4RM bench press endurance (p=0.00). Strength for 4RM bench press was significantly greater in the HIRT group (p=0.03). Both groups showed notable improvements when executing the TUG (p=0.00) and the STS (p=0.04), although HIFIT demonstrated greater increase in SCPT (p=0.01). Aerobic

capacities (VO_2max), anaerobic threshold (AT), and respiratory compensation threshold (RCT) were measured in relation to lean mass (LM) and body weight (BW). Also, both HIFIT and HIRT group had significant increase for VO_2max LM (p=0.03), AT LM (p=0.01), RCT LM (p=0.01), VO_2max BW (p=0.02), AT BW (p=0.02), and RCT BW (p=0.01). There was a significant increase for lean mass (p=0.04) and decrease in fat mass (p=0.04) for both groups from pre to post-test but no between group differences. In addition, HIFIT and HIRT groups have similar level of physical activity enjoyment (Cronbach's α = 0.97) and self-confidence feedback (80-82%), with 96% adherence. There were no significant findings for ISWT (p=0.72), and gait speed tests (FGS, p=0.34 and CGS, p=0.54).

Conclusion:

HIFIT and HIRT interventions have similar remarkable effects on strength, body composition adaptations, aerobic capacity, functional performance, exercise efficacy, and enjoyment level over time ; however, group by time interaction revealed HIFIT had significantly greater increase in performing stair climb power test and HIRT significantly greater increase in strength for older adults.

Keywords: high intensity interval training; high intensity resistance training; older adults; body composition; adaptation.

ACKNOWLEDGEMENT

In my life's journey, my deep sense of gratitude and admiration to The Almighty God. He constantly enlightens and guides the path for me….always making my burden light.

I am forever thankful to my family, relatives, employers and friends for their prayers and moral support.

I would like to express my appreciation to Dr. Phil Chilibeck for his extended help and in depth assessment. He is a true model professor; willing to impart knowledge and leave a good legacy to his students.

I acknowledged my supervisor, Dr. Scotty Butcher, Dr. Stephan Milosavljevic (Chairman), Dr. Angela Busch (Former Chairman), Dr. Gordon Zello (External Member), and Dr. Darcy Marciniuk, Dr. Susara Van Der Spuy, as my advisory committee for their inputs and support throughout this entire process.

I am fortunate to know Ms. Angie Zoerb. She came at the right place and at the right time. An angel sent by God who helped unconditionally. Words cannot repay all the things she has done. Thank you for the friendship and for helping me become what I am today.

I would like to recognize a person whom I considered a doctor in his own right, Mr. Ron Clemens (Doki) for all the technical skill, support, and in training me to manage the pulmonary research equipment. To Blanc Star, for the encouragement and assistance to keep this moving forward. My colleague Karla, Chad Benko of Synergy Strength Gym and its staff, namely: Courtney and Ben for their skills and flexibility in dealing with the study participants.

Finally, my special appreciation goes to all the motivated study participants for their cooperation, and providing their valuable time for the collection of data required for the research study.

Evelyn T. Pata

DEDICATION

To Almighty God,
Husband and Buddy, Onassis
Daughter, Kylie Emmanuelle
Parents, Cesar and Cornelia Tarongoy
Brothers, John Clyde and Stephen
Sister-In-Laws, Mary Ann, Gwendolyn and Analyn
Nephews and Nieces, Kurt Ian, Erika Shayne, Nino Emmanuel and Stefhanie
Mama Loling, Papa Gorio, Arnold, Family of Erwin & Genie, Family of Sarah & Arnel
Tito Lino & Family, Relatives and Friends
To the older adults, to us, to the study participants, to the students and health professionals who have the desire to make the golden years an enjoyable stage of the human life by being physically active through exercise and fun, this work is dedicated.

I am ever grateful to my Husband and Buddy, Onassis. You are my strong foundation of love, support and understanding. Your encouragement and tons of humor keeps us going and it reached us a long way. Likewise, to my daughter, Kylie Emmanuelle (nine years old when the start of this study). You, who showed the true meaning of sacrifice and patience. Supporting by helping with result tabulations and assisting participants in the gym study as a means to spend “play and bonding time” with Mama. Both of you are my treasures and source of inspirations. Thank you for the love, faith and always believing in me.

EVELYN TARONGOY PATA

TABLE OF CONTENTS

PERMISSION TO USE i
ABSTRACT ii
ACKNOWLEDGEMENTS...iv
DEDICATION...v
TABLE OF CONTENTS vi
LIST OF TABLES x
LIST OF FIGURES xi
LIST OF COMMON ABBREVIATIONS USED xii
CHAPTER 1 1
INTRODUCTION 1
CHAPTER 2 3
REVIEW OF LITERATURE 3
2.1 Older Adults and Public Health 3
2.2 Changes Seen in Older Adults Affecting Activities of Daily Living (ADL) 4
2.2.1 Physical and Physiological Deterioration in Aging 4
2.2.2 Risk Factors that Contribute to Decline in Functional Performance in Older Adults 6
2.2.3 Factors that Contribute to Decline in Cardiovascular and Respiratory Performance in Older Adults 6
2.2.4 Modifiable Risk Factors that Will Increase Functional Performance........................7
2.2.5 Types of Training to Improve Functional Performance..8
2.3 High Intensity Interval Training (HIIT) for Older Adults 12
2.3.1 Definition and Importance of HIIT...12
2.3.2 Acute Responses to HIIT 12
2.3.3 General Health, Physiological, and Performance Adaptations in HIIT 14
2.3.4 HIIT in Older Adults...14
2.3.5 Limitations of HIIT...16
2.4 High Intensity Resistance Training (HIRT) for Older Adults 17
2.4.1 Definition and Importance of HIRT 17

2.4.2 Acute Responses to HIRT 17
2.4.3 General Health, Physiological, and Performance Adaptations in HIRT 19
2.4.4 Limitations of HIRT 21
2.5 Concurrent Training for Older Adults 22
2.5.1 Definition and Importance of Concurrent Training 22
2.5.2 Acute Responses to Concurrent Training 22
2.5.3 General Health, Physiological, and Performance Adaptations in Concurrent Training 23
2.5.4 Limitations of Concurrent Training 25
2.6 Summary of Limitations in Current Knowledge 26
2.7 Research Objectives and Hypotheses 27
CHAPTER 3 29
METHODOLOGY 29
3.1 Study Design 29
3.2 Participants 30
3.3 Test and Measures 31
3.3.1 Screening 31
3.3.2 VO_2max Testing 31
3.3.3 DEXA Testing 32
3.3.4 Functional Testing 33
3.3.5 Repetition Maximum (RM 34
3.3.6 Exercise Self-Efficacy and Level of Enjoyment 34
3.4 Training Program (Muscle Strength and Endurance Testing 35
3.4.1 Familiarization 36
3.4.2 Training Protocol 37
3.5 Statistical Analysis 37
CHAPTER 4 40
RESULTS 40
4.1 Body Composition in HIFIT vs. HIRT 40
4.1.1 Lean Mass 40
4.1.2 Fat Mass 40

4.1.3 Total Mass 40
4.2 Muscle Strength in HIFIT vs. HIRT 43
4.2.1 Bench Press 43
4.2.2 Bench Press Endurance 43
4.2.3 Dead Lift 43
4.3 Functional Performance in HIFIT vs. HIRT 43
4.3.1 Stair Climb Power Test (SCPT) 43
4.3.2 Time Up and Go (TUG) 45
4.3.3 Gait Speed Test (Fast (FGS) and Comfortable (CGS)) 45
4.3.4 Sit to Stand (STS) 45
4.3.5 Incremental Shuttle Walk Test (ISWT) 45
4.4 Aerobic Capacity of HIFIT vs. HIRT 45
4.4.1 VO_2max adjusted for Lean Mass (VO_2max LM) 45
4.4.2 Anaerobic Threshold adjusted for Lean Mass (AT LM) 46
4.4.3 Respiratory Compensation Threshold adjusted for Lean Mass (RCT LM) 46
4.4.4 Relative VO_2max on Body Weight (VO_2max BW) 46
4.4.5 Relative Anaerobic Threshold on Body Weight (AT BW) 46
4.4.6 Respiratory Compensation Threshold on Body Weight (RCT BW) 46
4.5 Questionnaires 47
4.5.1 Self-Efficacy for Exercise 47
4.5.2 Physical Activity Enjoyment 47
CHAPTER 5 51
DISCUSSION 51
5.1 Main Findings 51
5.2 Strength, Muscle (Lean) Mass, and Fat Mass Changes 52
5.3 Functional Performance Changes 53
5.4 Aerobic Capacity Changes 54
5.5 Strength Training and Confidence / Enjoyment Level 54
5.6 Limitations 55
5.7 Practical Implications and Future Research 56

CHAPTER 6 57
CONCLUSION 57
REFERENCES 58
APPENDICES 83
1 Participant Information 83
2 Consent Form 90
3 The Physical Activity Readiness Questionnaire 91
4 HIFIT Gym Program Outline 97
5 HIRT Gym Program Outline 99
6 The Self-Efficacy for Exercise Scale 101
7 Physical Activity Enjoyment Scale 102

LIST OF TABLES

Table 2.1 Endurance and Resistance Exercise for Older Adults 10

Table 2.2 High Intensity Interval Training Protocols 18

Table 2.3 Summary Differentiation between HIRT, HIIT and Concurrent Training 28

Table 3.1 Exercise Protocol for HIFIT and HIRT 39

Table 4.1 Participant's Demographics 41

Table 4.2 Body Composition of Participants during Pre-Test and Post-Test using the Dual Energy X-ray Absorptiometry (DEXA Scan) for Lean Mass, Fat Mass and Total Mass 42

Table 4.3 Muscular Strength and Endurance 44

Table 4.4 Functional Performance of the HIFIT and HIRT group for SCPT, TUG, FGS, CGS, STS and ISWT as presented with means and standard deviations 48

Table 4.5 Post-Test Analysis of HIFIT and HIRT for Exercise Self-Efficacy 49

Table 4.6 Post-Test Analysis of Physical Activity Enjoyment for HIFIT and HIRT 50

LIST OF FIGURES

Figure 3.1 Study Design 30

Figure 3.2 Study Participants 30

Figure 3.3 Participants Performing the Deadlift 36

Figure 3.4 Double Rope Undulations Executed by the Participants 36

Figure 3.5 Participants during the Study Training Performing the Dumbbell Press 36

LIST OF COMMON ABBREVIATIONS USED

ADL	Activities of daily living
ANCOVA	Analysis of co-variance
ANOVA	Analysis of variance
AT	Anaerobic threshold
BMD	Bone mineral density
BMI	Body mass index
BW	Body weight
CGS	Comfortable gait speed test
CSA	Cross sectional area
DEXA	Dual energy x-ray absorptiometry
EXSE	Exercise Self-Efficacy Scale
FGS	Fast gait speed
HIFIT	High-intensity functional interval training
HIIE	High-intensity intermittent exercise
HIIT	High-intensity interval training
HIRT	High-intensity resistance training
HR	Heart rate
ISWT	Incremental shuttle walk test
LM	Lean mass
PACES	Physical Activity Enjoyment Scale
PPO	Peak power output
RCT	Respiratory compensation threshold
RM	Repetition maximum

SCP	Stair climb power test
STS	Sit to stand test
TUG	Time up and go test
VO_2max	Maximum amount of oxygen used when performing exercise
1RM	One repetition maximum
3RM	Three repetition maximum
4RM	Four repetition maximum

CHAPTER 1

INTRODUCTION

An essential component of a healthy lifestyle is performing regular physical activity. Exercise training and physical activity are beneficial for the enhancement of bodily functions and has been shown to increase longevity and the overall quality of life (Helgerud et al., 2007). Physical exercise maintains general health and wellness, and is therefore suitable for everyone, including older adults. There is an increasing concern for the welfare of older adults as it has been reported by the World Health Organization (WHO) that seniors will make up the fastest-growing age group in the next several decades. This will result in an estimate of 2 billion people age 60 years or older in 2050 (WHO, 2015).

A seniors report conducted by the Government of Canada (2014) shows that good quality of life for older adults is to have freedom in performing independently the activities of daily living (ADL) (e.g. walking, climbing stairs, sit to stand, and lifting simple tasks), to delay the development of chronic diseases, to have chances for social interaction, and develop emotional well-being (ACSM, 2010); however, older adults experience limitations as a result of long-term physical conditions caused by injury, disease, and aging (Statistics Canada, 2007; Public Health Agency of Canada, 2008). One of the common problems seen among older adults is sarcopenia, a condition where there is progressive loss of muscle mass, muscle strength, and power in aging (Davis et al., 1982). Prevalence estimates of sarcopenia are 6-9% in the 60 to 70 year olds and 11% for aged 80 years and older (Janssen et al., 2002).

Reduced lower limb function and dependence in ADL is strongly connected with loss of muscle mass, power, and strength (Guralnik et al., 1995; Fatouros et al., 2005); Metter et al. (1997) revealed that power decreased at a much greater rate than strength among older adults. This declined in function can be avoided by performing resistance exercise training (Ramos et al., 2015; Gibala, 2009).

Studies showed that performing high intensity resistance training (HIRT) is more advantageous than lower intensity resistance training and endurance training as HIRT demonstrates significant beneficial training-induced improvements (Ramos et al., 2015; Fatouros et al., 2005; Cassilhas et al., 2007; Gibala, 2009; Helgerud et al., 2007). Exercising using High-intensity resistance training (HIRT) builds strength, anaerobic endurance, and the size of skeletal muscles; resulting in enhancement of muscle power and functional performance (Caserotti, 2010). Likewise, another type of exercise is High intensity interval training (HIIT) that increases cardiovascular function and could be accomplished in a shorter period of time (Gibala, 2009). With the benefits of HIRT and HIIT, undertaking these two types of exercises would be more advantageous; however, performing them individually would be time-consuming and time is a known barrier for adherence to physical activity (Springen, 2012). Performing concurrent training, which is a combination of both endurance and resistance training, may be a prudent solution to keep older adults physically fit; thereby, minimizing the weakening effects of sarcopenia in aging (Dolezal & Potteiger, 1998; Izquierdo et al., 2004; Cadore et al., 2013; Holviala et al., 2012; Sillanpaa et al., 2012; Karavirta et al., 2011). Nevertheless, effects of concurrent training revealed contradictory outcomes. Some demonstrate it to be effective (Aagaard et al., 2010; Davis et al., 2008; Hoff et al., 2002) and other investigations declaring it to be unfavourable to strength, power, and endurance adaptations (Hickson, 1980; Hawley, 2009; Wilson et al., 2012). Therefore, further research is needed to clarify these findings.

There is little research in older adults examining combined exercises using nearly the same criteria for mode, intensity, and frequency. With the increasing worldwide older adult population, the need to identify which types of exercise intervention to alleviate the effects of sarcopenia will be a significant public contribution. This research study will provide useful information about 1) High intensity functional interval training or the "HIFIT Protocol"; a time-efficient multi-modal exercise training that primarily focuses on strength, power and high intensity endurance to improve functional performance; 2) The effects of two exercise methods: HIFIT and HIRT, regarding the effectiveness for achieving gains in aerobic capacity, body composition, and functional performance; and 3) The exercise training intervention to maintain older adults' physical activity but with less training time, but inducing significant health benefit. This study aimed to determine the effectiveness of a functional training program that will assist practitioners in exercise management for older adults.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Older Adults and Public Health

A decline in sensorimotor function and integration system is reflected in the operational ability to work, which is apparently lower for women than in men. The transition in livelihood which usually occurred between the ages of 45 to 55 for women and ages 55 to 75 years for men, became the basis for the definition of old age (Miller et al., 2005; Miszko et al., 2003). Therefore, in this study, the age 55 and above will be considered as older adults to represent the population and in order to determine their functional abilities, body composition, and muscle power and strength.

Chronic conditions such as heart disease, cancer, respiratory diseases, stroke, Alzheimer's disease, diabetes, influenza and pneumonia are the leading causes of death among older adults (Statistics Canada, 2015). To address the challenges posed by an aging population, public health agencies and community organizations worldwide continue to expand health promotion in older adults, prevention of disability, and maintenance of capacity in those with frailties and disabilities, and enhancement of quality of life (Brooks et al., 1994).

The performance of regular exercise and physical activity reduces the risk of chronic conditions such as coronary heart disease, hypertension, type 2 diabetes, osteoporosis (bone structure decomposition), gastrointestinal problems, sensory impairment, and compromised immune system (Warburton et al., 2006). Evidence-based reviews have determined that exercise may help prevent breast cancer (Friedenreich, 2001), and hypertension (Kokkinos et al., 2001), and improve insulin resistance in non-diabetics and with type 2 diabetes (Ryan, 2000). In addition, performing exercise is associated with lower risk of stroke (Hu et al., 2000). A review of prospective cohort studies has also connected exercise to increased longevity (Oguma et al., 2002) and decreased mortality due to coronary heart disease (Fraser & Shavlik, 1997). Likewise, performing exercise appears to benefit aspects of mental health, including depression and anxiety disorders (Brosse et al., 2002; Dunn et al., 2001), as well as sleep problems (King et al., 1997).

ACSM (2010) stated that significant gains in strength are attainable with proper resistance training. Resistance training is an important way to increase levels of physical activity in the older adult and has positive effects on insulin action, bone density, energy metabolism, and functional status. A study of nursing home residents (90 year olds), found an improvement of 167-180 percent in their knee extensor after just 8 weeks of weight training (Fiatarone et al., 1990).

2.2 Changes seen in Older Adults affecting Activity of Daily Living (ADL)

2.2.1 Physical and Physiological Deterioration in Aging

Physical and physiological changes occur with advanced age. Many older adults experience problems in performing their activities of daily living (ADL's) due to the decrease in the strength (force-generating) ability in the skeletal muscles (Rogers & Evans, 1993; Frontera et al., 2000). Muscle strength and power are needed to execute functional activities (Reed et al., 1991; Reid et al., 2008; Rolland et al., 2008; Bassey and Short, 1990; Bassey et al., 1992; Foldvari et al., 2000) and loss of strength and power is related to mobility problems, poor endurance, osteoporosis, risks of falls and fractures, inability to perform ADL, disability, and frailty (Cruz-Jentoft et al., 2010; Fried et al., 2001; Newman et al., 2003). While muscle strength is defined as the amount of force a muscle can generate (Reed et al., 1991; Reid et al., 2008; Rolland et al., 2008), power is work (force × distance) divided by time; a "function of both strength and speed and is demonstrated by producing very rapidly high forces" (Weir and Cramer, 2006). In the older population, it has been found that power decreases at a much greater rate than strength (Metter et al., 1997); hence, choosing the appropriate exercise training regimen that will both increase strength and power at the same time is very essential to be able for one to maintain optimal function.

Decreases in skeletal muscle cross-sectional area (CSA) seen in sarcopenia could be the result in reduction of fiber size, fiber number, or combination of the two (Frontera et al., 2000, Lexell et al., 1988, 1991; Kent-Braun & Ng, 2000) that could lead to increased risk of falls (Cruz-Jentoft et al., 2010; Fried et al., 2001; Newman et al., 2003). Many researchers who have investigated sarcopenia consider the "gold standard" of using whole muscle sampling in analyzing for muscle fiber size and number (Young et al., 1985; Coggan et al., 1992; Hakkinen et al., 1996); however, evaluation of microscopic whole human cross-sections of vastus lateralis muscles suggests that, even with the presence of minor decrease in the fiber size, the main source of sarcopenia is the reduction in the total number of fibers within the muscle (Lexell et al., 1988). Likewise, a study of Kent-Braun et al. (1999) showed that the muscles of older people (65-83 years old) do not only have a decrease in skeletal muscle CSA, but also contain less contractile tissue and more non-contractile tissue (i.e., fat and connective tissue) compared with skeletal muscle of a younger age group (26-44 years old). This increase in the amount of non-contractile tissues results in a decreased strength capability. Also, several studies have focused on the relationship between aging and the types of muscle fibers (Rogers & Evans, 1993; Lexell et al., 1988; Coggan et al., 1992). The majority of the studies support the conclusion that the size of type I (slow) fibers does not change considerably with age, and that only type II (fast) fibers undergo selective atrophy in aging people with impairments (Rogers & Evans, 1993; Porter, 1995). Although, only type II fibers significantly decrease in size, the number of type I and type II fibers seems to decline in the same way with aging (Rogers & Evans, 1993).

Several investigations determined that alpha motorneurons that are responsible for initiating muscle contraction also decrease with old age (Gardner, 1940; Tomlinson & Irving, 1977; Kawamura eta l., 1977), resulting in less motor units (MU) (Campbell et al., 1973; Vandervoort & McComas, 1986). The abandoned muscle fibers are often re-innervated by the other existing MUs through collateral sprouting (Roos et al., 1997). Thus, some existing MUs become larger even when there is a decrease in the number of MUs (Roos et al., 1997). Studies as well revealed that there is inconsistency in MU firing rates (Connelly et al., 1999; Erim et al., 1999; Laidlaw et al., 2000), apparently caused by the denervation of type II fibers and re-innervation by collateral sprouting by associated type I fibers. These increased inconsistencies in MU firing rates may result in deficiencies in motor control and strength (Roos et al., 1997).

In addition to changes in motor units, Andersen et al. (1999) revealed that older people have decreased ability to synthesize muscle protein. The ratio between protein synthesis and breakdown are reduced in people who are of middle and old age (52-79 years), hence, leading to reduction in muscle mass and muscle strength (Balagopal et al., 1997).

2.2.2 Risk Factors that Contribute to Decline in Functional Performance in Older Adults

It is important to understand the risk factors that result to functional limitations of the older population. Functional limitation is the "inability to carry out functional tasks at the personal level" (Institute of Medicine, 1991). It is also defined as loss of ability to perform one or more of the eight basic ADL which includes feeding, toileting, selecting proper attire, grooming, maintaining continence, putting on clothes, bathing, walking and transferring (e.g., moving from bed to wheelchair) (Sarkisian et al., 2000).

Risk factors that contribute to the decline of older adults' functional performance are divided into two: Firstly, comorbid health conditions, such as cognitive and vision impairment, cardiorespiratory problems, diabetes, stroke, depressive symptoms, decrease bone mineral density, obesity, effects of medications, and physical weakness (e.g., slow gait, weak grip). Secondly, health behaviors, such as lack of regular vigorous physical activity, low social functioning, smoking, and use of alcohol (Dunlop et al., 2005; Sarkisian et al., 2000).

2.2.3 Factors that Contribute to Decline in Cardiovascular & Respiratory Performance in Older Adults

An increase in cardiovascular disease comes with aging. In the study of Strait & Lakatta (2012), cardiovascular changes seen in older adults can be divided into three areas. (1) Structurally, there is a major increase in the heart's muscle thickness (Gerstenblith et al., 1977), and shape from elliptical to spheroid with an asymmetric increase in the interventricular septum that affects the contractile properties of the heart, resulting in stiffness (Hees et al., 2002) and eventually, leading to diastolic dysfunction, increased afterload and heart failure (Lakatta & Levy, 2003; Scholz et al., 1988). (2) Functionally, the aging heart reduces its ability to adjust to increased workload and thereby lessens its reserve capacity especially with exercise or stress. Some of the functional responses include changes in maximal heart rate, end-systolic/diastolic volume, and diminished contractility. (3) Cardioprotection and Repair Processes: With aging, there is a defect in the cardiac mechanism responsible for protection from injury and repair. This leads to increase prevalence of cardiovascular disease (e.g., coronary artery disease, hypertension and diabetes) and other organ system defects (Lakatta &Levy, 2003; Scholz et al., 1988).

The effects of aging on the cardiovascular system are most evident with exercise. Decreased exercise tolerance is apparent in the progressive decline in VO_2max which usually starts at the age of 20-30 and declines nearly 10% per decade (Fleg & Lakatta, 1988) and ultimately declines an average of 50% from age 20-80 years of age (Fleg et al., 2005). To address this concern, evidence shows that aerobic exercise programs can provide improvements in peak oxygen consumption and increases in ventilatory threshold and submaximal endurance for older adults with heart failure (Fleg, 2002). Likewise, a longitudinal study in older males in the upright position indicated that an enhanced physical conditioning status increases oxygen consumption (Schulman et al., 2002).

2.2.4 Modifiable Risk Factors that Will Increase Functional Performance

From a public health point of view, it is significant to know the modifiable risk factors in relation to functional deterioration in order to prevent or find solutions to the decrease functional performance in the older population. Sarkisian et al. (2000) stated that modifiable risk factors are aspects that could be expected to change over a period of time. Studies showed that lack of regular vigorous physical activity is a modifiable risk factor that could considerably increase functional performance and decrease health care costs (Dunlop et al., 2005; Sarkisian et al., 2000). In a study of Dunlop et al. (2005) of arthritic participants, there was a 32% increase of function in older adults who engaged in regular vigorous physical activity. These findings revealed that older adults with chronic conditions need to be encouraged to participate in physical activities, regardless of their current functional abilities.

Clinical studies demonstrate that physical activity results in improved strength, aerobic capacity, flexibility, and physical function in sedentary older people (Cress et al., 1999; Keysor et al., 2001). There was improved strength noted in a study of aerobic and resistance exercise programs (Ettinger et al., 1997), or just solely performing resistance training (Topp et al., 2002) for osteoarthritic patients. Repetitions with loads of 50-70% of maximum using strength training of all major muscle groups of the lower and upper extremities including the trunk, demonstrated increased strength in patients with rheumatoid arthritis (Hakkinen et al., 2001). Likewise, a designed procedure of combined endurance and strength training at 75-80% of maximal intensity, done 3 times/week for 6 months for participants without musculoskeletal problems showed improvements in muscle strength (Cress et al., 1999).

2.2.5 Types of Training to Improve Functional Performance

Researchers have recommended that the two major categories in muscle training are endurance and resistance training; both types of training can control the weakening effects of sarcopenia in older adults (Hakkinen et al., 1996 &1998; Coggan et .al., 1992; Harridge et al., 1999). Endurance (cardiorespiratory) training refers to exercise focused at improving the duration that a person can sustain strenuous activity and aerobic capacity (VO_2max), whereas resistance training pertains to exercise directed at developing the muscle's strength capacity (Rogers & Evans, 1993; Kraemer et al., 1996). In designing an exercise program, normally the therapist usually starts with an "easy mode" especially with the older population or in the presence of comorbidities (e.g., heart and lung disease, diabetes, balance disorders). However, numerous investigations suggest that this is a misconception, as findings showed that there is no difference in the reaction of healthy older people vs. younger people who performed endurance and resistance training (Rogers & Evans, 1993; Kraemer et al., 1996; Cartee et al., 1994).

Two studies of Coggan et al. (1992a) showed muscle adaptation to both endurance and resistance training. The first investigation showed significant increases of the fiber CSA of the lateral gastrocnemius muscles of older participants (60-70 years old) after 10 months of endurance training that consisted of walking or jogging for 45 minutes per day, 3 times per week. The results revealed a major increase of 6-18% in fiber CSA of type IIA fiber (fast, fatigue-resistant), while the type IIB (fast, fatigable) increased by 9-12% and type I (slow) fibers remained unchanged. These researchers also indicated that there was a percentage increase of type IIA fibers of 8% more than the type IIB fibers suggesting a conversion of type IIB fibers to type IIA with training. A second study by Coggan et al. (1992b) showed increased muscle capillarization and oxidative capacity in response to both endurance and resistance training. There was a decrease in both the muscle capillary to fiber ratio and oxidative capacity in the skeletal muscle of older persons compared with the muscle of younger individuals. There was an increase in the muscle capillarization of the older people (60-70 years old) who engaged in an endurance training program that comprised of walking or jogging for 45 minutes per day, 3 times per week, for 10 months at 80% of their age-adjusted maximal heart rate. Moreover, findings explained that new capillaries were generated in the muscles of the participants, as the capillary densities (capillaries per square millimeter) improved by 20%, while the number of capillaries per muscle fiber increased by 25%.

Likewise, research of Meredith et al. (1992) demonstrated that there was an increase of 125% in the oxidative ability of the muscles of older men (65 years of age) who performed the cycle ergometer at 70% of their age-adjusted maximal heart rate for 45 minutes per day, done 3 days per week.

The Canadian Society for Exercise Physiology (CSEP) (2015), American College of Sports Medicine/American Heart Association (ACSM/AHA) (2011) have developed Physical Activity recommendations regarding endurance and resistance exercises for older adults with respect to the frequency, intensity, and duration of exercise and physical activity. ACSM/AHA, and the US Department of Health and Human Services (DHHS) (2008) Physical Activity Guidelines for Americans recommend 150 mins per week of exercise for health benefits. However, there are more added benefits as the amount of physical activity increases with high intensity, greater frequency, and longer duration (CSEP, 2015; DHHS, 2008). (Table 2.1)

ACSM/AHA (2011) Guidelines recommended that consideration should be given to older adults when prescribing exercise and physical activity. The progression of activities should be designed for tolerance and preference for each individual older adult.

Table 2.1 Endurance and Resistance Exercise for Older Adults (CSEP, 2015; ACSM/AHA, 2011)

	ENDURANCE EXERCISE	RESISTANCE EXERCISE
Frequency	Moderate-intensity activities: - 30-60 mins/day in bouts of at least 10 mins to total of 150-300 min/week Vigorous-intensity activities: - 20-30 mins/day or more to total of 75-150 min/week - (equivalent combination of moderate and vigorous activity) • Lower ranges → adults not in any exercise program → frail individuals	Average: 3 days/week (At least 2 days/week but not more than 4 days/week)
Intensity	➢ Intensity by heart rate: • For most adults Moderate: 40-60% of heart rate reserve (HRR) Vigorous: 60-90% HRR • For deconditioned individuals Light: 30-40% of HRR Moderate: 40-60% of HRR ➢ Intensity by perceived exertion: • Assess appropriateness of heart rate ranges using a scale of 0-10 for level of physical exertion 3-4 → light intensity 5-6 → moderate intensity 7-8 → vigorous intensity	➢ Intensity by repetition maximum (RM): • For beginner adults on resistance training program Moderate: 60-70% of 1-RM Light: 40-50% of 1-RM ➢Intensity by perceived exertion: • Assess appropriateness of heart rate ranges using a scale of 0-10 for level of physical exertion 5-6 → moderate intensity 7-8 → vigorous intensity Average: 65-75% of 1-RM (low to mod. intensity)

Table 2.1 Endurance and Resistance Exercise for Older Adults (CSEP, 2015; ACSM/AHA, 2011) (Continued)

	ENDURANCE EXERCISE	RESISTANCE EXERCISE
Repetitions	• Continuous for the whole duration during the exercise session.	16-20 reps → 60% of 1RM} for muscular endurance 14-15 reps → 65% of 1RM } for strength 12-13 reps → 70% of 1RM]} for strength 10-11 reps → 75% of 1RM]} strength & power 8-9 reps → 80% of 1RM] strength & power 6-7 reps → 85% of 1RM 4-5 reps → 90% of 1RM 2-3 reps → 95% of 1RM 1 rep → 100% of 1RM ➢ 2 – 4 sets of each exercise - older adults improve their strength and power
Duration	Moderate-intensity activities: -At least 30 min/day in bouts of at least 10 min. each Vigorous-intensity activities: -At least 20 min/day of continuous activity	Average: 30 minutes per session. (At least approximately 20-45 minutes per session)
Type	• Any modality that does not impose excessive orthopedic stress; ➢ Walking - most common ➢ Aquatic exercise and stationary cycle exercise - for those with limited tolerance for weight bearing activity.	• Progressive weight training program • Weight bearing calisthenics (8–10 exercises involving the major muscle groups of 8–12 repetitions each) • Stair climbing • Other strengthening activities that use the major muscle groups. • Older adults should have at least 48 hours rest between resistance training sessions. • To avoid excess fatigue, a 2-3 minute rest period between sets and exercises is recommended.

2.3 High-Intensity Interval Training (HIIT) for Older Adults

2.3.1 Definition and Importance of HIIT

High-intensity interval training (HIIT), also known as high-intensity intermittent exercise (HIIE), is a short, intense workout type of cardiovascular exercise usually lasting from 4-30 minutes; applying alternate exercise periods between high and low intensity exercise or between high intensity anaerobic exercise and short periods of rest (Tabata et al, 1996; Shiraev, 2012). The main aim of HIIT is to improve speed, cardiovascular fitness, glucose metabolism, and fat burning (Laursen et al., 2002; Perry et al., 2008; Talanian et al., 2006). The fundamental principles of HIIT are that exercise should be brief, infrequent, and intense. One might ask, why do we need to perform HIIT or what makes HIIT unique among the other forms of exercise training? Recently, randomized controlled studies have demonstrated the safety and effectiveness of HIIT in cardiac clinical populations (Munk et al., 2009; Nilsson et al., 2008). It was also identified that one of the common barriers for participation in exercise activity is the reported "lack of time to do exercise" (Anshel, 1948). This barrier can be resolved using HIIT because performing HIIT exercise is time-efficient (e.g. 30 minutes/session) and an effective method of achieving comparable, or sometimes greater changes in endurance, cardiovascular health, and body composition (Humphrey, 2012) compared when doing continuous endurance exercise that usually needs 60 minutes to perform per session (ACSM-HIIT, 2011).

One of the main benefits of HIIT is adaptability. HIIT can be adapted for people of all fitness levels and could be performed on all exercise modes (e.g. walking, swimming, exercise/workout classes) (ACSM, 2011). Another advantage of HIIT is the "after burn" (also known as excess post-oxygen consumption (EPOC)). HIIT will increase the body's metabolism and burn calories between 15 minutes to 48 hours after the exercise compared to traditional exercise training (Laursen et al., 2002).

2.3.2 Acute Responses to HIIT

In a study of Guiraud et al. (2011), acute responses showed no evidence of severe or prolonged ischemia, significant arrhythmias, or abnormal blood pressure. Moreover, blood cardiac-specific troponin T (cTnT) (protein responsible for cardiac muscle contraction) levels at 20 min and 24 hour after exercise remained well within normal limits showing no myocardial injury. This high intensity interval exercise session consisted of 10 min warm-up at 50% of peak power output, followed by two sets of 10 min composed of repeated phases of 15 sec at 100% of peak power output combined with 15 sec of passive recovery. Four minutes of passive recovery was allowed between the two sets, as well as a 5-min cool-down after the last 15-sec exercise phase. In another study of Gibala (2009) using a Wingate-based “all-out” procedure involving 4-6 x 30 sec intervals; there were metabolic adaptations induced by HIIT, including mitochondrial production and an increased capacity for glucose and fatty acid oxidation. Additionally, in a study of Helgerud et al. (2007), HIIT with 4 sets of 4 repetitions (4x4) procedure performed at an intensity of 90-95% of maximal heart rate showed improvement in VO_2max and stroke volume compared to moderate training.

In a study of Heinrich et al. (2014), a high intensity training group utilized CrossFit training for 60 minute sessions which composed of aerobic (e.g., rowing), bodyweight (e.g., push-ups), and weightlifting (e.g., deadlifts) exercises in singular or multiple combinations. The results showed that the participants spent significantly reduced time to perform the exercise, were able to maintain exercise enjoyment and likely to adhere and sustain doing this type of training to maintain fitness.

It is also important to assess the initial responses of the participants in terms of adherence and enjoyment when performing HIIT. Adherence is defined as the number of sessions attended divided by the total number of training sessions or completing 90% of exercise sessions. It should be noted that the recommended adherence level of 80-85% is needed in order for an intervention to be qualified as satisfactory and have a therapeutic value (Pisters et al., 2006). Contradicting results regarding enjoyment level were reported (Carlson et al., 2012; Heuvelen et al., 2006; Bartlett et al., 2011; Martinez et al., 2015; Saanijoki et al., 2015). The common answer of participants when asked why they are interested to take part in a study was “I enjoy doing exercise” (Carlson et al., 2012). However, evidence showed that adherence to exercise training was frequently very low and that 50% of people who begin on an exercise program discontinue within 6 months of training (van Heuvelen et al., 2006). In a study of Bartlett et al. (2011) which used a prescription strategy of 3-minute intervals at a stimulus intensity of 90% of VO_2Peak and a 3-minute recovery period at an intensity of 50% of VO_2Peak; both training conditions had an average intensity of 70% of VO_2Peak. Results demonstrated that it was more enjoyable to exercise with high intensity shorter interval trials (60 sec) compared to a longer interval or heavy continuous exercise (120 sec) (Bartlett et al., 2011; Martinez et al., 2015). In contrast, outcomes revealed that the initial responses to HIIT among sedentary men were increased negative emotions and exertion; although, displeasure decreased over time (Saanijoki et al., 2015). Thus, with these findings, it is critical to identify what kind of HIIT protocol is realistic and functional for sedentary older adults.

2.3.3 General Health, Physiological, and Performance Adaptations with HIIT

There are similar beneficial training-induced improvements when training with HIIT as when performing endurance training (Ramos et al., 2015; Gibala et al., 2012; Burgomaster et al., 2005; Gibala et al., 2006; Rakobowchuk et al., 2008). Ramos et al. (2015) suggested at least 12 weeks of 4 sets of 4 repetitions (4x4) HIIT, done three times per week is a powerful form of training to improve brachial artery vascular function. Likewise, the HIIT study model of Gibala et al. (2012) which takes only 10 mins of exercise over a 20 min. training session is effective for inducing rapid skeletal muscle remodelling and improving functional performance. The model consists of 10x60 sec work bouts at constant intensity corresponding to approximately 90% of maximal HR, combined with 60 sec of recovery. Physiological improvements seen when performing HIIT were increased skeletal muscle oxidative capacity and cardiovascular adaptation. In addition, other endurance-like adaptations have been recorded after several weeks of performing HIIT including an increased resting glycogen content, reduced rate of glycogen utilization and lactate production during matched-work exercise, an increased capacity for whole-body and skeletal muscle lipid oxidation, enhanced peripheral vascular structure and function, improved exercise performance as measured by time-to-exhaustion tests or time trials and increased maximal oxygen uptake (Burgomaster et al., 2005; Gibala et al., 2006; Rakobowchuk et al., 2008).

2.3.4 HIIT in older adults

The most commonly mentioned barrier to regular exercise participation is “lack of time or have no time to exercise” (Springen, 2012). Therefore, it is important to design an exercise protocol that is time efficient while at the same time having wider application to different populations, especially older adults including those at risk for chronic medical conditions.

The ACSM Position stand (2014) states that it is very essential to consider the duration, intensity, frequency of the work intervals, and the length of the recovery intervals when formulating a HIIT program. The intensity during the high intensity work interval should range ≥80% of the estimated maximal HR (e.g. feel like exercising very hard, difficult to carry on a conversation), while the intensity of the recovery interval should be 40-50% of the estimated maximal HR (i.e., feel very comfortable), in order to help the body recover and prepare for the next work interval. The relationship of the work and recovery interval is essential in order to improve the different energy systems of the body. The ratio of exercise to recovery usually ranges from 1:1 to 1:3 (e.g. 1:1 ratio might be a 3 min. high intensity hard work bout followed by a 3 min. low intensity recovery bout). Also, the "sprint interval training method" is another popular HIIT training protocol. This kind of program will have 30 sec. of "sprint or near full-out effort" which will be followed by 4 to 4.5 min. of recovery and can be repeated 3 to 5 times. These higher intensity work efforts are usually shorter bouts (30 sec) with sprint interval training (ACSM, 2014).

It is important to describe the methods used for HIIT that have proved to be effective. Some of the HIIT protocols that are widely used are the Tabata Training Method (Tabata et al., 1996), Gibala & Little Method (Gibala & Little, 2006), and the Turbulence Training Method (Ballantyne, 2003) (Table 2.2).

It would be beneficial to collect evidence and compare the impact of HIIT in relation to other intensities of exercise training. Based on a meta-analysis of Ramos et al. (2015), seven randomized trials comparing the effects of at least 2 weeks of HIIT and moderate-intensity continuous training were investigated. The studies used the common HIIT prescription of four intervals of 4 min (4 × 4 HIIT) at 85–95 % of maximum or peak heart rate (HRmax/peak), interspersed with 3 min of active recovery at 60–70 % HRmax/peak, three times per week for 12–16 weeks. Results revealed that HIIT was more effective at improving brachial artery vascular function than moderate-intensity continuous training. HIIT also had a greater tendency than moderate-intensity continuous training to induce positive effects on secondary outcome measures, including cardiorespiratory fitness, traditional cardiovascular disease risk factors, oxidative stress, inflammation, and insulin sensitivity (Ramos et al., 2015). Tjonna et al. (2008) concluded that high-intensity exercise training (90% of highest measured heart rate) yields more favorable results than programs with low to moderate intensities for reducing the risks of metabolic syndrome. The study showed an increase in maximal oxygen consumption and was associated with removal of more risk factors that constitute the metabolic syndrome. As well, HIIT is superior to continuous moderate-intensity exercise for enhancing endothelial function, excitation-contraction coupling, reducing blood glucose and lipogenesis in adipose tissue. The effects of HIIT were similar to continuous moderate-intensity exercise for decreasing mean arterial blood pressure, body weight and fat (Cauza et al., 2005).

Low-volume HIIT (10 × 60-sec cycling bouts eliciting ∼90% maximal heart rate, interspersed with 60 sec rest) can greatly improve glucose control and induce adaptations in skeletal muscle that are linked to improved metabolic health in patients with type 2 diabetes (Little et al., 2011). Similarly, a study of Parpa (2008) examined the effect of HIIT in type 2 diabetic patients using 3-minute warm-up period, several short (2-min), maximum-intensity (80-90%) efforts separated by moderate intensity (50-60%) recovery intervals (2-min) and a 3-minute cool down period on cardiovascular autonomic function as determined by heart rate variability. HIIT resulted in significantly greater heart rate variability in type 2 diabetics after 12 weeks of training. Also, there was significantly lowered heart rate, systolic blood pressure, diastolic blood pressure, fasting glucose levels (Parpa, 2008), total and trunk fat mass, and improved lipid profile and triglyceride / high-density lipoprotein ratio (Gremeaux et al., 2012). Insulin resistance is primarily located in the leg muscle (Olsen et al., 2005) suggesting that HIIT exercise performed on a stationary cycle ergometer, that focuses on the legs is likely to show the greatest increases in insulin sensitivity (Boutcher, 2011).

2.3.5 Limitations of HIIT

A study of Nybo et al., (2010) showed that HIIT for 12 weeks was an effective training stimulus for improvement of cardiorespiratory fitness and glucose tolerance, however, HIIT was less effective than prolonged training in the management of hyperlipidemia and obesity. Moreover, in comparison to strength training, 12 weeks of HIIT had no impact on muscle mass or indications of skeletal health (Nybo et al., 2010). Therefore, HIIT is not as effective for increasing muscle strength and power. In addition, there was high risk for injury and muscle soreness especially the deconditioned older adults since performing HIIT is a strenuous training (Nybo et al., 2010). Thus, proper diligence and guidance from an experience exercise trainer is very important.

2.4 High-Intensity Resistance Training (HIRT) for Older Adults

2.4.1 Definitions and Importance of HIRT

Strength training is a combination of selected resistive training exercises that are performed in a sequence or repetitions with variable rest (30–300 sec) periods to cause desired changes in strength, muscular endurance or size by overloading a group of muscles. Resistance that is progressed occasionally to maintain intensity is called progressive resistance strength training. (Sagiv, 2009).

HIRT is a type of progressive resistance training that focuses on the number of repetitions, the amount of weight, and the amount of time the muscle is exposed to tension (Philbin, 2004), in order to induce muscular contraction which builds strength, anaerobic endurance, and size of skeletal muscles; resulting in enhanced muscle power and functional performance (Caserotti, 2010). HIRT exercises usually commence with a 70-89% of 1 repetition maximum (RM) as baseline (Raymond et al., 2013). HIRT can provide significant functional benefits and improvement in overall health and well-being, including increased bone, muscle, tendon and ligament strength and toughness, reduced potential for injury, increased metabolism and elevated high density lipoprotein level (Shaw, 2008; 2014). Thus, this form of exercise makes it suitable for training programs for older individuals (Sagiv, 2009).

2.4.2 Acute Responses to HIRT

Several researchers suggested that the muscle of older adults are damaged more easily with loading which makes them vulnerable to muscle soreness and injuries after exercise compared with muscles of younger people (Frontera et al., 1988; Meredith et al., 1989; Manfredi et al., 1991; Fielding et al. 1991; Roth et al., 2000). Older adults who perform regular strength exercise may require higher dietary requirements to promote optimal muscle growth than the younger people who perform the same exercise (Meredith et al., 1989). In order to maintain and regain muscle in older adults when performing exercise, Bauer et al., (2013) recommended an increase of dietary protein intake or providing supplemental protein of at least 1.2 gm protein/kg BW/day; prescribing a 20-gm protein supplement after exercise sessions.

Table 2.2 High Intensity Interval Training Protocols

Parameter	**Tabata Training** (Tabata et al., 1996)	**Gibala & Little Training** (Gibala et al., 2006)	**Turbulence Training** (Craig Ballantyne, 2002)
Work Intensity	-Most common -High intensity vs. moderate intensity	Low volume sprint-interval training	Alternate high-weight/low-rep strength training with high-intensity endurance training
Activity	All out cycling	All out cycling	Combination of strength and endurance movements
Exercise Protocol	2:1 (20 seconds On, 10 seconds Off)	1:8 (30 seconds On, 240 seconds Off) 1:6 (10 seconds On, 60 seconds Off)	8-rep weight training sets alternated with 1-2 minute endurance sets
Total exercise training time	4 minutes (total of 8 intervals)	2–3 min (4-6 intervals)	4 minutes (8 intervals)
Frequency	2-4 times per week for 6 weeks	3 times per week for 2 weeks	3 times per week
Training Protocol	5 minutes warm up 4 minutes intense exercise 5 minute cool down	15 min (intervals only)	5 minutes warm-up 8-rep set of weightlifting movement followed by 1 min endurance sets 5 minute cool down
Total session training time	14 minutes	18–27 min	45 minutes
Advantages	7 ml/kg/min increased VO_2max 28% increased anaerobic capacity	Time efficient strategy to increase muscle buffering capacity and glycogen content comparable to endurance training	Improved VO_2max and burned 200% more fat than endurance training (King, 2001)

2.4.3 General Health, Physiological, and Performance Adaptations in HIRT

Training-induced adaptations have positive effects on the aging skeletal muscle and depend on the intensity, frequency, duration, and mode of exercise (Rogers & Evans, 1993; Coggan et al., 1992; Kraemer et al., 1996; Hurley et al., 1998; Adams et al., 1999; Fleck & Kraemer, 1987; Pearson & Massetti., 1999). In relation to osteoporosis, numerous investigations revealed the relationship between muscle mass and bone mineral density (BMD), as well as the effects of weight bearing on bone and suggested that osteoporosis and sarcopenia are related (Sinaki et al., 1996; Wolff et al., 1999; Nguyen et al., 2000; Kronhed et al., 1998; Nelson et al., 1994). These studies showed that aerobic exercises and strength training that greatly load the lower extremity prevent or slow osteoporosis. Muscle contractions during strength training repetitively load the bone which in turn can maintain or increase BMD. With appropriate strength training exercise, some of the age-related physiological changes that occurred in the muscle (i.e., sarcopenia, reduced lean mass, and decrease strength), and in the bone (i.e., fractures) can be altered, slowed, or can be even partially reversed (Hakkinen et al., 1998; Harridge et al., 1999; Frontera et al., 1988; Brown et al., 1990).

High-intensity strength training improved oxidative capacity of elderly participants' muscle with an increased capillary per muscle fiber ratio of 15% (Frontera et al., 1988). This finding was evident in a 6 months randomized controlled pilot study of older adults with symptomatic peripheral arterial disease that revealed considerable improvement with 6 min. walk ability with intermittent claudication compared to performing low intensity resistance training; this was related to an increased endurance in the bilateral calf and hip extensor muscle (Parmenter et al., 2013). In the management of hemiparesis after a stroke (~6.5 yrs.), HIRT performed on the less affected dorsiflexor resulted to increase muscle activation in the more affected tibialis anterior muscle. Muscle activation remarkably increased bilaterally in the trained leg (~59%) and untrained leg (~20%) (Dragert and Zehr, 2013).

Studies show that high-intensity resistance training can have an important effect on strength and CSA in older adults (Hakkinen et al., 1998; Harridge et al., 1999; Frontera et al., 1991; Brown et al., 1990; Fiatarone et al., 1990). With training, the observed increases in strength are greater that the gains observed in muscle CSA (Hakkinen et al., 1998; Harridge et al., 1999; Taaffe et al., 1990; Brown et al., 1990). Increases in strength occur not only from muscle hypertrophy (muscle CSA), but also as a result of training-related changes in the recruitment and firing rates of MU (neural adaptations) (Hakkinen et al., 1998). HIRT conducted with untrained older people reported that neural adaptations are the primary source of strength gains in the first 8 weeks of training, while increases in muscle hypertrophy are the primary source of strength gains afterwards (Kraemer et al., 1996). In HIRT studies among older adults (60-97 years) that consisted of 2 lower extremity exercises – the bilateral leg press and the knee extension exercise, there were significant strength improvements of the quadriceps femoris muscle of 30-60% (Hakkinen et al., 1998), 134% (Harridge et al., 1999), and 48-174% (Brown et al., 1990; Fiatarone et al., 1990) with smaller to moderate increase in the CSA from 27.5 +/- 9.6 cm^2 to 30.2 +/- 10.0 cm^2 of 10% (i.e., lean CSA – contractile tissue only) (Harridge et al., 1999), and 15-17% (Brown et al., 1990; Fiatarone et al., 1990; Hakkinen et al., 1998).

A number of studies have compared HIRT with lower intensities of resistance training ((Fatouros et al., 2005a; Cassilhas et al., 2007; Vincent et al., 2002; Harris et al., 2004; Kalapotharakos et al., 2004; Willoughby et al., 1998). A meta-analyses conducted by Raymond et al. (2013) defined HIRT as 70-89% of 1RM, maximal intensity as 90% 1RM, moderate intensity resistance training as 50-69% 1RM, and low-intensity resistance training as <50% 1RM. The majority of events reported for HIRT were minor musculoskeletal injuries, and there were no deaths because of high-intensity training. Thus, the risks associated with HIRT showed no difference in rates of adverse events between intensities of training (Raymond et al., 2013).

Reported trials on lower-limb strength showed data preferring HIRT over low intensity resistance training (LIRT) (Seynnes et al., 2004; Singh et al., 2005; Taaffe et al., 1996; Hortobagyi et al., 2001; Pruitt et al., 1995) or moderate intensity resistance training (MIRT)(Fatouros et al., 2005a; Cassilhas et al., 2007; Kalapotharakos et al., 2004). Results of additional investigations benefiting from the use of high intensities versus low intensities revealed greater bone mineral density (Tsuzuku et al., 2001), positive outcomes in terms of muscle power, strength and endurance, stair-climbing power, chair-rising time, and 6 min. walk (Ramirez et al., 2014; Seynnes et al., 2004). Also, quality of sleep is improved, treatment of depression in older patients is more effective, and thus, quality of life is improved (Singh et al., 2005). These results also correspond to improved muscle power of 98% of the injured leg compared to 83% of non-injured leg at week 20 after anterior cruciate ligament reconstruction using high intensity resistance training (Bieler et al., 2014). Therefore, HIRT appears to be as safe as lower intensity resistance training but was more effective physiologically and functionally (Seynnes et al., 2004).

Despite the advantages of performing HIRT, studies show that improvements gained in performing HIRT can also be achieved by using lower intensities when exercise training. Functional improvements revealed with HIRT in older adults, such as ability to stand from a chair (Rosendahl et al., 2008; Fiatarone et al., 1990), reduced need for walking aids (Fiatarone et al., 1990), and self-paced gait speed (Rosendahl et al., 2008) are similar to improvements with moderate and low intensity resistance training (Steib et al., 2010). Likewise, HIRT and moderate intensity resistance strength training have also been shown to have a favourable impact on depression and quality of life (QOL) across 6 of the 8 health-related QOL domains: physical function, role physical, vitality, social function, role emotional, and mental health (Cassilhas et al., 2007; Singh et al., 2005). Furthermore, some studies have shown that limited function and falls might be a result of reduced flexibility in older adults (Jette et al., 1990; Thrash & Kelly, 1987). In a review of Raymond et al., (2013), HIRT and moderate intensity resistance training similarly improved flexibility by increasing knee flexion and hip extension range of motion compared to when using low intensity resistance training. Thus, arguments exist that HIRT may not be needed to improve functional performance, as performing lesser intensities can resolve these problems (Raymond et al., 2013).

2.4.4 Limitations of HIRT

With high intensity resistance training (HIRT), there was an increase in maximal cardiac output combined with a widening of maximal arteriovenous oxygen difference and increased fat-free mass (Hurley et al., 1984). However, HIRT produced no changes in both cardiac contractility and cardiovascular adaptive function. This lack of cardiovascular adaptation may be due to the low percentage of VO_2max elicited by this form of exercise (Hurley et al.. 1984). After a single session of strength training, cardiac sympathetic modulation and heart rate remain elevated in elderly subjects, keeping cardiac work elevated for a long period of time (Queiroz et al., 2013). Heart rate (HR) and systolic blood pressure (SBP) response to resistance training are related to the intensity and duration of the exercise. Similarly, another study determined that HIRT was effective for increasing muscle mass and strength, but does not promote changes in cardiovascular function or autonomic neural regulation (e.g. blood pressure, cardiac output, systemic vascular resistance, stroke volume, and heart rate) (Kanegusuku et al., 2015). Therefore, exercise training that improves strength, power as well as cardiovascular capacity is needed.

2.5 Concurrent Training for Older Adults

2.5.1 Definition and Importance of Concurrent Training

Simultaneously combining both resistance and endurance exercise within a training program is known as concurrent training (Fyfe et al., 2014). It is also defined as an exercise routine that completes the cardiovascular and strength training workouts during the same training cycle (Sporer & Wenger, 2003).

According to guidelines for whole-body physical fitness conditioning and exercise prescriptions for health, both endurance and resistance exercises should be integrated in exercise training programs with a frequency of up to three and two times a week, respectively (Haskell et al., 2007). Performing two different exercises individually on different days during trainings, however, could be demanding in terms of time. As mentioned in the previous section, lack of time was commonly reported to be among the barriers that could influence compliance and sustainability when performing a physical exercise program. (Moschny et al., 2011). The simultaneous execution of both endurance and resistance exercises in the same training session, would be a realistic solution to this problem of lack of time (ACSM, 2010; Drummond et al., 2005 Haddock et al., 2006). The use of concurrent training also provides variation in performing exercise training (Villaca et al., 2011).

2.5.2 Acute Responses to Concurrent Training

Coffey et al. (2009) determined the acute molecular responses to different contractile stimuli (resistance vs. endurance exercise) by doing concurrent training exercise in subjects who had training experience in both modes of exercise. Subjects performed either resistance exercise followed by a session of endurance exercise, or vice versa, with muscle biopsies taken before and 15 min after the exercise sessions, and following 3 hours of recovery. The effect of the combined exercise protocols resulted in different mRNA responses revealing that (acute) concurrent training does not stimulate the ideal activation of pathways that simultaneously promote both anabolic and endurance responses (de Souza et al., 2013).

A 5 weeks study of concurrent training versus resistance training alone on quadriceps femoris cross-sectional area (CSA) and isokinetic/isometric strength, showed muscle hypertrophy; however, no between-limb/group differences in isometric strength was noted when resistance was preceded by aerobic exercise, compared with resistance training alone (Lundberg et al., 2013; Souza et al., 2013). In 2005, the study of Atherton and colleagues revealed that concurrent training might induce different types of signalling responses in skeletal muscle. The researchers electrically stimulated the isolated rat muscles with either high frequency (to imitate resistance exercise) or low frequency (to imitate endurance exercise), to determine exercise-specific signalling responses. Resistance-based exercise stimulates the signalling to regulate the synthesis and/or breakdown of proteins and, over a prolonged period (weeks to months), develops muscle hypertrophy, whereas endurance-based exercise activates signalling pathways involved in metabolic homeostasis. This activation of the pathways for metabolic homeostasis by endurance training may inhibit the signalling and suppress resistance-exercise-induced muscle-protein synthesis. However, due to the limited studies in this field, further research is needed.

2.5.3 General Health, Physiological, and Performance Adaptations with Concurrent Training

In spite of the visible potential benefits of Hickson's study of concurrent training in 1980, it has been recognised that combining resistance and endurance exercises results in compromised adaptation, in contrast with training for either exercise mode alone (Leveritt et al., 1999). This is known as the interference effect or concurrent training effect (Hawley, 2009; Wilson et al., 2012). The interference effect results in compromised resistance training adaptation compared with performing only resistance training. For instance, several studies reveal that concurrent training results in compromised strength (Hickson, 1980; Bell et al., 2000; Dolezal & Potteiger, 1998; Hakkinen et al., 2003; Kraemer et al., 1995), hypertrophy (Hickson, 1980; Kraemer et al., 1995; McCarthy et al., 2002), and power development (Hakkinen et al., 2003; Hennessy & Watson, 1994; Hunter et al., 1987).

Studies investigated the effects of concurrent training by utilizing either endurance or strength training alone or the combination of both (Dolezal & Potteiger, 1998; Medeiros et. al, 2015; Gergley, 2009; Chtara et al. (2008). In examining the effects of two different modes of lower body endurance exercise (cycling and incline treadmill walking) on lower body strength development with concurrent resistance training designed to improve lower body strength (i.e., bilateral leg press 1 repetition maximum (RM)), findings revealed reduced strength development with concurrent training compared with resistance-only training (Gergley, 2009). Also, solely exercising on circuit training induced significantly greater improvements in strength and power compared to concurrent training (Chtara et al., 2008). Furthermore, performing only resistance training increased basal metabolic rate and muscular strength, and executing endurance training alone increased aerobic power and decreased body fat; while, concurrent training increased both of these beneficial qualities, but to a lesser degree (Dolezal & Potteiger, 1998).

On the other hand, outcomes also concluded that concurrent training produced significant increases in maximal and explosive strength, walking speed and balance, general and mental health, and in improvement in the management of pain (Holviala et al., 2012; (Sillanpaa et al., 2012). Concurrent training can increase both short (<15 min) and long-duration (>30 min) endurance performance by enhancement of neuromuscular function (Aagaard & Andersen, 2010). In addition, concurrent training improved insulin sensitivity in healthy and obese nondiabetics (Kahn et al., 1990; Kirwan et al., 1993; Miller et al., 1994; Balducci et al, 2010; Rennie et.al, 2003). Markedly, the positive effect on insulin sensitivity has been shown 12-48 hours after the last exercise session, however, pre-exercise levels return in 3-5 days (Eriksson et al., 1997), emphasizing the importance of performing regular exercise.

There are several investigations on concurrent training in relation to cardiovascular and cardiorespiratory adaptations (Davis et al., 2012; Hama & Magied, 2014; Gur et al., 2012; Sodowsky (2007). An investigation in younger population, showed larger gains in terms of decrease systolic and diastolic blood pressure, increased estimated VO_2max, and an inclination toward decreased resting heart rate (Davis et al., 2012; Hama & Magied, 2014). In another study, the interference effect of concurrent training did not manifest in 6 weeks in relation to strength and VO_2max in 22 year old sedentary healthy men (Gur et al., 2012). It revealed no significant difference for increases inVO_2max between concurrent (16%) versus endurance training (18%) and for increases in maximum strength between concurrent (31%) versus strength (39%) training (Gur et al., 2012).

Regardless of the reported interference effect (Hickson, 1980; Leveritt et al., 1999; Wilson et al., 2012; Karavirta et al., 2011) on strength gains when performing concurrent training, it is still considered the most effective and practical approach to counteract the weakening effects of aging as concurrent training improves neuromuscular and cardiorespiratory functions along with functional capacity in the elderly (Cadore & Izquierdo, 2013). Concurrent training completed with different weekly training frequencies does not affect the beneficial outcomes of concurrent training in the elderly population as it promotes comparable increases in neuromuscular and cardiovascular adaptations whether performed once, twice or three times a week when executing the same exercise program (Izquierdo et al., 2004; Umpierre et al., 2014). With the conflicting results and limited data on concurrent training on older adults, it is imperative that further research is needed.

2.5.4 Limitations of Concurrent Training

As quoted in a review of concurrent strength and endurance training by Leveritt et al. (1999), two hypothesis were emphasized by Craig et al. (1991) explaining why concurrent training may not be beneficial. The first chronic adaptation hypothesis states that "skeletal muscle cannot adapt metabolically or morphologically to both strength and endurance training simultaneously". This was due to the fact that the adaptations that take place at the muscle level in response to strength training are different to those found with endurance training (Crag et al., 1991; Leveritt et al., 1999). The second acute response hypothesis states that "residual fatigue from the endurance component of concurrent training compromises the ability to develop tension during the strength element of concurrent training". This was due to the implied reduction in the quality of strength training due to fatigue following endurance training, which would result in a decrease in strength development over time (Crag et al., 1991; Leveritt et al., 1999). These results were supported by Wilson et al. (2012) that analyzed 21 studies on concurrent training. Findings revealed that power was significantly decreased in the concurrent training group versus the strength training group. In addition, concurrently performing strength training and running led to significant decrease in hypertrophy and strength gains (Wilson et al., 2012). Therefore, further research is needed to assess the responses on concurrent training especially in the older population.

2.6 Summary of Limitations in Current Knowledge

There have been numerous studies indicating the importance of high intensity resistance training (HIRT) to maintain independent function and health especially in the older adult population. However, resistance training alone has a moderate effect on cardiovascular function and frequently requires additional exercise methods in order to attain cardiovascular benefits when training (Raymond et al., 2013; Frontera et al., 1998; Ramirez et al., 2014; Seynnes et al., 2004; Daly et al., 2005; Singh et al., 2005). On the other hand, high intensity interval training (HIIT) has superior cardiovascular advantages to HIRT (Guiraud et al., 2011; Gibala, 2009; Tabata et al., 1996; Helgerud et al., 2007; Heinrich et al., 2014). Undertaking these two types of training separately would be time-consuming. Therefore, combining these two types of training into one session would be a sensible solution (Dolezal & Potteiger, 1998; Izquierdo et al. 2004; Cadore et al., 2013; Holviala et al. 2012; Sillanpaa et al. 2012; Karavirta et al. 2011). With concurrent training, the older adult will continue to be physically fit, as well as, have pleasure in exercising as it was shown to reduce the monotony (i.e. repetitiveness and boredom of performing the same set of exercise movement) when exercise training (Villaca et al., 2011).

Despite the numerous studies looking at the effects of concurrent training, there are still inconsistencies in the findings, with some studies claiming it to be effective and other investigations showing it to be detrimental to strength, power, or endurance adaptations. In addition, there are many concurrent training studies conducted with younger athletic individuals; however, limited research has been conducted using high-intensity training for the older adult population. Consequently, there is a need to perform further assessment on this area. Therefore, this study developed a time-efficient multi-modal exercise training that primarily focuses on strength, power and high intensity endurance to improve functional performance for older adults and called this High intensity functional interval training (HIFIT) for older adults or the "HIFIT Protocol". The aim of this study was to compare the effects of high-intensity functional interval training (HIFIT) with high-intensity resistance training (HIRT) in terms of muscle strength, body composition and aerobic capacity as an exercise intervention for promoting health, and maintaining functional abilities among the older adult population.

2.7 Research Objectives and Hypotheses

Given the importance of being physically active, the increasing population of older adults, and the so many different types of exercises available, all claiming to be the universal perfect exercise for everyone, it was essential to gain knowledge on commonly used exercise methods and functional abilities of older adults and be able to formulate a functional training program that would assist practitioners and allow them to better design, prescribe and implement an exercise management program for the support of older adults.

The specific objective of this study was to examine the effects of six (6) weeks of high-intensity functional interval training (HIFIT) compared with high-intensity resistance training (HIRT) on functional abilities in older adults. This objective was addressed by conducting six (6) weeks exercise training in the gym using the two methods in older adult participants with outcome measures to determine aerobic fitness and body composition (i.e., VO_2max, DEXA) functional testing.

Hypothesis '1:' HIFIT and HIRT would result in similar increases in muscle mass, strength and functional performance, as well as decrease in fat mass. This was addressed by measuring pre-test and post-test data with participants performing the 4RM bench press (BP), 3RM deadlift (DL), and bench press (BP) endurance. BP endurance was executed by computing 80% of the weight that participants are able to lift for BP and lifting the weight as many repetitions as they could. Fat and muscle mass measurement was taken by the use of the dual energy x-ray absorptiometry (DEXA) scan. Functional abilities were tested by performing sit to stand (STS), incremental shuttle walk test (ISWT), stair climb power test (SCPT), time up and go (TUG), and gait speed tests (FGS/CGS).

Hypothesis '2:' HIFIT would result in greater increase than HIRT in aerobic capacity (i.e. maximum oxygen consumption (VO_2max), anaerobic threshold (AT) and respiratory compensation threshold (RCT). This was addressed by having the participants perform VO_2max testing.

Hypothesis '3' HIFIT and HIRT would have similar level of physical activity enjoyment and self-confidence feedback after the training. This was addressed by asking the participants to answer the Exercise Self-Efficacy and Physical Activity Enjoyment Scale questionnaires after the 6 weeks exercise training.

Table 2.3 Summary Differentiation between HIRT, HIIT and Concurrent Training

Parameter	High Intensity Resistance Training (HIRT)	High Intensity Interval Training (HIIT)	Concurrent training
Definition	A progressive resistance training that focuses on the number of repetitions, the amount of weight, and the amount of time the muscle is exposed to tension (Philbin, 2004).	A short, intense workout type of endurance exercise usually lasting from 4-30 minutes; applying alternate exercise periods between high and low intensity exercise or between high intensity anaerobic exercise and short periods of rest (Tabata et al., 1996; Shiraev, 2012)	Simultaneously combining both resistance and endurance exercise within a training program (Fyfe et al., 2014).
Aim	To induce muscular contraction which builds strength, anaerobic endurance, and size of skeletal muscles (Caserotti, 2010).	To improve speed, cardiovascular fitness, glucose metabolism, and fat burning (Laursen et al., 2002; Perry et al., 2008; Talanian et al., 2006).	To increase strength, power, and endurance in a time-efficient way (Dolezal and Potteiger, 1998; Izquierdo et al., 2004; Cadore et al., 2013; Holviala et al. 2012; Sillanpaa et al., 2012; Karavirta et al., 2011).
Principle	Overload	Brief, infrequent, and intense.	Overload. Brief, infrequent, and intense performed in short duration
Results/Benefits	Enhanced muscle power and functional performance (Caserotti, 2010).	Greater changes in endurance, cardiovascular health, and body composition (Humphrey, 2012)	Increases strength, power, and endurance adaptations (Hickson, 1980; Hawley, 2009; Wilson et al., 2012).
Limitations	Produced no changes in both cardiac contractility and cardiovascular adaptive function (Hurley et al., 1984).	Not as effective for increasing muscle strength and power (Nybo et al., 2010).	May decrease gains in muscle mass, strength, and power (Hickson, 1980; Leveritt et al., 1999; Wilson et al., 2012; Karavirta et al., 2011).

CHAPTER 3

METHODOLOGY

3.*1 Study Design*

This study is a group randomized trial design which assessed the functional capacity, muscle function and cardiovascular fitness of older adults using HIFIT.

The screening process and participant consent approval, maximal cardiopulmonary exercise training to obtain VO_2max, functional testing (i.e. stair climb power test, time up and go test, fast/normal walking test, sit-to-stand test and the incremental shuttle walk test) and data analysis were done in the Royal University Hospital (RUH) – University of Saskatchewan - Integrative Clinical Exercise Physiology Research Laboratory. The dual energy x-ray absorptiometry (DEXA) measurements were performed in the University of Saskatchewan – Kinesiology Gym – RJD Williams Building. The strength testing and training were done in Synergy Strength and Conditioning Gym, Saskatoon, Saskatchewan. All testing procedures and informed consent were approved by the University of Saskatchewan Research Ethics Board. (Appendices 1 and 2)

Prior to enrollment, the potential participants were screened for entry to check if they were fit to join the exercise study using the PAR-Q questionnaire. On enrollment, participants attended five separate phases (Fig.2). Phase 1 is subdivided into three stages: Taking vital signs, cardiopulmonary exercise test (VO_2max), and dual energy x-ray absorptiometry (DEXA). Phase 2 consist of assessing the functional abilities by performing the Jones and Rikli (2002) four common tests of functional performance; the stair climb power test (SCPT), the time up and go test (TUG), the gait speed test (comfortable and fast gait speed (CGS and FGS, respectively)), and the 30-seconds sit to stand test (30STS). Also, the incremental shuttle walk test (ISWT) (Singh et al., 2008) was performed. Phase 3 includes the six weeks training intervention done in the gym which compared HIFIT vs. HIRT. Phases 4 and 5 was a repeat of Phases 1 and 2 respectively, and was conducted after the 6-weeks training intervention period.

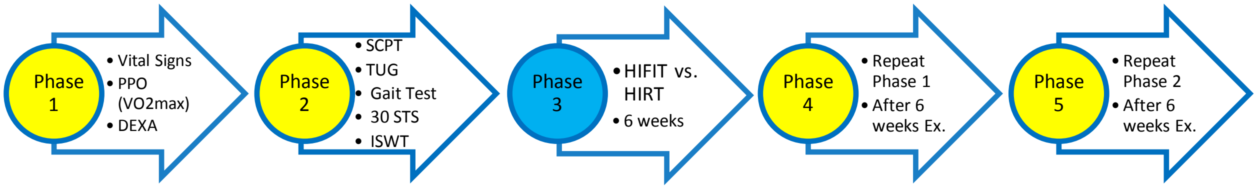

Figure 3.1: Study Design. Legend: PPO = peak power output, DEXA = dual-energy x-ray absorptiometry, SCPT = stair climb power test, TUG = timed up and go, STS = sit to stand, ISWT = incremental shuttle walk test, HIFIT = high intensity functional interval training, HIRT = high intensity resistance training

3.2 Participants

Thirty-one individuals were screened and nine of them did not qualify to take part in this research study due to health issues (i.e. recent operations, history of back problems, heart and blood pressure problems), and by reason of already doing weight training. Twenty-two apparently healthy older adults were enrolled and participated in this study, of which only twenty older adults trained and completed the six weeks of training program. Two dropped-out of the HIRT group due to conflict of schedules. Participants were grouped using convenience assignment based on their availability for training times and each group was then randomly assigned to complete either the HIFIT or the HIRT training program. (Fig. 4.2)

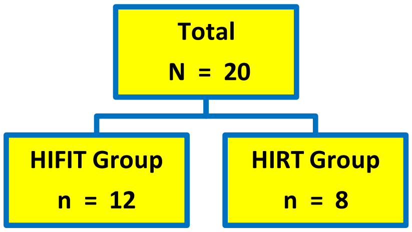

Figure 3.2: Study Participants

<u>Inclusion criteria:</u>

- At least 56 years old apparently healthy older adults
- Participants should be active, but are not performing weight training on a regular basis or not doing high-intensity aerobic training (i.e. jogging, high amounts of cycling) in the past 6 months

- Passed the medical screening and PAR Q form (e.g. follow-up with their family physician if necessary according to this form)

Exclusion criteria:

- Significant musculoskeletal, cardiovascular, or metabolic disease/illness that would limit their ability to exercise as determined by the PAR Q form.
- Taking medications known to influence cardiovascular or neuromuscular performance (i.e. beta blockers, insulin, bronchodilator and anti-inflammatory agents)

3.3 Test and Measures

3.3.1 Screening

Prior to enrollment, the potential participants were screened for entry to the study by answering the Physical Activity Readiness Questionnaire (PAR-Q). Participants were instructed to follow-up with their family physician as necessary according to this form. (Appendix 3)

3.3.2 VO_2max Testing

Initially, baseline vital signs were taken such as blood pressure, height and weight. Then, the participants performed the maximal cardiopulmonary exercise test to determine the individual's maximal aerobic capacity (VO_2max) by identifying the peak power output (PPO) using a cycle ergometer (stationary bike). VO_2max also known as maximal aerobic capacity is the maximum capacity of an individual's body to transport and use oxygen during exercise, which reflects the physical fitness of the individual (Guyton & Hall, 2011). The higher one's oxygen utilization capacity, the better is the potential for endurance during exercise. VO_2max is expressed either in litres of oxygen per minute (L/min) or in millilitres of oxygen per kilogram of bodyweight per minute (mL/kg/min) (Guyton & Hall, 2011).

To get the VO_2max, we used the Sensormedics Vmax pulmonary function test (PFT) machine. In order to get accurate results, the machine was calibrated before testing each participant, making sure that flow sensor flow rates are within the 2% standard acceptable range between 2.94 – 3.06 L and the calculated volume differences of the gas analyzer within the $\pm$ 0.03%, signifying an adequate performance. The participants are then asked to board the cycle ergometer and the seat heights are adjusted. A headgear was placed on the participant's head for the attachment of the mouthpiece to measure the gas exchange when breathing while executing the exercise. Also, a nose clip was put in place to make sure that the participant was only breathing through the mouthpiece. Detailed monitoring of vital signs was done by attachment of electrocardiogram (ECG), pulse oximetry, and blood pressure monitor. The test commenced with participants seated on the cycle ergometer for 2 minutes of resting breathing, followed by 3 minutes of warm-up at 0 watts pedalling the cycle ergometer. Then initial workload of 15 watts was automatically loaded by the machine and from then on, an incremental increase in resistance by 15 watts/minute ramp (i.e. 5 watts/20 secs) was applied while the participants tried to maintain a constant speed above 60 rpm (revolutions per minute). For each of the exercise sessions, participants were instructed to exercise as long as possible, until discomfort or exhaustion. Dyspnea (rate of perceived exertion (RPE)) was evaluated at 2-min intervals using the Borg CR-10 scale (0-nothing at all, 10-extreme), as well as the blood pressure. The time to exhaustion, symptoms of dyspnea, leg fatigue, total work performed, and reason for exercise termination (either dyspnea, leg fatigue, or both) were recorded. Upon cessation of the exercise, participants were given 3 minutes cool-down by continuous pedaling without resistance and given adequate periods of rest. Blood pressure should be normal or same as baseline before participants were allowed to leave the testing room.

3.3.3 DEXA Testing

Assessment of body composition was measured by using dual energy x-ray absorptiometry (DEXA) for whole body lean tissue (i.e. muscle), bone, and fat mass. DEXA is a simple, quick and non-invasive procedure to assess an individual's risk for developing fractures and is the most accurate method for diagnosing osteoporosis. DEXA is today's established standard for measuring bone mineral density (BMD).

The procedure took about 10 - 15 minutes and was conducted by a nuclear medicine technologist. This involved lying on a table while the participants' lumbar spine and hips are scanned with an X-ray, making sure there was no presence of any metal on the body. A DEXA scanner machine produces two invisible low beam x-rays with two distinct energy peaks; one peak is absorbed mainly by soft tissue and the other by bone. A special software computes and displays the participants' bone density measurements on a computer monitor. A T-score showed how much higher or lower the bone density is than that of a healthy 30-year-old, the age when bones are at their strongest. The lower the score, the weaker the bones are (i.e. T-score of -1.0 or above = normal bone density, between -1.0 and -2.5 = low bone density, or osteopenia, and -2.5 or lower = osteoporosis).

3.3.4 Functional Testing

Functional abilities were tested by performing the Rikli and Jones (2002) four common tests of functional performance; the stair climb power test (SCP), the time up and go test (TUG), the gait speed test (comfortable and fast gait speed (CGS and FGS, respectively)), and the 30-seconds sit to stand test (30STS). The tests were done thrice to get participants' baseline. These helped with test familiarization and improved reproducibility of the functional tests in the laboratory. In addition, incremental shuttle walk test (ISWT) (Singh et al., 2008) was also performed.

The stair climb power test (SCPT) measures the time it takes a participant to climb 9 steps of stairs as safely and as fast as they can without using the handrail. This test correlates with leg strength and anaerobic power (Bennell et al., 2011). The timed up and go (TUG) is a valid and reliable test to determine balance in elderly people. It correlates with gait speed, balance, functional mobility, and falls risk (Matias et al., 1986). It measures the time it takes a participant to stand up from an armless chair, walk a distance of three meters, turn, walk back to the chair, and sit down. This is important in tasks that require quick movements, such as getting off a bus in time or getting up to attend to something in the kitchen, to go to the bathroom or to answer the phone. The gait speed test is appropriate for goals of ambulation improvement. The participant was instructed to walk 10 meters and both comfortable (CGS) and fast gait speed (FGS) were tested. The ability to increase/decrease walking speed above or below a "comfortable" pace characterizes normal healthy walking and indicates the potential to adapt to varying environments (e.g. crowded hallways, crossing streets) (Steffen et al., 2002). The ability to stand from a chair is a crucial factor in independence in older adults; hence, sit-to-stand test was used to assess lower-extremity strength and balance. A participant was directed to stand up and sit down as quickly as possible, keeping arms folded across the chest done for 30 seconds. They were instructed to fully sit between each stand and encouraged to complete as many full stands as possible within 30 seconds. The best of 3 trials of completed full stands was recorded for each test. Finally, participants performed the incremental shuttle walk test (ISWT) to identify maximal walking speed. The participant walked a 10 meters course for as long as possible, there and back, keeping to the speed indicated by the beeps at regular intervals on the cassette. Participants walked at a steady pace, aiming to turn around the cone at one end of the course upon hearing the first beep and at the other end when one hears the next beep. The aim is to follow the set rhythm for as long as possible. Each single beep indicates the end of a shuttle and each triple beep signals an increase in walking speed. The test is maximal and progressive which means it is easier at the start and harder at the end. Participants stopped walking only when one became too breathless to maintain the required speed or could no longer keep up with the set pace. The number of stages and cones were recorded.

3.3.5 Repetition Maximum (RM)

Repetition maximum (RM) is the number of repetitions that one can lift a weight maximally 3 or 4 times (3RM or 4RM). In identifying the RM, the participant estimated a light warm-up weight which they could lift easily for 6-8 reps then they were instructed to rest. Then the weight was increased by adding 5-20 pounds (2-8 kg) or 5-10% to the light warm-up weight and the movement completed in 5-7 reps. Next the participant estimated a conservative, near-max weight with which they could complete 3-4 reps. This was done for the core movements of 3RM deadlift and 4RM bench press. Upon identification of the 4RM bench press, 80% of the weight was calculated and recorded to use for the bench press endurance. The participant performed as many bench presses as he could until he could no longer execute the movement properly. In addition, a rest of 2 to 5 minutes was given every time there was an increase in the weight and if repetitions are made.

3.3.6 Exercise Self-Efficacy and Level of Enjoyment

The participants for both the HIFIT and HIRT group were tested for their feedback for exercise self-efficacy (confidence) and enjoyment by answering questionnaires after the 6 weeks training study. Self-efficacy for the exercise training was measured using the Exercise Self-Efficacy Scale (EXSE) (Bandura, 1997; Shin et al., 2001) and enjoyment to the exercise was measured using the Physical Activity Enjoyment Scale (PACES) (Kenzierski et al., 1991).

The EXSE questionnaire assessed the individual's beliefs in their ability to continue exercising on the frequency of three times per week at high intensities for 30+ minutes per session in the future. For each item, participants indicated their confidence to execute the behavior on a 100-point percentage scale comprised of 10-point increments, ranging from 0% (not at all confident) to 100% (highly confident). Total strength for each measure of self-efficacy is then calculated by summing the confidence ratings and dividing by the total number of items in the scale, resulting in a maximum possible efficacy score of 100 (McAuley, 1993; Bandura et al., 1997).

Meanwhile, the PACES questionnaire consists of 18 bipolar statements rated on a seven point scale (Kenzierski & DeCarlo, 1991). The participants were asked, "Please rate how you feel about the physical activity (i.e., high intensity training) you have been doing" based on a scale of 1 through 7. The PACES has items that are reversely scored (Appendix 7), with lower scores reflecting a greater level of enjoyment, for example, on Question 1, 1 = *I enjoy it* to 7 = *I hate it*. For questions without asterisks, higher scores indicate a greater level of enjoyment, for example, on Question 2, 1 = *I feel bored* to 7 = *I feel interested* (Kenzierski & DeCarlo, 1991).

3.4 Training Program (Muscle Strength and Endurance Training)

The exercise program consisted of ten weeks gym training done three times per week. This tested the methods HIFIT vs. HIRT. This gym phase has 4 sub-phases: two weeks familiarization, one week pre-testing measurements, six weeks proper intervention training, and another one week post-testing measurements. Throughout the whole training program, participants were closely supervised and monitored by coaches, insuring proper execution of exercise techniques. Appropriate coaching was rendered for individuals with mobility limitations in order to deliver the exercise safely and accurately within the exercise training standards and protocol. Training and testing sessions were preceded by a standardized warm-up and finished by a cool-down period. Testing was the same for the 1 week pre and post testing measurements, and was performed before and after the 6-weeks training intervention period. All tests were separated by at least 48 hours and were conducted at a similar time of day and under similar environmental conditions.

3.4.1 Familiarization

The first two weeks of the training sessions were familiarization sessions whereby participants were taught and given a chance to practice the movements used for testing and training. During these sessions, participants were objectively further assessed for any musculoskeletal limitations that would prevent full participation in the study. In the third week, baseline measurements were taken for 4RM (repetition maximum) bench press plus the 80% of the 4RM for the bench press endurance, and 3RM deadlift.

Fig. 3.3 Participant performing the deadlift.

Fig. 3.4 Double rope undulations executed by the participants.

The essential movements accomplished were deadlift, bench press, dumbbell press, back squat, pull ups or ring rows, bent-over rows, dodge ball slams, length sprints, low box steps-up, and double rope undulations. All movements were scaled to each individuals' functional and mobility abilities.

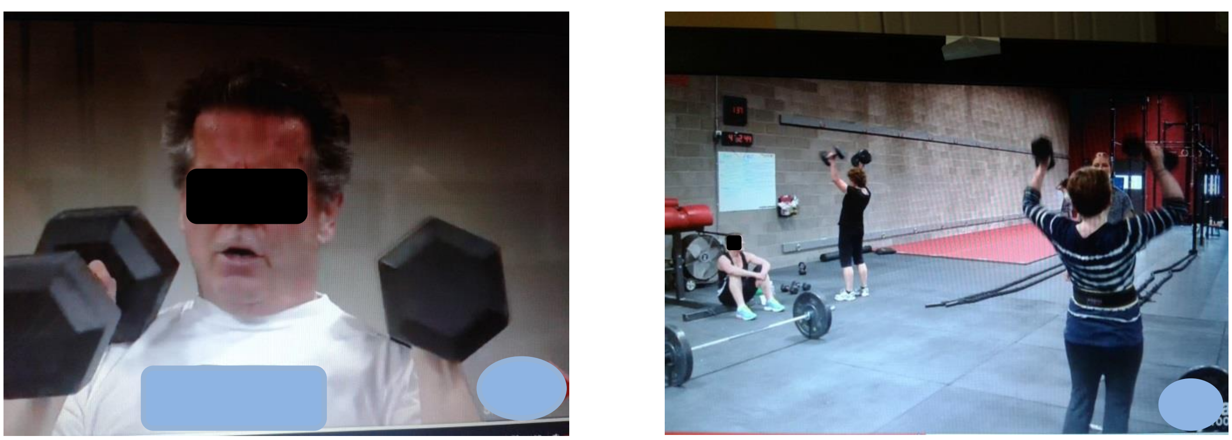

Fig. 3.5 Participants during the study training performing the dumbbell press.

3.4.2 Training Protocol

Exercise protocols are as follows:

- HIFIT Group: This group trained using multi-modal exercises for 6 sets. Each set was performed by 75 seconds of all out work, followed by 3 minutes and 45 seconds of rest (5 mins per set) (a total of 30 minutes each session). Each session had the same exercises within each set. There were three movements used in each set, namely: strength, power, and sprint like movements. The strength movement (i.e. bench press, back squat, deadlift) was for 6 repetitions. The faster body power movement followed the strength movement immediately, such as dumbbell press, dumbbell bent-over rows, pull up or ring rows, bench press for 12 repetitions. The very fast, sprint-like movement followed the body power movement such as dodge ball slams, length sprints, double rope undulation (battling ropes), low box step-ups, and sprint for the remainder of the 75 seconds. The intent of each set was to be completed with as much effort as possible across the full 75 seconds. (Table 3.1) (Appendix 4)
- HIRT group: This group trained two (2) movements per set (i.e., strength and faster body power). The group accomplished 6 sets of 5 minutes exercise with 30 seconds rest between the strength and power exercise movement of whole body resistance training (total of 30 minutes per session). The strength and power movements are the same strength movement as with the HIFIT group. Each session had the same exercises within each set. (Table 3.1) (Appendix 5)
- Training progression: The load was progressed in the next session if the participants were able to sustain all maximum repetitions for all the training movements across all 6 sets using the same exercise. Load progression depends on the participant's strength ability.

3.5 Statistical Analysis

All statistical analyses were performed using Statistica V8 (StatSoft, Inc., Tulsa, OK, USA). Repeated measures analysis of variance (ANOVA) was used to test the differences of the main effects between groups (i.e., HIFIT and HIRT) and changes across time (i.e., pre-training (week 0) and post-training (week 6)). Likewise, analysis of covariance (ANCOVA) was used when there was pre-testing difference between the groups (i.e., the pre-test difference of HIFIT & HIRT in relation to the post-test of either HIFIT or HIRT). Where appropriate, since there was unequal sample sizes, post hoc comparisons were conducted using Tukey's test to compare all means that were significantly different from each other. As well, internal consistency of the total scale for PACES 18 items was assessed with Cronbach's alpha. Tests results are reported as means ± SD (standard deviation). Significance was accepted at $p < 0.05$.

Table 3.1 Exercise Protocol for HIFIT and HIRT

Parameter	**High Intensity Functional Interval Training (HIFIT)**	**High Intensity Resistance Training (HIRT)**
Work Intensity	Alternate high-weight/high-rep strength training with high-intensity endurance training	High-weight/high-rep strength training
Activity	All out combination of strength and endurance movements	Strength movements
Exercise Protocol	1:3 75 seconds all out exercise 225 seconds rest Total: 300 seconds (5 mins) (6 sets)	1:3 30-45 seconds exercise 30 sec rest in between movements Additional 225 seconds rest after the second movement. Total: 300 seconds (5 mins) (6 sets)
Total exercise training time	75 seconds all out	30-45 seconds
Frequency	Three times per week for 6 weeks	Three times per week for 6 weeks
Training Times	5 minutes warm up 5 minutes exercise x 6 sets 5 minutes cool down	5 minutes warm up 5 minutes exercise x 6 sets 5 minutes cool down
Total session training time	40 minutes	40 minutes

CHAPTER 4

RESULTS

Twenty participants (55% females and 45% males) completed the exercise training program. There were no adverse events during the training programs. Frequency and descriptive data for other demographic information and baseline scores measured are in Table 4.1.

4.1. Body Composition in HIFIT vs. HIRT

4.1.1 Lean Mass

There was no significant group by time interaction ($p=0.22$). A significant time main effect was seen ($p=0.04$), showing both groups' lean mass increased over time. However, no notable group main effect ($p=0.12$), indicating no difference between HIFIT and HIRT groups. (Table 4.2)

4.1.2 Fat Mass

Results showed no significant group by time interaction ($p=0.96$). A vital time main effect was seen ($p=0.04$), revealing reduction of fat mass for both groups from pre-test to post-test. A group main effect for HIFIT and HIRT group at $p=0.05$, illustrated slight inclination for group difference but considered not significant. (Table 4.2)

4.1.3 Total Mass

Analysis revealed no significant group by time interaction ($p=0.14$). There was no notable time main effect ($p=0.32$) and no significant group main effect ($p=0.92$). (Table 4.2)

Table 4.1 Participant Demographics

Variables	HIFIT (n = 12)	HIRT (n = 8)
Age (years)	62.9 ± 5.0	61.1 ± 3.8
Gender (M:F)	8:4	1:7
Height (cm)	168.5 ± 8.7	166.4 ± 5.9
Weight (Kg)	74.1 ± 11.3	74.3 ± 10.2
Body Mass Index (BMI)	26.4 ± 3.1	27.3 ± 5.0

Data listed as Means ± Standard Deviation

Table 4.2 Body Composition of Participants during Pre-Test and Post-Test using the Dual Energy X-ray Absorptiometry (DEXA Scan) for Lean Mass, Fat Mass and Total Mass

Body Composition	HIFIT		HIRT		P-Value (Group x Time Interaction)
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**	
Total Mass (kg)	74.1 ± 11.3	74.0 ± 11.2	74.3 ± 10.2	75.0 ± 0.9	0.14
Fat Mass (kg) †	21.2 ± 5.9	20.8 ± 5.9	28.4 ± 9.5	28.0 ± 9.7	0.96
Lean Mass (kg) †	50.3 ± 9.8	51.6 ± 9.6	43.6 ± 5.9	44.5 ± 6.8	0.22

†Significant for main effects for time at p<0.05.

4.2 Muscle Strength in HIFIT vs. HIRT

4.2.1 Bench Press

Outcomes for strength showed a significant group by time interaction at p=0.03. Post hoc results showed both groups had significantly increased their strength when performing bench press from pre-test to post-test, HIFIT (p=0.00) and HIRT (p=0.00). Post-test differences between groups revealed the HIRT group increased more in their strength compared to HIFIT group at p=0.02. (Table 4.3)

4.2.2 Bench Press Endurance

Results for strength endurance revealed no significant group by time interaction (p=0.15). A remarkable time main effect was seen at p=0.00, showing both groups' endurance (i.e. repetitions) to perform bench press increased over time. There was no significant group main effect (p=0.60), indicated no difference between HIFIT and HIRT groups. (Table 4.3)

4.2.3 Dead Lift

There was no noticeable group by time interaction (p=0.92). However, an important time main effect was seen at p=0.00, showing both groups' strength to perform dead lift increased over time. There was no significant group main effect (p=0.09), indicating both HIFIT and HIRT groups improved but not differently. (Table 4.3)

4.3 Functional Performance in HIFIT vs. HIRT

4.3.1 Stair Climb Power Test (SCPT)

A significant group by time interaction at p=0.01 for performing the SCPT. Post hoc results showed both groups had significantly changed over time but differently. Post-test difference between groups revealed HIFIT group had remarkable increase in their stair climbing power while HIRT group decreased slightly at p=0.02. (Table 4.4)

Table 4.3 Muscular Strength and Endurance

Variables	HIFIT		HIRT		P-Value
	Pre-Test (X ± SD)	**Post-Test** (X ± SD)	**Pre-Test** (X ± SD)	**Post-Test** (X ± SD)	(Group x Time Interaction)
4RM Bench Press (Kg) ♯ ¶	48 ± 15	52 ± 14	27 ± 9	35 ± 9	0.03 ♯
Bench Press Endurance (reps) †	12 ± 3	21 ± 5	11 ± 3	23 ± 4	0.15
3RM Deadlift Max (Kg) †	76 ± 32	88± 26	54 ± 20	67 ± 5	0.92

♯ Significant for group by time interaction at p<0.05. ¶ Post hoc data for HIFIT (p=0.00) and HIRT (p=0.00) with post-test difference between groups (p=0.04). † Significant for time main effects at p<0.05. RM = repetition maximum, Kg = kilogram, reps = repetitions.

4.3.2 Time Up and Go (TUG)

There was no significant group by time interaction (p=0.88). A vital time main effect was seen at p=0.00, showing both groups' decreased their time to perform the TUG from pre-test to post-test. There was no considerable group main effect (p=0.63), indicated both HIFIT and HIRT groups improved but not differently. (Table 4.4)

4.3.3 Gait Speed Test (Fast (FGS) and Comfortable (CGS))

Results revealed no significant group by time interaction (p=0.34, p=0.59) for the gait speed test. There was no important time main effect (p=0.24, p=0.31) and no group main effect (p=0.06, p=0.39) for FGS and CGS, respectively. Results revealed no considerable changes between groups in performing the gait speed test; thus, no difference in how fast or comfortable they were walking. (Table 4.4)

4.3.4 Sit to Stand (STS)

There was no significant group by time interaction (p=0.20). A significant time main effect was seen at p=0.00, showing both groups' leg strength and endurance increased over time. There was a considerable group main effect (p=0.04), indicating both HIFIT and HIRT groups improved but not differently. (Table 4.4)

4.3.5 Incremental Shuttle Walk Test (ISWT)

Baseline differences were evident between the two groups (p=0.05). ANCOVA showed no group differences in executing the ISWT at post-test (p=0.72). (Table 4.4)

4.4 Aerobic Capacity of HIFIT vs. HIRT

4.4.1 VO_2max adjusted for Lean Mass (VO_2max LM)

Outcomes demonstrated no significant group by time interaction (p=0.07). There was no important time main effect (p=0.99). An essential group main effect was seen at p=0.03, with HIFIT higher than HIRT group across time points. (Table 4.4)

4.4.2 Anaerobic Threshold adjusted for Lean Mass (AT LM)

No significant group by time interaction (p=0.08) for the AT LM. A prominent time main effect was seen at p=0.01, showing both groups' anaerobic threshold capacity increased over time. No considerable group main effect (p=0.12), revealing no differences between each group. (Table 4.4)

4.4.3 Respiratory Compensation Threshold adjusted for Lean Mass (RCT LM)

Results revealed no notable group by time interaction (p=0.55) and no time main effect (p=0.07). However, revealed significant group main effect at p=0.01, showing increased respiratory compensation threshold capacity, and was higher across time points in the HIFIT group. (Table 4.4)

4.4.4 VO_2max relative to Body Weight (VO_2max BW)

There was no noticeable group by time interaction (p=0.38). Also, no significant time main effect (p=0.57). Results showed important group main effect at p=0.02, showing that VO_2max relative to body weight was greater in the HIFIT group averaged across time points. (Table 4.4)

4.4.5 Anaerobic Threshold relative to Body Weight (AT BW)

Results for AT BW demonstrated no meaningful group by time interaction (p=0.16). A significant time main effect was seen at p=0.01, showing both groups AT BW increased over time. In addition, a considerable group main effect (p=0.02) was seen, revealing HIFIT had higher AT average across time points. (Table 4.4)

4.4.6 Respiratory Compensation Threshold relative to Body Weight (RCT BW)

No significant group by time interaction (p=0.80) for the RCT BW. An essential time main effect was seen at p=0.04, showing both groups RCT BW increased over time. Outcomes revealed a significant group main effect (p=0.01), indicating the HIFIT group had higher values averaged across time points. (Table 4.4)

4.5 Questionnaires

4.5.1 Self-Efficacy for Exercise

The items for the self-efficacy questionnaire are divided into 3 factors namely: situational / interpersonal, completing demands, and internal feelings (Shin et al., 2001). Mean ± standard deviations showed no difference between HIFIT and HIRT in their efficacy beliefs on a 100-point scale ranging in 10-unit intervals from 0 (cannot do) through midway level of self-confidence as 50 (moderately can do) to 100 (absolute full self-confidence) (Bandura et al., 1997). This also showed that the older adults in both groups can perform more than moderately the exercise training with mean ± standard deviation of HIFIT (67 ± 6) and HIRT (61 ± 5). (Table 4.5)

4.5.2 Physical Activity Enjoyment

The participants for both the HIFIT and HIRT groups showed enjoyment when performing the high intensity exercise trainings as revealed by the positive feedback. Out of PACES 126 perfect score, the total score for HIFIT (101 ± 24) and HIRT (103 ± 22), with Cronbach alpha of 0.97. (Table 4.6)

Table 4.4 Functional Performance of the HIFIT and HIRT group for SCPT, TUG, FGS, CGS, STS, ISWT and Aerobic Capacity as presented with means and standard deviations.

Variables	HIFIT		HIRT		P-Value
	Pre-Test (X ± SD)	**Post-Test** (X ± SD)	**Pre-Test** (X ± SD)	**Post-Test** (X ± SD)	(Group x Time Interaction)
SCPT (Watts) ♯	470 ±111	529 ± 17	403 ± 88	417 ± 93	0.01 ♯
TUG (sec) †	5 ± 1	4 ± 1	5 ± 1	4 ± 0	0.88
FGS (m/sec)	2.57 ± 0.40	2.71 ± 0.45	2.31 ± 0.27	2.33 ± 0.26	0.34
CGS (m/sec)	1.74 ± 0.33	1.71 ± 0.19	1.69 ± 0.15	1.60 ± 0.16	0.59
STS (reps) † *	17 ± 4	19 ± 3	15 ± 2	16 ± 2	0.20
ISWT (m)	713 ± 134	753 ± 119	545 ± 118	561 ± 166	0.72
VO_2max LM* **(ml/Kg/min)**	41 ± 7	43 ± 6	36 ± 8	34 ± 7	0.07
AT LM† **(ml/Kg/min)**	27 ± 6	31 ± 3	25 ± 5	26 ± 4	0.08
RCT LM* **(ml/Kg/min)**	31 ± 11	36 ± 12	26 ± 13	28 ± 12	0.55
VO_2max BW* **(ml/Kg/min)**	28 ± 6	29 ± 5	21 ± 7	21 ± 8	0.38
AT BW † * **(ml/Kg/min)**	18 ± 5	21 ± 4	15 ± 3	16 ± 3	0.16
RCT BW† * **(ml/Kg/min)**	21 ± 8	24 ± 9	15 ± 8	17 ± 9	0.80

♯ Significant for group by time interaction at $p<0.05$.
† Significant for time main effect at $p < 0.05$.
* Significant for group main effect at $p < 0.05$.

SCPT = stair climb power test, TUG = time up and go, FGS = fast gait speed, CGS = comfortable gait speed, STS = sit to stand, ISWT = incremental shuttle walk test, VO_2max = maximal aerobic capacity, AT = anaerobic threshold, RCT = respiratory compensation threshold in relation to lean mass (LM) or body weight (BW).

Table 4.5 Post-Test Analysis of HIFIT and HIRT for Exercise Self-Efficacy

Variable	Items (100 pts / item)	HIFIT Mean ± SD	HIRT Mean ± SD
Situational / Interpersonal Sub-Factor – Factor 1 (six items)			
11	When I have too much work at home.	63 ± 28	59 ± 16
12	When visitors are present.	59 ± 31	53 ± 15
13	When there are other interesting things to do.	69 ± 25	63 ± 20
16	During a vacation.	61 ± 31	45 ± 17
17	When I have other time commitments.	66 ± 25	51 ± 22
18	After experiencing family problems.	64 ± 28	60 ± 18
Completing Demands Sub-Factor – Factor 2 (five items)			
4	After recovering from an injury that caused me to stop exercising.	62 ± 30	36 ± 21
8	After recovering from an illness that caused to stop exercising.	63 ± 28	50 ± 30
10	After a vacation.	77 ± 19	76 ± 13
14	If I don't reach my exercise goals.	78 ± 16	66 ± 32
15	Without support from my family or friends.	71 ± 25	75 ± 17
Internal Feelings Sub-Factor – Factor 3 (seven items)			
1	When I am feeling tired.	70 ± 23	64 ± 18
2	When I am feeling under pressure from work.	75 ± 22	66 ± 17
3	During bad weather.	74 ± 28	69 ± 24
5	During or after experiencing personal problems.	64 ± 27	68 ± 15
6	When I am feeling depressed.	64 ± 26	68 ± 19
7	When I am felling anxious.	71 ± 23	70 ± 16
9	When I feel physical discomfort when I exercise.	63 ± 30	64 ± 19
	EXSE Total Scale Score	67 ± 6	61 ± 5

Scale: 0 – 100 points
Note: EXSE = Exercise Self-Efficacy Scale (EXSE)

Adapted from:
1. Bandura, A. Self-efficacy: The exercise of control. New York: Freeman & Co. 1997
2. Shin YH, Jang HJ, Pender NJ. Psychometric Evaluation of the Exercise Self-Efficacy Scale Among Korean Adults with Chronic Diseases. Research in Nursing & Health, 2001, 24, 68±76

Table 4.6 Post-Test Analysis of Physical Activity Enjoyment for HIFIT and HIRT

Description	HIFIT Mean ± SD	HIRT Mean ± SD	Description
*I enjoy it.	2.0 ± 1.4	2.0 ± 1.4	I hate it.
I feel bored.	5.0 ± 1.6	6.0 ± 1.0	I feel interested.
I dislike it.	6.0 ± 1.9	6.0 ± 1.2	I like it.
*I find it pleasurable.	3.0 ± 1.8	3.0 ± 1.4	I don't find it pleasurable.
*I am very absorbed in this activity.	2.0 ± 1.9	3.0 ± 1.8	I am not at all absorbed in this activity.
It's no fun at all.	6.0 ± 1.2	6.0 ± 1.7	It's a lot of fun.
*I find it energizing.	2.0 ± 1.7	3.0 ± 1.7	I find it tiring.
It makes me depressed.	6.0 ± 1.5	6.0 ± 0.8	It makes me happy.
*It's very pleasant.	3.0 ± 1.5	2.0 ± 1.4	It's very unpleasant.
*I feel good physically while doing it.	3.0 ± 2.2	2.0 ± 1.7	I feel bad physically while doing it.
*It's very invigorating.	2.0 ± 1.5	2.0 ± 1.5	It's not at all invigorating.
I am very frustrated by it.	6.0 ± 1.4	6.0 ± 1.5	I am not at all frustrated by it.
*It's very gratifying.	3.0 ± 1.9	2.0 ± 1.8	It's not at all gratifying.
*It's very exhilarating.	2.0 ± 1.0	2.0 ± 1.7	It's not at all exhilarating.
It's not at all stimulating.	6.0 ± 1.5	6.0 ± 1.1	It's very stimulating.
*It gives me a strong sense of accomplishment.	2.0 ± 1.9	2.0 ± 1.8	It doesn't give me a strong sense of accomplishment.
*It's very refreshing.	3.0 ± 1.4	3.0 ± 1.7	It's not at all refreshing.
I felt as though I would rather be doing something else.	5.0 ± 1.6	5.0 ± 1.1	I felt as though there is nothing else I would rather be doing.
PACES total scale score	101 ± 24	103 ± 22	
Cronbach's α	0.97	0.97	

Scale: 1-7 scoring with 7 as the highest otherwise stated. * Denotes reversal when scoring (i.e., lower scores reflected greater level of enjoyment).

Note: PACES = Physical Activity Enjoyment Scale

Adapted from: Kenzierski, D., DeCarlo, K.J. (1991). Physical activity enjoyment scale: Two validation studies. Journal of Sport Exercise Psychology. 13, 50-64.

CHAPTER 5

DISCUSSION

5.1 Main Findings

There have been very few research studies to date that have examined the effects of a combined exercise training method in the older adult population. This study compared the effects of high intensity functional interval training (HIFIT) to high intensity resistance training (HIRT) in older adults. The investigation revealed that performing high intensity functional interval training appears to be either superior or comparable in the functional adaptations of the older adult sample compared to high intensity resistance training.

The first hypothesis stating that both modes of strength training would have similar changes in muscle and fat mass, strength, and functional performance was supported for the majority of the variables through acceptance of the alternative hypothesis. However, it is important to note that the HIFIT group exhibited greater improvements in the stair climb power test (SCPT), while the HIRT group showed greater improvements in the bench press strength. The groups combined significantly lost fat mass and increased lean mass from pre-test to post-test. Both groups significantly improved in the bench press endurance, deadlift strength, sit to stand (STS), and timed up and go (TUG) from pre to post-test but showed no differences between the groups. There were no changes and no group differences in terms of gait speed tests (FGS / CGS), and incremental shuttle walk test (ISWT).

The second hypothesis, HIFIT would induce a greater increase in aerobic capacity (i.e. maximum oxygen consumption (VO_2max), anaerobic threshold (AT), and respiratory compensation threshold (RCT)), was rejected. Although the HIFIT group had higher values averaged from pre-test to post-test in terms of relative VO_2max on lean mass (VO_2max LM), respiratory compensation threshold on lean mass (RCT LM), as well as relative VO_2max on body weight (VO_2max BW), anaerobic threshold on body weight (AT BW), and respiratory compensation threshold on body weight (RCT BW) in comparison to the HIRT group, results revealed no group by time interaction. Both groups showed significant increase in anaerobic threshold on lean mass (AT LM) from pre-test to post-test but there were no group differences.

Finally, the third hypothesis, HIFIT and HIRT groups have similar level of physical activity enjoyment and self-confidence feedback when participants are performing the exercise training, was accepted. Both groups show the same above moderate level of confidence in performing the exercise training as presented by 65 ± 7 (means ± SD). Also, both groups enjoyed the exercise training given that the percentage were at 80-82% and overall attendance rates were excellent, approximately 96%.

5.2 Strength, Muscle (Lean) Mass, and Fat Mass Changes

There are two main mechanisms responsible for improving overall strength in response to resistance training: neural adaptations and hypertrophic adaptations within the muscle (McDonagh & Davies, 1984; Phillips, 2000). Neural adaptations are the cause for the gains of strength early in a training program (i.e. participants will gain strength before they begin to add muscle mass (Chilibeck et al., 1998; McDonagh & Davies, 1984; Phillips, 2000; Sale, 2010)). In our study, both the HIFIT and HIRT participants showed increased strength to execute bench press and dead lift as well as showed major improvements in the bench press endurance after the training. The total mass of the participants from pre-test to post-test remained the same; however, both groups decreased fat mass and increased lean mass. The short duration of this training program and the majority of the participants' inexperience with strength training offer itself to neural adaptations as being primarily responsible for the strength gains seen in our study, though hypertrophy might have had a small influence on strength gains towards the end of the training program.

There was significant loss of fat mass and increase in lean mass during the 6 weeks (3x/week) for both HIFIT and HIRT groups. Our result was in conformity with studies that showed repeated HIIT exercise sessions done 3 days/week for 6 weeks (Latham et al., 2004) may be effective than continuous endurance exercise at reducing subcutaneous and abdominal body fat (Trapp et al., 2008; Whyte et al., 2010) in untrained individuals (Kryger & Andersen, 2007; Ross & Leveritt, 2001). Likewise, our result was also consistent with the findings of a HIRT study that induced a visceral fat loss (Dutheil et al., 2013).

Regular high intensity training has been shown to significantly improve maximal exercise capacity; thereby, increasing high-density lipoprotein ratio, inducing fat oxidation during and after exercise and suppressing appetite (Gremeaux et al., 2012). As mentioned previously, the excess post exercise consumption (EPOC) might influence post exercise fat metabolism due to the need to provide energy for removal of lactate and H+ and to resynthesize glycogen (Boutcher et al., 2011; LaForgia, Withers and Gore, 2006); therefore, resulting in decrease in total fat mass, body mass index, and waist circumference (Gremeaux et al., 2012).

5.3 Functional Performance Changes

The HIFIT finding of this study in relation to functional performance was a significant improvement in the stair climb power test (SCPT). Both the HIFIT and HIRT group significantly improved in the strength training (i.e., bench press endurance, and 4RM deadlift), time up and go (TUG), and increased number of repetitions in the sit to stand (STS) tests, however, showed no group difference. As well, HIRT revealed better significant improvement in the bench press. On the other hand, no significant changes were observed for gait speed activities (FGS/CGS) and incremental shuttle walk test (ISWT) for both groups.

Our study revealed no changes in the gait speed and ISWT for both groups. This outcome was confirmed by the 8 weeks study of Serra-Rexach et al. (2011) that focused on lower limb strength exercise of 1 RM leg press, showing increased leg press strength, but no changes in gait ability. On the other hand, studies indicated that gait velocity increased at week 9, but the same velocity increase disappeared by the 17th week (Fahlman et al., 2011) as supported by the study of Topp et al. (1993) that showed post-test results after 12 weeks training of decreased gait velocity and balance. Also, performing progressive resistance strength training conducted among nonagenarians showed modest improvements in gait speed (Van Abbema et al., 2015; Latham et al., 2004). This presented us a speculative conclusion that in order for gait abilities to improve, strength training exercise must be progressive and must be done longer, at least 9 weeks in order to see improvements in gait velocity. However, an appropriate exercise program is needed to sustain the achieved increase in the gait speed; therefore, further research is essential to focus on the relationship of strength training and gait abilities in the older population.

5.4 Aerobic Capacity Changes

The results demonstrated that both the HIFIT and HIRT group experienced significant increased in VO_2max from pre-test to post-test. However, it is surprising to see that there was no group by time interaction. The group main effect finding is related to the demographic difference of the current study being mostly males in the HIFIT group and majority of females in the HIRT group. Further study is required to clarify this issue to see if the response of VO_2max to HIFIT remains in older adults.

5.5 Strength Training and Confidence / Enjoyment Level

In the current study, the participants' feedback was surveyed after the 6 weeks training program through the questionnaires. Using the mean $\pm$ standard deviation from the EXSE and PACES questionnaires, it was found out that the HIFIT and HIRT groups exhibited similar level of above moderate confidence in performing the exercise training (Tables 4.5). They also showed the same physical activity enjoyment level (Table 4.6). These results provided indication that both groups were equivalent on all test measures. This further indicated that neither HIFIT nor HIRT was superior from the other in influencing physical activity enjoyment and self-confidence among older adults.

The study groups enjoyed the exercise training given that the percentage for the means were on the 80-82% scale and overall attendance rates were excellent, approximately 96%. This result correspond to the outcome of Mullen et al. (2011) study which concluded that older adults experienced sufficient levels of joy by the overall attendance rates of 80%. It should be noted that the recommended adherence level of 80-85% is needed in order for an intervention to be qualified as satisfactory and have a therapeutic value (Pisters et al., 2006).

Enjoyment was considered identical with fun which was described as "a simple positive emotion, affective state, or response reflecting feelings of pleasure, liking, and fun" (Scanlan et al., 1992; 1993; Wankel et al., 1993). In this study, assessing the confidence and enjoyment level of the participants was necessary to investigate whether performing strength training with high intensities was enjoyable and at the same time beneficial to the physical health of the older adult doing the exercise activity. It was stated that the greatest potential to boost human movement and involvement in daily life will be by increasing participation in a meaningful physical activity which has both pleasurable leisure experience (i.e. recreation, play and sport) and physical exercise

(Godbey et al., 2001). In addition, it was revealed that an activity that is enjoyable and sustainable can promote an active lifestyle (Carraro et al., 2008). Also, according to Mullen and colleagues (2011), enjoyment was a predictor of physical activity participation. Older adults reported that enjoyment was a motivation to participate in physical activity (O'Driscoll et al., 2014). Thus, our study was supported by a longer duration study of 12 weeks of high intensity resistance training demonstrating that it can improve physical fitness, mood, and physical self-efficacy in older adults (ACSM 1998; 2000).

We did not find a significant difference between training groups on measures of physical activity enjoyment and self-efficacy maybe due to the following assumptions: participants' strength training experience and the training duration. The participants in the current strength training study had minimal to no exercise or strength training experience prior to onset of this study. Most of the participants had no background in exercise training and thus nothing to compare their experience. Another belief for reason why there was no difference between groups on self-efficacy and physical activity enjoyment was the short training period. A longer duration training of more than 6 weeks might have allowed for more clear identification of the differences in self-efficacy and physical activity enjoyment (Parkinson, 2006).

5.6 Limitations

The current investigation has some limitations. Firstly, the study had a small number of participants. Most of the participants are still working and schedules are barriers for them to join the study. Our evidence would be more reliable in the interpretation of the results if the numbers of participants were large enough to represent the older adult population.

Secondly, another limitation was the unequal number of participants and the uneven gender ratio assigned in each group due to availability of participants' schedule. This resulted to unequal baseline data among the two groups.

Thirdly, we failed to include a practice test (e.g. cardiopulmonary exercise testing and ISWT) for possible learning effect of the tests. It could have potentially strengthened the protocol and might result to a better performance. The tests were explained thoroughly to the participants, but still it was observed that the participants were initially apprehensive in performing the tests as they were unfamiliar with the procedure. Hectic participants' schedules and issues with parking were a hindrance to perform any additional longer exercise activity.

Finally, the researchers did not require the participants to control their diets during the duration of the training.

5.7 Practical Implications and Future Research

High intensity interval training has been determined to be safe in patients with complicated health conditions (i.e., cardiac problems, chronic lung disease and metabolic syndrome) and even the frail elderly. The HIFIT protocol intervention would be advantageous to utilise in formulating an exercise program as it is realistic to implement and its practicality suits the needs of the healthy older adult individuals who prefer to do less exercise time but want significant functional improvements.

Future studies could examine the effects of the HIFIT protocol performed to a larger population with exercise training duration of longer than 6 weeks to compare the results to this present study. Further research also needs to focus on the relationship of strength training and gait abilities in the older population.

To our knowledge, this investigation has been the first to combine and compare the two important different exercise training programs using high intensity exercise in healthy older adults. The surveyed assessment in this area will allow researchers to more accurately compare the various effects of high intensity interval training in older adults.

CHAPTER 6

CONCLUSION

HIFIT group demonstrated greater improvement in functional performance (i.e., stair climb power test) compared to the HIRT group. HIRT group revealed greater increase in strength (i.e., bench press) compared to the HIFIT group. Both HIFIT and HIRT groups had a significant loss of fat mass and a significant increase in lean mass; significant increase in bench press endurance, deadlift strength, TUG, STS, and significant outcome in aerobic capacity (i.e. VO_2max LM, AT LM, RCT LM, VO_2max BW, AT BW, RCT BW). Both groups have the same level of physical activity enjoyment and exercise self-efficacy. No changes were seen in performing the gait speed and ISWT.

This study demonstrated that performing the high intensity functional interval training (HIFIT) protocol was considered superior compared to performing high intensity resistance training in apparently healthy older adults in improving functional performance. No adverse events occurred during this study. Replication in a study using a greater sample size and longer training duration would benefit in the care management of older adults and would support the rationale for high intensity functional interval training.

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APPENDICES

APPENDIX 1

Participant Information and Consent Form

Participant Information and Consent Form

STUDY TITLE: High Intensity Functional Interval Training for Older Adults

PROTOCOL / STUDY NUMBER: 13-261

PRINCIPAL INVESTIGATOR: Scotty Butcher, Ph.D., Physical Therapy, University of Saskatchewan, Saskatoon, Saskatchewan, scotty.butcher@usask.ca

CO-INVESTIGATORS: Philip Chilibeck, Ph.D., Kinesiology, University of Saskatchewan, Saskatoon, Saskatchewan, phil.chilibeck@usask.ca

Evelyn Pata, MSc. student, M.P.A, B.Sc.(P.T.), Physical Therapy, University of Saskatchewan, etp712@mail.usask.ca

Chad Benko, B.Sc.(Kin.), Synergy Strength and Conditioning, Saskatoon, Saskatchewan, chad@synergystrength.ca

CONTACT NUMBER: (306)966-1711 (Dr. Scotty Butcher)

We would like to invite you to take part in a research study that is being run at the University of Saskatchewan and Synergy Strength and Conditioning. Please take the time to read this consent form and if you wish, discuss it with the researchers. This consent form may contain words that you do not understand. Please ask the study investigator and/or student researcher to explain any words or information that you do not clearly understand, or if you would like more information**.** Take as much time as you need to decide whether or not to take part. Your participation in this study is entirely voluntary, so it is up to you to decide whether or not to take part. If you do decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your current exercise program and working relationship with any of the research team or fitness team will not change.

Introduction
You are being invited to take part in this research study if you are at least 55 years old and active, but not training regularly. It is important that you read and understand the following information. Please feel free to ask the primary researcher or research staff any questions that will help you understand the study and what you are expected to do. Before you agree to take part in this study, you may take this information home and discuss it with a family member.

Purpose of the Study
This study is being conducted to help exercise professionals and researchers better design exercise training protocols for older adults to improve their fitness and health. Both high-intensity interval training and resistance training have been shown independently to increase fitness, health, and body composition; however usually require increased time to complete as separate programs. The effect of combining resistance and cardiovascular training through High-Intensity Functional Interval Training (HIFIT) may decrease the overall time required for training and elicit similar benefits. This study will involve comparing HIFIT training with more traditional resistance training. The purpose of this study is to examine HIFIT compared with traditional resistance training to provide information regarding the efficacy of each training method for achieving gains in the formulation of a functional training program that will assist practitioners in the preventative measures and care management for older adults.

Disclosure of potential conflicts of interest
This study is funded by the Office of Outreach and Engagement, University of Saskatchewan; to allow Synergy Strength and Conditioning to provide the training facilities and the time and expertise of their staff. The Principal Investigator (Dr. Butcher) has established a professional relationship with Synergy Strength and Conditioning where he is an unpaid consultant, providing professional advice to guide exercise testing and programming. Ms. Pata is a graduate student of Dr. Butcher's, but has no other conflicts for this study. Mr. Benko is a co-owner of Synergy Strength and Conditioning, is interested in promoting research in exercise training methodology, but has no financial interest in this research study. Mr. Benko, however, may benefit from advertising or familiarizing participants for future business and will be exposed to your contact information. The investigators will not attempt to recruit or coerce you, or contact you for the purposes of recruiting or coercion, to become a member of Synergy Strength and Conditioning. You will be enrolled at Synergy Strength and Conditioning for the purposes of the study only. All contact information will be removed from Synergy Strength and Conditioning upon the completion of the study. Dr. Chilibeck is a co-investigator and has no conflicts for this study. As a participant in this study, there is no expectation from you to become a member of Synergy Strength and Conditioning either during or after the study and you will not be charged for any aspect of the study.

Study Visits and Procedures
The study staff will carefully explain all exercises and procedures and you should ask whenever you need more information. You must provide consent to participate in this study before you perform any study-related exercises and procedures.

As a participant in the study, you will be asked to complete the following procedures:

PAR Q Questionnaire: You will be asked to answer a Physical Activity Readiness Questionnaire (PAR-Q) which asks information regarding your medical history. If indicated by your answers to the PAR-Q, you may be requested to follow up with your family physician if necessary. In addition, you may be deemed ineligible for participation in this study.

Screening, VO_2max, questionnaires, and leg strength (2.5 hours at the U of S):
Screening: Screening will occur at Royal University Hospital in the Integrative Clinical Exercise Physiology Laboratory (E3620). A physical therapist will take a detailed medical and physical history and measure your resting blood pressure and pulse to ensure you are safe and eligible to participate in this study. If issues arise during this screening that may make it unsafe for you to participate, you will be asked to see your doctor to obtain medical clearance and/or be asked to withdraw from the study.

VO_2max Test: You will be asked to exercise on a stationary bike for as long as you can. Throughout the exercise test, it will become increasingly harder to pedal – it will feel similar to biking up a hill that gradually gets steeper and steeper. We will place several stickers on your shoulders and ribs to allow us to measure your heart rate and rhythm (ECG). We will measure your breathing by having you breathe through a mouthpiece while wearing nose clips. We will ask you to try and breathe normally throughout the test. If, at any time during any of the exercise tests, you do not wish to continue for any reason, you may stop exercising voluntarily.

Questionnaires: Following the VO_2max test, you will rest for one hour. During this one hour rest break, research personnel will give you three questionnaires to complete during this hour. These questionnaires will assess your 1) self-reported physical activity, 2) physical self-perception, and 3) self-efficacy (belief in one's ability to complete tasks and reach goals).

Muscle Strength Test: After the one hour rest, you will be asked to perform muscle strength tests on your thigh muscles (quadriceps) that are routinely used to assess fitness. These tests will be done on an isokinetic dynamometer where you will be asked to straighten your knee maximally against the applied resistance. The best of three trials will be recorded.

Body Composition (30 minutes at the U of S): Lean tissue, fat, and bone mass will be assessed with dual energy X-ray absorptiometry (DEXA) by a nuclear medicine technologist in the RJD Williams Building (221 Cumberland Ave North, Room 108). This involves lying on a table while you are scanned with an X-ray. This test takes about 10 minutes.

Functional Tests: Determining the functional abilities of older adults will be tested using Rikli and Jones functional performance tests. Firstly, the stair climb power (SCP) test measures the time it takes a participant to climb a set number of stairs (typically 10). This test correlates with leg strength and anaerobic power. Secondly, the time up and go (TUG) is a valid and reliable test to determine balance in older adults. It correlates with gait speed, balance, functional mobility, and falls risk. It measures the time it takes a participant to stand up from an armless chair, walk a distance of 8 feet (2.44m), turn, walk back to the chair, and sit down. This is important in tasks that require quick movements, such as getting off a bus in time or getting up to attend to something in the kitchen, to go to the bathroom or to answer the phone. Thirdly, gait speed test is appropriate for goals of ambulation improvement. The participant will be instructed to walk 10 meters and both comfortable (CGS) and fast gait speed (FGS) will be tested. The ability to increase/decrease walking speed above or below a "comfortable" pace characterizes normal healthy walking and indicates the potential to adapt to varying environments (e.g. crowed hallways, crossing streets).[68] Fourth, the ability to stand from a chair is a crucial factor in independence in older adults, hence, sit-to-stand test is to assess lower-extremity strength and balance. Participant will stand up and sit down as quickly as possible, keeping arms folded across the chest done for 30 seconds. The best of 3 trials will be recorded on the data sheet for Test 1, 2, 3 and 4. Finally, participant will be asked to do the incremental shuttle walk test (ISWT) to identify maximal walking speed. The participant is to walk a 10 meter course for as long as possible, there and back, keeping to the speed indicated by the bleeps at regular intervals on the cassette. Participant should walk at a steady pace, aiming to turn around the cone at one end of the course upon hearing the first bleep and at the other end when one hear the next bleep. The aim should be to follow the set rhythm for as long as possible. Each single bleep indicates the end of a shuttle and each triple bleep signals an increase in walking speed. The test is maximal and progressive which means it is easier at the start and harder at the end. Participant will stop walking only when one become too breathless to maintain the required speed or can no longer keep up with the set pace.

Familiarization Sessions (One hour each): There will be four familiarization sessions held at Synergy Strength and Conditioning. These sessions are designed to teach you the proper movement techniques for the exercises you will be tested upon and for which you will use during training. You will learn proper techniques for the following exercises for which you will be training. During the last familiarization session, the first test (Wingate Anaerobic Test below) will be conducted.

Performance Testing: Following the Familiarization Sessions, you will be tested during three subsequent test sessions as follows:

Wingate Anaerobic Test (held during the final familiarization session at Synergy): For this test, you will be asked to ride a stationary bicycle at maximal speed. You will be given a 5 minute period to warm up and become accustomed to the bicycle. You will then have 5 minutes of rest before the test begins. The test will last 30 seconds, during which you will be asked to pedal the bicycle, against a pre-determined resistance, as fast as you can. A certain amount of discomfort and difficulty should be expected, however you are free to stop the test at any time, for any reason. After the 30 second test has been completed, you will be asked to keep pedaling the bicycle, with no resistance, for a minimum of 5 minutes, to cool down.

Gym Strength Tests (2 days, 1 hour per day each at Synergy):
For these tests, you will be tested on a three repetition maximum load (3RM) for two separate exercises (one each day) of deadlift and bench press. As per standard Synergy protocol, you will complete a warm up and preparation for the test. You will be reminded of and coached for proper technique while you work up to the maximum load you can lift correctly three times. Your highest weight lifted for 3RM on each exercise will be recorded.

Training sessions: You will be randomly assigned to one of two training groups: HIFIT– a high-intensity functional interval training group using multimodal exercises (i.e. resistance, body weight, and fast movement techniques); or HIRT – a high-intensity resistance training group as described below. Randomization will be done by a computer, but will be organized such that there are similar numbers of males and females in each group.

Each group will train for 6 weeks in a group setting at Synergy Strength and Conditioning. Each training session will last 60 minutes each over the six week training program (3 times per week). All exercise sessions will be supervised and coached closely. Your exercise technique will be closely monitored and technique correction will be completed. At the first and last exercise session, you will be asked to complete a very short questionnaire related to your enjoyment of the exercise. At these sessions, you will wear a heart rate monitor, perform a standardized Synergy warm up and exercise instruction, then complete your assigned exercise session for the day under the direction of the coach as follows:

HIFIT Group: These groups will complete 4-6 sets of 75 seconds of all out work, followed by 3:45 minutes of rest (a total of 20-30 minutes each session). Each session will have the same exercises within each set, but every session will be different than the others for movements utilized. There will be three movements used in each set. The first movement will be a strength movement (such as bench press, squat, deadlift) for 4-6 repetitions. The second movement follows the first immediately and is a faster body weight power movement such as lunges, body weight squats, ring rows (a modified pull up on gymnastics rings), or push-ups for 6-8 repetitions. The third movement follows the second immediately and is a very fast, sprint-like movement such as hopping, sprint rowing, or battling ropes (fitness ropes used for gym or indoor training) for the remainder of the 75 seconds. The intent of each set is to be completed with as much effort as possible across the full 60 seconds. All movements will be scaled to each individual's functional and mobility abilities, so don't worry if you think you can't do a movement. The coaches and study staff will assist you in finding a suitable alternative movement.

HIRT group: This group will train using 4-6 sets of 5-7 repetitions with a 2:00 minute rest between exercises of whole body resistance training movements. The exercises will be the same exercises performed in the strength movement in the HIFIT group.

Follow-up testing: Upon completion of the training program, you will be asked to attend follow up testing sessions. Each group will repeat the VO2max test, muscle strength test, Body composition, Functional performance tests, questionnaires, Wingate Anaerobic Test, and the Gym Strength tests.

The total time commitment for this study, including all testing and training sessions is approximately 30 hours.

<u>Benefits Associated with the Study</u>

There are no direct benefits to you as a participant in this study other than participation in an exercise program and potentially increasing your fitness levels. We will, however, provide you with a summary of your data at your request. In addition, we will conduct an open presentation to training participants which will be held in University of Saskatchewan to give feedback regarding the results of the study conducted.

Potential Risk and Discomforts

As with any type of strenuous activity, there is a very small risk that the stress of performing exercise will cause heart rhythm abnormalities, chest discomfort or light headedness. People with a history or presence of significant cardiac (heart) disease, heart rhythm disorders, or currently pregnant should not participate in this study. The high-intensity training program may at times leave your muscles in discomfort or fatigue. These are common effects of high-intensity training and will be monitored by study personnel. The study investigator may decide that you should not perform the exercise tests, based on information in your medical history. ***It is important that you let the study investigator or staff know if you have ever been advised not to participate in strenuous activities***. It is also important that you report any pain, discomfort, fatigue or other symptoms that you might have during the exercise test to the study staff in attendance.

There is a small amount of radiation exposure from the dual energy X-ray (DEXA) scans. This is equal to one tenth of the amount of radiation you would receive from taking a trans-Atlantic flight from North American to Europe, or less than 0.5% from what you would receive from a routine full-mouth dental X-ray.

Risks of the study are related to the training program and measurements being performed (see above). Risks and discomforts will be minimized by preliminary screening and examination, by close observations made throughout the study by the study personnel, and through close access to emergency equipment and medical personnel. In the event of an injury or medical concern, participants will be assessed (using First Aid procedures) for severity of the concern, and appropriate action will be taken. If the issue/injury can be treated using standard first aid, First Aid will be applied. If the concern requires medical attention, participants will either be referred to a physician for care, or EMS will be activated, as appropriate. An Automated External Defibrillator is available in both study locations. In addition, participants will be informed of warning signs of excessive or abnormal muscle trauma. You will be carefully monitored throughout training and testing. All tests will be performed by staff who is trained in CPR and First Aid to deal with problems that may arise. At any time during the study, it is important that you tell the study staff if you feel unwell or experience any problems or side effects.

Research-Related Injury

There will be no costs to you for participation in this study. You will not be charged for any research procedures. In the event that you become ill or injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights.

Voluntary Participation and Withdrawal

Your participation in this study is voluntary and you may refuse to participate or withdraw from the study, at any time, without affecting your working relationship with the research team or fitness team at the time of withdrawal or in the future. If you withdraw, any data collected prior to withdrawal will be retained for analysis, unless you request otherwise. The study investigator and/or student researcher may also remove you from the study at any time if it is decided that it is not in the best interest of the study and/or your health to continue, or if you do not follow the study staff's instructions.

If you develop a problem that requires medical attention, you should seek emergency medical treatment, and then contact the primary researcher immediately.

Payment to Participants

You will not be paid for taking part in the study; however, you will be offered a study t-shirt and there will be no charge to you for the familiarization sessions, testing sessions, and training done as part of the study. Participation may involve added out-of-pocket expenses such as parking or other direct or indirect costs to participate.

Confidentiality

In Saskatchewan, the *Health Information Protection Act (HIPA)* defines how the privacy of your personal health information must be maintained so that your privacy will be respected. Your confidentiality will be respected. You will be identified in the study by an assigned study number. Only the researchers will have access to the study data. The results of this study may be presented in a scientific meeting or published, but your identity will not be disclosed. Your records will be kept in a secure, locked location in the office of the study investigator at the School of Physical Therapy, University of Saskatchewan for a minimum of five years. Upon completion of the study, the study records will be shredded or otherwise destroyed.

Further Information

You may contact Dr. Scotty Butcher, at (306) 966-1711 for questions or concerns. For medical emergencies, please go to a hospital emergency room.

You have the right at any time to request information from the study investigator and/or student researcher about your condition. You may also request that any other person be given this information and a copy of this form.

If you wish to obtain a copy of the study results, please inform study investigator and/or student researcher and one will be provided to you in person or by mail on publication.

The study has been reviewed and approved by the University of Saskatchewan Biomedical Research Ethics Board. They are responsible for safeguarding the safety, rights and well-being of human participants partaking in research studies.

For additional information regarding your rights as a research participant or concerns about the study, contact the Chair of the Biomedical Research Ethics Board, c/o the Ethics Office, University of Saskatchewan at (306) 966-4053.

Please take a copy of this form home with you.

APPENDIX 2

CONSENT FORM

High-Intensity Functional Interval Training in Older Adults

- I have read and I understand the information presented in this form.
- I have had the purpose, procedures and technical language of this study fully explained to me. I have been given ample time and opportunity to consider the above information, to inquire about details of the study and to decide whether or not to participate.
- Having read all pages of this information and consent form and understand the requirements of the study, my signature below indicates that I voluntarily consent to participate in this study.
- I understand that I will receive a copy of this information and consent form.
- I understand that by signing this document I do not waive any of my legal rights.

____

Participant Name (print name)

____ ____________________

Signature of Participant Date

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

____

Investigator (or Designee) Name (please print)

____ ____________________

Investigator (or Designee) Signature Date

APPENDIX 3

CSEP SCPE approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH		
Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1. Has your doctor ever said that you have a heart condition OR high blood pressure?		
2. Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?		
3. Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).		
4. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?		
5. Are you currently taking prescribed medications for a chronic medical condition?		
6. Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.		
7. Has your doctor ever said that you should only do medically supervised physical activity?		

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

› Start becoming much more physically active – start slowly and build up gradually.
› Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
› You may take part in a health and fitness appraisal.
› If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP) or CSEP Certified Personal Trainer® (CSEP-CPT).
› If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

(!) Delay becoming more active if:

› You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
› You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PAR med-X for Pregnancy before becoming more physically active OR
› Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

SECTION 2 - CHRONIC MEDICAL CONDITIONS		
Please read the questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1. Do you have Arthritis, Osteoporosis, or Back Problems?	If yes, answer questions 1a-1c	If no, go to question 2
1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		
1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?		
1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months?		
2. Do you have Cancer of any kind?	If yes, answer questions 2a-2b	If no, go to question 3
2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?		
2b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?		
3. Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	If yes, answer questions 3a-3e	If no, go to question 4
3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		

3b. Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)		
3c. Do you have chronic heart failure?		
3d. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)		
3e. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?		
4. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	If yes, answer questions 4a-4c	If no, go to question 5
4a. Is your blood sugar often above 13.0 mmol /L? (Answer YES if you are not sure)		
4b. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?		
4c. Do you have other metabolic conditions (such as thyroid disorders, pregnancy related diabetes, chronic kidney disease, liver problems)?		
5. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	If yes, answer questions 5a-5b	If no, go to question 6
5a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		
5b. Do you also have back problems affecting nerves or muscles?		
6. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure	If yes, answer questions 6a-6d	If no, go to question 7
6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		
6b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?		

6c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?		
6d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?		
7. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia	If yes, answer questions 7a-7c	If no, go to question 8
7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		
7b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?		
7c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?		
8. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event	If yes, answer questions 8a-c	If no, go to question 9
8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)		
8b. Do you have any impairment in walking or mobility?		
8c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?		
9. Do you have any other medical condition not listed above or do you live with two chronic conditions?	If yes, answer questions 9a-c	If no, read the advice on page 4
9a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?		
9b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?		
9c. Do you currently live with two chronic conditions?		

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

› It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
› You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
› As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
› If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:
› You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:
› You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better.
› You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PAR med-X for Pregnancy before becoming more physically active OR
› Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 – DECLARATION

› You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
› The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
› If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

› Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

Name ____
Date ____
Signature ____
Witness ____
Signature of Parent/Guardian/Care Provider____________________________________

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES
1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3- S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidencebased AGREE process (1) by the PARQ+Collaborationchaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

APPENDIX 4

PROGRAM OUTLINE

HIGH INTENSITY FUNCTIONAL INTERVAL TRAINING

Week	Monday	Wednesday	Friday
1	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. 10 – 15 lbs. D-ball slams for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Bench press A2. 12 Dumbbell bent-over rows A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlift A2. 12 Dumbbell press A3. Double rope undulations for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds
2	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Press A2. 12 Pull-ups or ring rows A3. Low box step-ups for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlifts A2. 12 Dumbbell bench press A3. Row for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds
3	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. 10 – 15 lbs. D-ball slams for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Bench press A2. 12 Dumbbell bent-over rows A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlift A2. 12 Dumbbell press A3. Double rope undulations for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds

4	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Press A2. 12 Pull-ups or ring rows A3. Low box step-ups for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlifts A2. 12 Dumbbell bench press A3. Row for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds
5	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. 10 – 15 lbs. D-ball slams for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Bench press A2. 12 Dumbbell bent-over rows A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlift A2. 12 Dumbbell press A3. Double rope undulations for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds
6	In 75 sec. complete; A1. 6 Back squats A2. 12 Dumbbell press A3. Gym length sprints for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Press A2. 12 Pull-ups or ring rows A3. Low box step-ups for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds	In 75 sec. complete; A1. 6 Deadlifts A2. 12 Dumbbell bench press A3. Row for the remainder of 75 sec. Rest for 3 mins & 45 sec. Every 5 min x 6 rounds

APPENDIX 5

PROGRAM OUTLINE

HIGH INTENSITY RESISTANCE TRAINING

Week	Monday	Wednesday	Friday
1	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Bench press Rest for 30 secs. A2. 12 Dumbbell bent-over rows Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Deadlift Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds
2	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Press Rest for 30 secs. A2. 12 Pull-ups or ring rows Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Deadlifts Rest for 30 secs. A2. 12 Dumbbell bench press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds
3	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Bench press Rest for 30 secs. A2. 12 Dumbbell bent-over rows Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Deadlift Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds

4	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Press Rest for 30 secs. A2. 12 Pull-ups or ring rows Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Deadlifts Rest for 30 secs. A2. 12 Dumbbell bench press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds
5	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Bench press Rest for 30 secs. A2. 12 Dumbbell bent-over rows Rest for the remainder of the 5 mins Every 5 min x 6 rounds	Perform; A1. 6 Deadlift Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins Every 5 min x 6 rounds
6	Perform; A1. 6 Back squats Rest for 30 secs. A2. 12 Dumbbell press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Press Rest for 30 secs. A2. 12 Pull-ups or ring rows Rest for the remainder of the 5 mins. Every 5 min x 6 rounds	Perform; A1. 6 Deadlifts Rest for 30 secs. A2. 12 Dumbbell bench press Rest for the remainder of the 5 mins. Every 5 min x 6 rounds

APPENDIX 6

The Self-Efficacy for Exercise Scale

DIRECTIONS: A number of situations are described below that can make it hard to stick to exercise regularly (3 or more times a week). On the items below, please rate your confidence that you can perform exercise on a regular basis. Please rate your degree of confidence by recording in each of the blank spaces a number from 0 to 100 using the scale below.

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Certain can do

(0-100)

1. When I am feeling tired. _____
2. When I am feeling under pressure from work. _____
3. During bad weather. _____
4. After recovering from an injury that caused me to stop exercising. _____
5. During or after experiencing personal problems. _____
6. When I am feeling depressed. _____
7. When I feeling anxious. _____
8. After recovering from an illness that caused me to stop exercising. _____
9. When I feel physical discomfort when I exercise. _____
10. After a vacation. _____
11. When I have too much work to do at home. _____
12. When visitors are present. _____
13. When there are other interesting things to do. _____
14. If I don’t reach my exercise goals. _____
15. Without support from my family or friends. _____
16. During a vacation. _____
17. When I have other time commitments. _____
18. After experiencing family problems. _____

APPENDIX 7

Physical Activity Enjoyment Scale

* I enjoy it	1	2	3	4	5	6	7	I hate it
I feel bored	1	2	3	4	5	6	7	I feel interested
I dislike it	1	2	3	4	5	6	7	I like it
* I find it pleasurable	1	2	3	4	5	6	7	I don't find it pleasurable
* I am very absorbed in this activity	1	2	3	4	5	6	7	I am not at all absorbed in this activity
It's no fun at all	1	2	3	4	5	6	7	It's a lot of fun
* I find it energizing	1	2	3	4	5	6	7	I find it tiring
It makes me depressed	1	2	3	4	5	6	7	It makes me happy
* It's very pleasant	1	2	3	4	5	6	7	It's very unpleasant
* I feel good physically while doing it	1	2	3	4	5	6	7	I feel bad physically while doing it
* It's very invigorating	1	2	3	4	5	6	7	It's not at all invigorating
I am very frustrated by it	1	2	3	4	5	6	7	I am not at all frustrated by it
* It's very gratifying	1	2	3	4	5	6	7	It's not at all gratifying
* It's very exhilarating	1	2	3	4	5	6	7	It's not at all exhilarating
It's not at all stimulating	1	2	3	4	5	6	7	It's very stimulating
*It gives me a strong sense of accomplishment	1	2	3	4	5	6	7	It doesn't give me a strong sense of accomplishment
* It's very refreshing	1	2	3	4	5	6	7	It's not at all refreshing
I felt as though I would rather be doing something else	1	2	3	4	5	6	7	I felt as though there is nothing else I would rather be doing

Kenzierski D & DeCarlo K. J. (1991). Physical activity enjoyment scale: Two validation studies. Journal of Sport Exercise Psychology, 13, 50–64.