Can Resistance Training Reach Moderate Exercise Intensity in Older Adults and Overweight Adults?

by

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ABSTRACT

Problem: Mostly attributed to lack of time, only about 15% of Canadian adults are currently reaching the Canadian Physical Activity Guidelines (CPAG). Recently, studies have suggested that any bout of aerobic exercise reaching moderate to vigorous intensity has the potential to improve health.

Methods: Sixty adults (20 young non-overweight adults, 20 overweight adults, 20 older adults) already doing some resistance training (RT) were recruited. Participants performed eight RT exercises during three visits. The objective was to identify the proportion of time spent at moderate to vigorous intensity during RT sessions.

Results: Overall, the participants were at moderate to vigorous intensity during 82% of the time. However, the older adult group compared to the young adult group spent lower proportion of time at moderate to vigorous intensity during RT sessions.

Conclusion: Most Canadian adults can reach HR equivalent to those achieved during moderate to vigorous aerobic activity by doing RT.

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DEDICATION

I would like to dedicate my thesis work to my family and friends who stood by my side all through these years. A special feeling of gratitude to my parents Hari Ram and Rajesh Bharti whose words of encouragement made me achieve my goals. I cannot thank them enough for everything and made me who I am. My brothers Manish and Sumeet who have always supported my decisions and are very special. Both of you have been cheerleaders in my life.

I dedicate this work and special thanks to my fiancé Neeraj and my friends for bringing out the best in me today, tomorrow and forever.

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ABBREVIATIONS

1-RM- One Repetition Maximum

BMI- Body Mass Index

BP- Blood Pressure

CPAG- Canadian Physical Activity Guidelines

HR- Heart Rate

HRmax- Maximum Heart Rate

HRR- Heart Rate Reserve

MET- Metabolic Equivalent

MVPA- Moderate to Vigorous Physical Activity

RT- Resistance Training

RPE- Rating of Perceived Exertion

VO_2- Volume of Oxygen

VO_2max- Maximum Oxygen Consumption

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CHAPTER-1: INTRODUCTION

According to the Canadian Physical Activity Guidelines (CPAG) every Canadian adult should participate in a minimum of 150 minutes of aerobic exercise per week at moderate to vigorous intensity in minimum bouts of 10-minutes or more to optimize health benefits. Additionally, every Canadian should engage in a minimum of two days on resistance training (RT) each week [1] with no specific intensity or duration. However, it is unlikely that someone would do a recommended bout of RT for less than 30 minutes to target all major muscle groups. When physical activity level is measured objectively, statistics show that only 15% of adults reach the CPAG in aerobic exercise component [2]. One of the concerns is that the majority of Canadians are not aware that they do not reach these guidelines because there tends to be a big difference between self-reported physical activity levels and what is actually measured. For example, a study showed a correlation ranging from -0.70 to + 0.96 [3] among participants, suggesting a huge variation between what is done and what is perceived as being done. This gap between objective and self-reported exercise suggests that many adults who say they are quite active in reality do not reach the CPAG requirements, and, therefore, are unlikely to see any health outcomes.

Recent studies have challenged the belief that 10- minute bouts of aerobic exercise of moderate to vigorous intensity are not needed to draw health benefits from aerobic exercise. Some studies have reported that as long as the exercise is achieved at moderate to vigorous intensity the length of bout does not matter to derive any health benefits [4-9]. If this is the case, one could benefit just as much from an accumulation of short bouts (<10-minute) of physical activities performed at moderate to vigorous intensity as from the traditional way of reaching the CPAG (≥10-minute). This notion of short bouts of moderate to vigorous intensity associated with health benefits opens up many other avenues to reach the aerobic component of the CPAG.

Since most Canadians do not reach the CPAG, it is important to explore alternative physical activities in shorter bouts of time performed at moderate to vigorous intensity that could potentially increase the number of people who reach the national physical activity guidelines. The CPAG suggest undergoing two days of RT per week in addition to aerobic exercise; as an alternative, one could focus on RT exercises and achieve two things at once. For example, if a typical RT session lasts 50 minutes, the total weekly commitment to reach the current CPAG is 250 minutes (150 minutes of aerobic exercise + two 50 minute RT sessions). As a result, the CPAG could be reached by performing RT at a moderate to vigorous intensity and reduce the required weekly time by 40%. This is important because the most cited reason for not engaging in regular physical activity is lack of time [10]. In addition, two groups of people who tend to suffer from poor mobility and/or low fitness levels – those who are overweight and older adults could benefit even more from this alternate way in meeting the CPAG. For overweight adults, it might sound contradictory to reduce the recommended amount of time for physical activity since one of the main goals for most overweight individuals is to engage in regular exercise to lose weight. The American College of Sports Medicines recommends more than 150 minutes per week to significantly reduce body weight [11]. However, the CPAG objective is not to lose weight, but to prevent the most common chronic conditions in adults and to maintain functional independence for older adults [12, 13].

The first objective of this study was to compare the time spent in moderate to vigorous intensity while doing RT at 70% or 80% of 1-RM for the entire sample group and for each subgroup (i.e., young non-overweight adults, overweight adults, and older adults). The second objective was to evaluate the proportion of time spent at moderate to vigorous intensity while doing a RT session in young non-overweight adults, overweight adults, and older adults. The third objective was to identify if the proportion of time spent at moderate to vigorous intensity was different in overweight adults and older adults when compared with young non-overweight adults. Finally, the study wanted to identify whether the collected variables (e.g., strength, age, and sex) were associated with the proportion of time spent at moderate to vigorous intensity while doing RT.

To answer our question, 60 participants were recruited – 20 young non-overweight adults [age 18-35 years old; body mass index (BMI) ≤25 kg/m^2], 20 overweight adults (BMI ≥27kg/m^2), and 20 older adults (age ≥60 years old, no limits were set on BMI). Recruitment was mainly done by sending emails to members of the University of Manitoba Recreation Services. Once individuals were contacted and their eligibility confirmed, the participants were asked to meet three times at the fitness facility. During the first visit, the consent form was signed and anthropometric data were collected (e.g., body weight, resting heart rate (HR), physical activity level). During that same visit, the maximal possible load that the participants could lift just once, commonly called the one Repetition Maximal (1-RM), was evaluated for seven of the eight RT exercises, as 1-RM cannot be measured for the abdominal planks exercise. During the second visit, participants performed all seven RT exercises at 70% of their 1-RM, for three sets per exercise of 10 repetitions each, while the abdominal exercise (i.e., abdominal plank) was done three times to exhaustion for three sets, respecting the same break between sets. The break between sets was 90 seconds long, while 30 seconds were allowed between exercises. During the third visit, participants performed the same RT exercises of the program, but this time using 80% of 1-RM. Both the second and third visits were performed while wearing a HR monitor. Moderate to vigorous intensity was determined based on whether participants reached a minimum Heart Rate Reserve (HRR) of 40%, whereas vigorous intensity was labelled as being a minimum HRR of 55% [14].

No difference was observed in the proportion of time spent at moderate to vigorous intensity between the RT performed at 70% of 1-RM and the RT done at 80% of 1-RM; all together and in between each of the three groups. Among all the participants, 82.3% of the workout time was spent at moderate to vigorous intensity during the RT session done at 70% of 1-RM. In looking at the individual groups, it was 82.6% for the young adults, 92.5% for the overweight adults, and 51.5% for the older adults ($p \leq 0.01$). RT session performed at 80% of 1-RM, the overall proportion of time spent at moderate intensity was 82.0%. For the individual groups, it was 81.0% for the young non-overweight adult group, 94.5% for the overweight adult group, and 59.4% for the older adult group ($p \leq 0.05$). No difference was observed between the overweight adult group and the young non-overweight adult group, whereas the older adult group spent a lower proportion of time at moderate to vigorous intensity during the RT sessions compared to the young non-overweight adult group ($p \leq 0.01$). Further analyses shows that older men reached a higher proportion of time spent at moderate to vigorous intensity while doing RT compared to older women ($p=0.02$). Interestingly, older men spent 81.1% of the time at moderate to vigorous intensity while older women spent 31.6% of the time at moderate to vigorous intensity when doing the workout at 70% of 1-RM. Similar results were observed when the workout was done at 80% of 1-RM. Age and 1-RM leg curl proved to be the variables that helped the most in predicting the proportion of time spent at moderate to vigorous intensity.

This study suggests that it is possible to reach moderate to vigorous intensity in short bouts while doing RT, especially for young non-overweight adults, overweight adults, and older men. If 10-minute bouts of aerobic exercise are not needed to reach functional and health benefits, the proposed RT could potentially reduce the commitment in meeting the CPAG.

Defining Terms

This section presents the terms that are specific and used often in this thesis.

Aerobic Exercise (AE)

The word *aerobic* means "living in air", and it is through the aerobic energy system the body uses oxygen to meet its demands [15] [16]. Aerobic exercise is also referred to as "cardio" exercise [17]. Aerobic exercises (e.g., running, jogging) involve many physiological responses, such as an increase in HR and oxygen consumption [18, 19], along with psychological responses that improved the mood and contribute to greater health [20].

Canadian Physical Activity Guidelines (CPAG)

The CPAG is the protocol developed by the Canadian Society for Exercise Physiology in collaboration with stakeholders for all age groups [1]. It was last updated in 2011. According to the CPAG, every Canadian adult should do a minimum of 150 minutes of aerobic exercise per week in bouts of 10- minutes at a minimum of moderate to vigorous intensity along with two days of RT.

Exercise

Exercise is a type of physical activity programmed and structured to improve one or more components of physical fitness [21].

Exercise Intensity

Intensity refers to the degree of effort needed to perform an activity [22]. Aerobic exercise intensity can be classified by using different methods, such as HR [23] and Rating of Perceived Exertion (RPE) [24]. HR can be expressed as percentages of HRmax or as a percentage of HR reserve (HRmax– resting HR). The activity is labeled as moderate intensity when HR is between 55-69% of HRmax or between 40-59% of HRR [14]. In terms of the RPE scale, the activity is labeled as moderate intensity when a person's effort is equivalent to 12-13 on a scale of 6 to 20 [25] or between 4 to 6 on a scale of 1 to 10 [26].

One Repetition Maximum

One Repetition Maximum (1-RM) is defined as the maximum load (or weight) that one person can lift at least once throughout a full range of motion in proper form [21].This is seen as being the gold standard measure to quantify maximal strength in clinical settings [27].

Physical Activity

Physical activity is body movement produced when skeletal muscles contract, which results in an increase in caloric requirements above the resting energy expenditure [28, 29].

Physical Fitness

A set of attributes or characteristics that relate to a person's ability to perform physical tasks is generally called *physical fitness* [29]. These characteristics are usually separated into different categories (cardiorespiratory endurance, body composition, muscular strength, and flexibility) or skill-related components (agility, coordination, balance, power, reaction time and speed) [30].

Resistance Training (RT)

RT is when at least one muscle is put to work against a force during any set of movements [31]. RT has many benefits, including an increase in fitness level [32], muscle strength [33], fat free mass [33], or a decrease in body fat mass [34].

CHAPTER-2: REVIEW OF THE LITERATURE

Benefits of Physical Activity

Many studies have shown that regular exercise is an effective strategy to prevent and treat several chronic diseases (e.g., cardiovascular diseases [35-37], diabetes, cancer [12] hypertension, depression and osteoporosis) [38]. It has been demonstrated that the current CPAG are sufficient to elicit health benefits, especially in people who were previously sedentary [39]. Generally, a positive linear relationship exists between physical activity level and health status [40]. Research has also shown that people who exercise on a regular basis are more productive and miss less work due to illness compared to their inactive peers [41, 42]. Both aerobic exercises and resistance exercises have been shown to be associated with positive health outcomes [43-45]. Greater physical activity level has been found effective in controlling blood lipid abnormalities, diabetes and body composition [38]. In addition, aerobic exercise has been shown to produce positive improvements in blood pressure, up to 10 mm Hg (both systolic as well as diastolic), in hypertensive individuals [46]. On the other hand, physical inactivity is an independent risk factor for development of coronary artery disease [38].

For older adults, people who exercise regularly have less functional limitations [12]. Similarly, high muscle strength level that comes from a routine exercise regimen also helps one to complete daily activities with less or no limitation [47]. Being free of physical limitations leads to a lower risk of falls and fewer injuries associated with falls [48].

One of the most common psychological benefits of aerobic exercise is stress relief by increasing norepinephrine concentrations in the blood [49]. Doing aerobic exercises also help in releasing endorphins and create a sense of euphoria and happiness [50]. Studies suggest that physical activity should be considered in the treatment of depression [51] or anxiety [52, 53]. Regular exercise done at moderate intensity has been recommended for treatment of anxiety [54]. Physical activity also helps a person gain a positive self-image and greater self-worth [55], especially if activities are done outdoors [56]. Specific to older adults, exercising prevent degeneration of cells in the hippocampus, an important gland responsible for one's memory [57].

Barriers Associated with Physical Activity

Health officials have identified so-called barriers - family responsibilities, pressures at work, lack of time [10] - that routinely deter people from regular exercise that is so essential to maintain good health and the benefits that go with it [58, 59]. Recent advances in technology have resulted in an increase in sedentary lifestyles, both at work [60] also in leisure time and at home (e.g., video games) [61, 62]. In addition, longer work days often leave people mentally exhausted, with little energy to do anything else [63]. Among older adults, there is a fear of getting injured and a lack of confidence that often restricts them from being sufficiently active to observe optimal health benefits [63]. However, lack of time reportedly is the greatest barrier for every age group [10]. Thus, it is important to find strategies for people to reach the CPAG in a more practical way in order to save time while still achieving the suggested minimum amount of exercise to optimize health benefits.

High intensity training, such as sprints, is being recognized as a way to reduce time commitment and yet still reach similar health outcomes. Studies suggest that a smaller volume of exercise performed at high intensity produces similar health benefits compared to the more traditional moderate intensity exercise conducted at a larger volume [64, 65]. Manipulating the work: rest ratio will target different energy systems depending on the length of each exercise intervals [66]. The results show increases in muscle capillary density [67], myoglobin, mitochondrial enzyme activity [68], and mitochondria number and size [68]. Many health benefits have been associated with interval training [69] such as aerobic capacity [70], cardiorespiratory, skeletal muscle adaptations [67], and metabolic syndrome risk factors [71]. Exercise volume, subsequently, can be reduced because the intensity is high compared to continuous moderate intensity sessions [68, 72]. High intensity training has been found to be more effective [43, 73] than traditional aerobic exercise at moderate to vigorous intensity in different populations (e.g., cardiac, diabetics) [74]. However, people with mobility issues and/or people with a low fitness level might not be able to adhere to, or enjoy, such training as an alternative to reach CPAG [75].

Canadian Physical Activity Guidelines

The CPAG promotes specific guidelines for five different age groups: early years (0-4 years), children (5-11 years), youth (12-17 years), adults (18-64 years), and older adults (65 years and older) [1]. Among adults, the CPAG recommend aerobic exercise for at least 150 minutes per week at a minimum of moderate to vigorous intensity in bouts of 10- minutes or more in addition to two days of RT in a week without any specific indications of the intensity. According to the CPAG, moderate intensity physical activities include brisk walking, cycling and gardening, while vigorous intensity physical activities include jogging, running, cross country skiing and swimming.

The goal of the CPAG for general adults is to increase or maintain health benefits, whereas in older adults, the objective is to increase or maintain functional abilities [1]. Although people are aware of the benefits associated with physical activity, only 27.3% of Canadians are aware of the CPAG, and only 15.6% know the details and specific recommendations of the CPAG [76]. These statistics were a bit of a surprise seeing that the national guidelines are among the most downloaded documents from the Health Canada website [77].

Methods to Measure Physical Activity Intensity

This section discusses different methods that can be used to measure the intensity of physical activity. The choice depends on various factors, such as individual needs and health issues, the resources available, and the intended goal (e.g., personal, research).

Heart Rate Monitors

The HR monitor provides immediate feedback of the heart rate and helps to adjust the activity according to the desired intensity. There are two types of HR monitors: 1) A wireless chest strap that sends data through an electromagnetic impulse to the monitor worn at the wrist; 2) A pulse monitor that requires having a hand or a finger in a particular position for a short period of time. With some models, information can be downloaded after the selected workout. The data may be recorded every 1, 5, 15, 30, or 60 seconds. During a typical aerobic exercise, the HR and oxygen consumption increase linearly with an increase in the workload [78, 79]. At a given intensity, the HR reaches a steady state level and as the workload increases, the time needed to reach a steady state goes up, affecting the typical linear relationship between the HR and oxygen consumption [80]. Consequently, the relationship between the HR and exercise intensity is weaker at high intensity physical activity compared to what is observed at low intensity.

Several exercise strategies can be used when looking at the HR. The most common methods are percentage of maximal HR (%HRmax) and percentage of HR reserve (%HRR) [81, 82]. To determine maximal HR (HRmax), expensive equipment and trained staff are needed. Therefore, using formulae to predict HRmax (e.g., 220- age) [83] that are validated are more convenient to use. Many researchers have challenged that equation over the years [84]. A recent study reported that this equation was not accurate when predicting the HRmax while performing upper body exercises [85]. For older adults, the equation of predicting HRmax = 220- age would overestimate the HRmax when doing such exercises. The authors recommended using the equation, but suggest reducing the HRmax prediction by 10 beats per minute for older adults and by 20 beats per minute for general adults.

The other method is percent of HR Reserve (%HRR). One major difference compared the percent of HRmax is that this method takes into consideration the resting HR and is recommended by the American College of Sports Medicine (ACSM) as this method is more specific to the person [86]. The measurement is calculated: [(HRmax- resting HR) X target % of exercise intensity] + resting HR [87]. The %HRR chosen for exercise prescription differs based on fitness level and goals [87].

Table 1: Main Methods to Measure Exercise Intensity

Intensity	%VO_2 max [80]	%HRmax [26]	RPE (0-20) [26]	Accelerometer (counts per minute) [88]	Walking Cadence (steps per minute) [89]
Very Light	<20	<50	<10		
Light	20-39	50- 64	10-11		
Moderate	40-59	64-77	12-13	≥1535-3959	100
Vigorous	60-84	77-94	14-16	≥3960	

VO_2 max-Maximal Oxygen Uptake
HRmax- Maximal Heart Rate
RPE- Rating of Perceived Exertion

Accelerometers

Accelerometers, devices that measure and record body accelerations caused by movements, are able to track the intensity, duration, and frequency of physical activities based on valid algorithms [90]. The data recorded by accelerometers can be used to estimate energy expenditure or steps taken at different intensities [91]. They are useful in measuring physical activity levels as they are valid, reliable and do not rely on self-reported information. However, they are more expensive than other methods to measure physical activity, and they are not reliable for some exercises, such as swimming or RT [92].

Pedometers

A pedometer is a device used to measure the number of steps taken in a certain time period, and is normally worn on the hip [93]. Pedometers are particularly useful in motivating people to get more active, and monitor how these people walk more in an effort to improve their health [89]. Most pedometers are valid and reliable for walking-based activities [94]. The use of a pedometer can result in a decrease in BMI, blood pressure [95, 96], and an increase in physical activity level [97]. A pedometer, however, does not provide the intensity involved in taking steps. New research shows walking intensity may be quantified with pedometers when counting steps per minute [89, 98]. More work is needed to identify how many steps are required to reach moderate intensity. Currently, people are advised to walk at a minimum of 100 steps per minute to reach moderate intensity [99].

Metabolic Equivalent of Tasks (MET)

A MET is used to estimate the energy cost of physical activities based on how much energy is spent doing an activity, compared to when a person is at rest [100]. Activities are measured in what are called METS. Activities equivalent to 4.8 to 7.1 METs are considered moderate intensity in young adults, between 4.5 and 5.9 METs in middle-aged adults, and between 3.6 to 4.7 METs in adults age 65 years and older. Activities at higher values are classified as being vigorous intensity [26]. Some studies suggest that three to six METs are usually considered moderate intensity for all people [101].

Oxygen Consumption

Oxygen consumption happens when the body transports and uses oxygen while performing a physical task [102]. It is often expressed as the VO_2, relative to body weight [103, 104]. Genetic factors and exercise training have been found to influence the body's ability to transport oxygen [105]. Research has shown that oxygen consumption is positively associated with HR [106]. However, at maximal capacity, oxygen consumption ceases to increase despite a HR increase. That peak is known as the VO_2max, and is considered to be a benchmark of _ maximal aerobic capacity [107]. There are advantages to prescribing exercise intensity based on VO_2 Reserve (VO_2R)compared to other methods of exercise intensity, such as RPE, %VO_2max [108, 109] or METs [110]. VO_2R is calculated as being the difference between VO_2max and resting VO_2 [86, 111]. The advantages of prescribing exercise intensity on the basis of VO_2R instead of VO_2max are: 1) There is a strong relationship between %HRR and %VO_2R, and, thus, using %HRR (by using the prediction of HRmax and measuring resting HR) provides an accurate clinical exercise intensity prescription when clinicians do not have access to a metabolic cart to measure VO_2max and resting VO_2 [112]; 2). VO_2max is not as sensitive to individual difference in fitness levels [113]; 3). Exercise prescriptions based on %VO_2R rather than %VO_2max can be directly translated into net caloric expenditure [114, 115]. In acknowledging these advantages, the American College of Sports Medicine recommends VO_2R instead of VO_2max to prescribe exercise intensity [86].

Self-Perceived Intensity

Exercise intensity can also be self-reported by using a Borg scale, which can have a measurement of 0 to 10 or 6 to 20 [18]. According to the 10 point Borg scale, 4 to 6 out of 10 is considered moderate intensity and ≥7 is considered vigorous intensity [25]. On the 20 point Borg scale, 12 to 13 out of 20 is considered moderate intensity and ≥14 is considered vigorous intensity [26]. Although self-reported methods such as the talk test are valid in determining exercise intensity [116, 117], objective tools such as HR monitors are preferred in following an exercise prescription based on exercise intensity in previously inactive clients [118, 119].

Challenging Length of Bouts of Aerobic Exercise

Despite CPAG recommendations, many studies have reported that a person does not need to perform 10- minute bouts of aerobic activity to derive health benefits as long as the exercise reaches moderate to vigorous intensity [4-7, 120, 121]. This challenges the current CPAG which suggest a minimum of 10- minute bouts of moderate to vigorous intensity to count towards the 150 minutes of aerobic exercise per week. Table 2 reports the methods and results of the most recent related studies in the area using accelerometers to measure exercise bouts.

Most of these studies concluded that bouts of moderate to vigorous intensity activities shorter than 10-minutes were associated with health benefits. However, the length of bouts was not the same in all the studies. In Mark and Janssen [7], the shortest bout considered was one minute while in another study the length of bouts compared was <10-minutes and ≥10-minutes [5]. Thus, even if the newest literature is challenging the need for 10-minute bouts at moderate to vigorous intensity, it is unclear whether such short bouts are associated with health benefits. Nonetheless, short intervals of moderate to vigorous intensity at less than 10-minutes have been associated with a similar protective factor for different chronic conditions (e.g., waist circumference) [9]. For example, Loprinzi in 2013 [5] presented the same risk of different health outcomes such as metabolic syndrome, cholesterol, BMI, triglycerides, and glucose levels for people who reach national guidelines using 10-minute bouts and those who did not.

This is an important area that needs to be explored. Not having to do activities in 10-minute bouts at moderate to vigorous intensity to optimize health benefits can help individuals who cannot perform such a task because of low fitness levels or health issues. Based on these studies, even if physical activities are performed in bouts shorter than 10-minutes, they could have similar health benefits compared to physical activities in 10-minute bouts or more. More research, especially a look at intervention, is needed to confirm these results.

Table 2: Length of Bouts of Aerobic Exercise in the Current Literature

Authors	Characteristics of Sample	Study design	Bouts of Moderate intensity exercise	Main Result
Ayabe 2013 [4]	N= 42 Age:50± 6	Cross sectional	> 32 seconds >1 minute, >3minutes >5 minute, >10 minute	≥ 1 minute and >10 minutes bouts associated with lower visceral fat.
Mark 2009 [7]	N = 2498 Age: 8-17	Cross-sectional	1-4 minutes 5-9 minutes ≥ 10 minutes	Any bouts of MVPA benefit adiposity status
Loprinzi 2013 [5]	N = 6321 Age:18-85	Cross-sectional	<10 minutes or ≥10 minutes	No difference in odd ratio for bouts <10 minutes and ≥ 10 minutes were similar for health outcomes (e.g., metabolic syndrome, HDL-cholesterol, waist circumference)
McGuire 2011 [122]	N = 135 Age: 35-65	Cross-sectional	< 10 minutes or ≥ 10 minutes	Both < 10 minutes and ≥ 10 minutes were predictors of change in cardio respiratory fitness.
Holman 2011 [9]	N = 2754 Age:6-19	Cross-sectional	< 5 minutes or ≥ 5 minutes	Relations between MVPA bouts associated with cardio metabolic risk factors

MVPA- Moderate to Vigorous Physical Activity
HDL-High Density Lipoprotein

Alternate Strategies to Reach the CPAG

In recognizing that 10-minute bouts are not needed, it might be possible to reach the CPAG by taking other approaches. For example, walking up a flight of stairs for a minute or two could count towards the time needed to reach the CPAG as long as moderate to vigorous intensity is reached. Lack of time is the most cited reason to indulge in physical activity [10], therefore, reducing the amount of time needed to reach the CPAG could potentially increase the overall number of Canadians in reaching it. Since RT is recommended in the current CPAG [1], and lack of time is the predominant barrier to regular physical activity [123, 124], it is logical to reach moderate to vigorous intensity while doing RT to reduce the total amount of time needed. Currently, the total time investment to reach CPAG is 250 minutes [150 minutes of aerobic exercise and two days of RT (about 50 minutes for each session)]. Achieving moderate to vigorous intensity while doing RT could potentially reduce the time needed to reach the guidelines by about 40% (i.e. 150 minutes instead of 250 minutes).

Resistance Training and Health Benefits

Traditionally, RT has been used to improve muscle strength, induce muscle hypertrophy, or enhance power for athletes. RT is also known to have many health benefits for the general public [125]. These benefits include weight management [126, 127], prevention and control of many chronic conditions such as type 2 diabetes [128] and cardiovascular diseases [129]. People doing RT can improve metabolic outcomes, quality of life, and physical function [130-132]. RT has also been found to be associated with an increase in resting metabolism, and, thus, daily energy expenditure [100, 133]. For older adults, improvements have been seen in balance, muscular strength [134, 135] and mobility [136-138]. In addition, RT exercises increase bone density, and, therefore, reduce the risk of osteoporosis [139, 140].

The current literature supports the inclusion of RT for a minimum two days each week to optimize health benefits for all adults [1, 141]. The current guidelines do not specify the intensity at which RT should be performed in terms of workload or HR. However, if bouts of aerobic exercise lasting less than 10- minutes can contribute to health benefits [5, 7], we can hypothesize that time spent doing moderate to vigorous intensity activities while doing RT could contribute to the aerobic time required to reach the CPAG. It should be noted that sub max 1-RM (predicted 1-RM) or maximal 1-RM testing are recommended before starting a RT program to create an exercise prescription based on maximal capacity and to track the progress [27].

Different variables of a RT program affect factors such as energy expenditure, HR response, and oxygen consumption [142, 143], and, as a result, could influence the intensity of RT programs. Five of the most studied elements include:

- Muscle Size: Compared to small muscle groups, large muscle groups induce greater energy expenditure. This can be because large muscle groups recruit more muscle fibers during the exercise and, because of an increase in oxygen consumption following the exercise session using large muscle groups compared with exercise sessions using smaller muscle size groups [144].
- Number of Sets: As the number of sets increases, the net energy expenditure is also increased. However, the net energy expenditure is maximized in the first set of any RT exercise protocol [145].
- Lifting Velocity: Higher lifting velocities (e.g., 1:1) involve more energy expenditure during, as well as after, a RT session because of greater post-exercise oxygen consumption compared to a RT session done at a lower lifting velocity (1:6) [146]. The recommendation is to follow a moderate tempo (e.g., 2:2) to maximize exercise intensity and energy expenditure while doing RT [147].
- Rest: Rest intervals do not influence total energy expenditure through RT training

[148]. Even though short rest intervals between sets are associated with higher rates of perceived exertion, the total energy cost per set is not increased [149]. However, it is hypothesized that shorter rest times would maintain an elevated HR in the moderate to vigorous intensity range as observed in circuit training programs [108].

- Exercise Order: The total oxygen consumption during the workout is not influenced by the exercise order [149].

Resistance Training Programs to Reach Moderate to Vigorous Intensity

To perform any activity, the muscles require energy to produce effective contractions [102]. There are three main pathways to produce energy: the phosphagen system, the glycolytic system, and the aerobic system [150]. Depending on the exercise intensity, the role of each system will vary in proportion [151]. Thus, the three systems do not work independently of each other. They all make contributions to the particular activity. Based on the intensity, one system, or perhaps two, would dominate the energy production for a specific physical activity. Typically, RT is not known to be an activity targeting the aerobic pathway to produce energy compared to aerobic exercises such as walking. When doing RT in a study, researchers rarely measure HR, RPE, or VO_2. If it is necessary to modify the number of repetitions, the % of 1-RM, the resting time, and/or the number of sets, it is logical that HR can reach and be maintained at moderate to vigorous intensity

Circuit Training

For people aiming to improve health, it is normally recommended to train each major muscle a minimum of two times per week [1]. Typically, it is recommended to perform 1 to 8 repetitions at 80% to 100% of 1-RM with 2 to 5 minutes of rest between 3 to 5 sets when aiming to improve strength. When targeting muscular endurance, 12 to 20 repetitions at 60 to 70% of 1-RM with 20 to 30 seconds of rest between 2 to 3 sets should be performed. A rest of at least 48 hours is usually recommended between RT sessions [45].

Circuit training is known to increase aerobic intensity (usually measured by HR) while doing RT [152] with a reduction in rest time compared to typical RT. Circuit training generally consists of eight to ten exercises repeated 2 to 3 times per session with a short resting interval between sets. Instead of doing several sets of one exercise, a person typically does one set with one exercise and then moves to the next exercise. There is generally no rest time between exercises other than the time needed to reach the next station. Circuit training is designed to alter the work: rest periods during a RT session to increase and maintain the intensity to a higher level. Circuit training programs are recommended for different groups of people, including cardiovascular patients when performed at low intensities (e.g., 40% to 60% of 1-RM) [125, 153]. Unlike a traditional RT program, in which more rest is taken for the same volume of exercise, circuit training appears to have substantial benefits. Some studies have shown a greater reduction in fat mass and cardiovascular adaptations when doing this program [154, 155] when doing circuit training.

It appears only two studies reported the average HR during a RT or circuit training program and both were done with non-overweight young adults. First, Peinado et al. (2010) documented an average of 50% HRR while doing circuit training [156]. They evaluated 26 participants in a seven-exercise circuit RT program. The participants were asked to perform three circuits of exercises at six different intensities (40%, 50%, 60%, 70%, 80%, 85% of 15-RM). The activities included: bench press, leg press, lat pull down, shoulder press, hamstring curl, biceps curl, and triceps push down. Each exercise was done in three circuits. This program took place on two separate days, one day at 40%, 50%, 60% of 15-RM, and the second day at 70%, 80%, 85% of 15-RM. There was one lap for each intensity and each exercise had a rest interval of 10 seconds with 5 minutes between each lap. No difference in the average %HRR was observed between the men and women at higher intensities (70%, 80% and 85% of 15-RM). The men, however, were performing a lower %HRR at lower intensities. The researchers concluded that it is possible to reach an average of 51.0% of %HRR while doing RT in a circuit training format and that HR, body weight and the amount of weight lifted can be used to predict the aerobic intensity during circuit weight training.

The second study was a pilot program undertaken in our facility [157]. In a cross-sectional study, we evaluated HR intensity in a nine-week RT program with 39 non-overweight young adults who were striving to increase muscular strength and improve body composition [157]. Participants were asked to exercise four times a week at the university fitness facility; two sessions involved lower body exercises and two sessions involved upper body exercises. To individualize the exercise sessions, 1-RM was assessed using a submaximal testing protocol for each of the 10 exercises; 1-RM was subsequently tested at five weeks and nine weeks to adjust the load in order to train at 70% of 1-RM. Participants performed three sets of each exercise for 12, 10, and 8 repetitions, respectively, with the exception of abdominal crunches, which were maximal as tolerated by the participant. The resting interval between sets was 90 to 120 seconds. The upper body workout included: bench press, lat pull-down, shoulder press, bicep curl, and triceps pushdown. The lower body workout included: leg press, leg extension, leg curl, calf raises, and abdominal crunches for the core. Of the 39 participants, 16 volunteered (median age of 28 years and median BMI of 24.3 kg/m^2) to wear a HR monitor during 4.1 ± 2.7 RT sessions. Moderate intensity was set at above or equal to 55% of predicted HRmax [158] where HRmax, which was estimated by using the common formula of 220-age [84]. The results show that the participants spent 51.5% ± 21.7 % of their time exercising at moderate intensity. However, when taking part in the lower-body RT session, the participants spent a median (25-75th percentile) of 75.0% (32.5%–89.2%) of their time above the moderate intensity cutoff, in comparison to a median of 45.8% (30.0%–66.8%) of the time spent during the upper-body RT session ($p=0.07$). To sum it up, both studies have shown that reaching moderate exercise intensity while doing RT is feasible for young adults with a "healthy" BMI. However, it has yet to be determined if overweight or older people (≥ 65 years) can reach moderate to vigorous intensity while doing RT.

Specific Populations

Overweight and Obese

Obesity is the term that defines a person with excessive body fat tissue [159]. BMI has been extensively used to classify obese and non-obese people because of the high correlation between body fat and BMI [160], and also because of the ease with which it can be measured. To calculate an individual's BMI, body weight (in kilograms) is divided by height (in meters squared) [161]. In 2004, 59% of Canadian adults were classified as being overweight or obese [162]. In 2010, the number increased slightly to 61% [163]. According to the CPAG, there is no specific exercise recommendation for overweight and obese individuals. However, in an effort to reduce body weight, the ACSM recommends at least five days of aerobic activities at moderate to vigorous intensity for 150 to 300 minutes per week [11]. Moreover, the ACSM suggests the exercise regimen should also include RT and flexibility exercises in addition to aerobic exercise [164].

Older Adults

Approximately 7% of the world's population is over 65 years of age and this proportion is expected to increase to 12% by 2030 [165]. By 2050 one-fifth of the Americans will be above 65 years old [166]. Also, age 85 and above is considered to be the fastest growing segment of the population [167] where 14.1% of adults currently aged over 65 years [168]. Age is the number one predictor of disability [169, 170]. Disability is a condition which includes a variety of impairments that restrict the ability to perform activities expected of one's age [171]. The costs in health care for the elderly are high, but it is even more expensive if older adults are overweight or obese [172]. As life expectancy is constantly increasing, so is the number of older adults who are considered disabled [173]. Thus, it is important to identify strategies to reduce the risk of disability in older adults. Both aerobic exercises and RT have been identified as key factors helping to reduce the risk of disability [174, 175], but only 13.2% of older Canadians are currently reaching the CPAG [2]. It is possible that doing RT exercises might be easier than traditional aerobic exercises for older people if they have mobility issues [176, 177]. There are CPAG guidelines specifically tailored for adults who are 65 years old and older [1]. The distinction for older adults is that the recommendations are based on optimizing autonomy, quality of life, and reducing disability, and not so much on decreasing the risk of diseases, as is the case for younger adults [13]. Clinically, the recommendations for physical activity are the same in adults and older adults with the addition of balance exercises if the person has mobility and balance issues [1].

Summary of the Review of the Literature

Based on the literature, it appears a person can expect to experience some health benefits when doing bouts of 10-minutes or less at moderate to vigorous intensity exercises. As a result, there are a number of new and different exercise approaches that should be explored in an effort to reach the CPAG. RT, no doubt, should be among the approaches because it is already recommended in the CPAG and it would certainly help people who struggle with a shortage of time. Overweight people and older adults, who generally suffer from serious medical conditions, can especially benefit from this alternate approach because their ailments often prevent them from taking part in common aerobic activities at required intensity.

CHAPTER-3: METHODS

Objectives

This study had four objectives: 1) To compare the proportion of time spent at moderate to vigorous intensity while doing RT when lifting 70% or 80% of 1-RM, among members in a specific group and in the overall sample of people partaking in the study; 2) To evaluate the proportion of time spent at moderate to vigorous intensity while doing a RT session in young non-overweight people, overweight people in general, and older adults; 3) To identify if the proportion of time spent at moderate to vigorous intensity was different in overweight adults and older adults when compared with young non-overweight adults; and 4) To identify if collected variables (e.g., 1-RM, age) were associated with proportion of time spent at moderate to vigorous intensity while doing RT.

Hypotheses

The hypotheses related to the objectives listed above are: 1) There will be a significant difference in the proportion of time spent at moderate to vigorous intensity between the RT done at 70% and the RT done at 80% 1-RM.; 2) Overweight adults and older adults will not have a significant difference in the proportion of time spent at moderate to vigorous intensity when compared with young non-overweight adults while performing RT at 70% and 80% of 1-RM.

Participants

Sixty members of the University of Manitoba Recreation Services Centre were recruited for the study in one of three groups: 1) Young non-overweight adult group between 18-35 years, and BMI ≤ 25 kg/m^2; 2) Overweight adult group between 18-59 years, and BMI > 27 kg/m^2; and 3) Older adult group 60 years and older, regardless of BMI. Most of the participants were recruited through biweekly emails sent out by the fitness facility. People were asked to contact the research staff if they were interested in taking part in the study. In addition, advertisements were placed on billboards and announcements were given at various workout classes at the University of Manitoba fitness facility.

Data Collection

Overview

Participants were asked to come and meet the research team. Three different visits were scheduled, with at least 48 hours between visits. Upon signing a consent form, during the first visit baseline measures were collected (e.g., body weight). These measures were to confirm inclusion criteria and to describe the samples recruited for the study. Additionally, two questionnaires on physical activity were administered to garner further background information on the participants. The first consisted of the short version of the International Physical Activity Questionnaire (IPAQ) [178, 179]; the second document consisted of the History of Physical Activity Questionnaire [180]. After baseline measurements were completed, the participants were asked to perform seven resistance exercises – lunges, squat, shoulder press, chest press, leg extension, lat pull down, and leg curl – at the fitness facility to determine their 1-RM for each exercise. The first visit lasted about 90 minutes. The second visit was involved eight different exercises (APPENDIX I). The second visit was performed at 70% of 1-RM (measured at the first visit) for each exercise, for three sets of 10 repetitions, while wearing a HR monitor. The participants were given 90 seconds of rest between each set and 30 seconds of rest between each exercise. That second visit lasted about 60 minutes. The work: rest ratio was 1: 2. The third visit was exactly the same as the second visit except that the exercises were done at 80% of 1-RM. If the participants were not able to perform 80% of 1-RM for an exercise for 10 repetitions, the load was lowered to complete three sets of 10 repetitions. During the second and third visits three times an abdominal plank was performed for a maximal time, utilizing the same rest interval between each set and the same rest interval between each exercise.

If the participants wanted to receive the results of the study they had to fill out a feedback form at the end of the program. Once the participants completed all the visits, a general conclusion was sent to them (APPENDIX II). The participants were also provided with the opportunity to ask questions about their current RT program at the end of the third visit. If they wished to have more information regarding their personal results, the researchers' contact information was made available.

Anthropometric Measures (Height, Weight, Waist Circumference

Anthropometric measures were taken in accordance to the Canadian Society for Exercise Physiology protocols [181]. With participants wearing light clothing and no footwear, body weight was measured using a digital scale (OMRON HBF-5186, Illinois, USA). Height was measured against a tape mounted on the wall ensuring the participants were standing perfectly straight with arms to the side of the body. The measurement was taken at the end of expiration and rounded off to the nearest 0.5 cm. BMI was calculated using the standard formula: BMI= weight (kg)/height $(m)^2$ [182]. For waist circumference, the participants were asked to remove clothing and accessories at the abdominal area. Everyone was then instructed to stand with feet shoulder width apart and arms crossed at the chest level. The measurements, rounded off to the nearest 0.1 cm, as recommended, were taken twice at the superior edge of the iliac crest at the end of expiration [183]. If the difference between the two readings was more than 0.5 cm, a third reading was taken and the mean of the two closest readings was retained for analysis.

Handgrip Strength

Following ACSM protocol [184], the participants were asked to grip the dynamometer (JAMAR 08-1028935, Sammons Preston, Illinois, USA) between the fingers and the palm at the base of the thumb, with the shoulder adducted and elbow at a 90-degree angle. The participants were then required to squeeze their grip as hard as possible while breathing out and not touching their elbow to their body. The measurement was taken twice on each side. The maximum score for each hand to the nearest 0.1 kg was kept for analysis [184].

Resting Heart Rate and Blood Pressure

Resting HR and blood pressure measurements were taken twice [185]. The participants were seated for at least five minutes in a chair with a back support before the first reading of their resting HR and blood pressure were taken. The cuff was wrapped around the upper arm, and aligned with the brachial artery. Using an automatic apparatus (OMRON HEM-432C, Illinois, USA) the procedure was repeated with two minutes between the readings. The lower of the two readings was retained for resting HR [181]and the mean of the two readings was kept for blood pressure analysis [185].

1-RM Measurement/Volume

The 1-RM was tested using a validated indirect strategy that is 95% correlated with maximal 1-RM testing [186]. For each RT exercise, the research assistant demonstrated the exercise and had the participants do a light warm-up set using a light weight or no weight at all. Based on a discussion with the participants, load was added so that the participants would be able to achieve between one and ten consecutive repetitions. Repetitions that lost form or were not performed throughout the full range of motion were not counted. If a participant completed more than ten repetitions, a minute of rest was provided and the procedure was then repeated. This procedure was repeated for a maximum of three attempts. After that, the 1-RM test was postponed to a future visit. Then, the 1-RM was estimated using a validated formula (Table 3 [186]). For example, if the maximal load a participant lifted was 43.5 kg and the participant was able to do seven repetitions, the estimated 1-RM was 60.5 kg. The volume of exercise was calculated during both exercise sessions using the metric ton formula: [load (kg) X reps (#) X sets (#) /1000] [21].

Physical Activity Questionnaires

The short version of the IPAQ was used to measure self-reported physical activity level. This questionnaire utilizes properties for measuring physical activity of all age groups in diverse settings [179, 187]. Briefly, the questionnaire provides an overview of light, moderate, and vigorous intensity activities self-reported in the past seven days. A History of Physical Activity questionnaire was also filled out [180]. This gave the research staff a sense of the participants' activity level in the past 10 years and the factors that could have influenced their lifestyles. If the participants considered themselves active, the kind of activities they liked were also documented.

Table 3: Estimation of 1-RM

Repetition completed	% 1-RM [186]
1	100
2	95
3	93
4	90
5	87
6	85
7	83
8	80
9	77
10	75

Baechle et al.,2008 [186]

Intensity during Each Session

The HR was measured by HR monitor and recorded every 15 seconds. As each participant performed RT sessions while wearing a HR monitor, the Karvonen Formula [Target HR= (HRmax (220-age)- Resting HR) X 40%) + Resting HR] was used to determine the minimum HR needed to reach moderate intensity (40% of HRR) [14]. The cutoff for vigorous intensity was ≥60% of HRR [14]. The proportion of time spent at moderate to vigorous intensity was calculated based on each 15-second period divided by the total time. The HR of 15 participants (n=5, each group) was monitored using a function in the HR monitor watch that indicated when each exercise started and finished. The results were used to calculate average HR during each exercise for this sub-sample. In addition, it was possible to pool the proportion of time spent in moderate to vigorous intensity for upper body exercises, lower body exercises, as well as for each exercise. A new study suggests that HRmax is overestimated by 10 to 20 beats per minute when using the commonly used equation of 220–age when performing upper body exercises; therefore, the formula used to calculate HRmax for upper body exercises – chest press, lat-pull down, shoulder press – was done with the traditional 220-age [84] and [(220-age)-15] [188].

A threshold of 75% of time spent at least at moderate to vigorous intensity while doing RT was identified as the minimum threshold needed to significantly reduce the time needed to reach the CPAG. This would be interesting for the population to reduce the time commitment to reach the CPAG. If a person only reaches moderate to vigorous intensity while doing RT 40% of the time, he or she would have to increase the weekly time commitment to reach the CPAG.

Length of Bouts

A bout is a short period of any activity of a specified kind [189]. In compiling calculations for this study, the research assistant manually counted the number of times the HR was ≥ 40% of the HRR every 15 seconds when using 220-age to predict HRmax for each participant. The mean and the longest length of time at moderate to vigorous intensity was calculated and reported as a bout in minutes.

Statistical Analysis

The distribution of every continuous variable was tested using the Shapiro-Wilk tests. Most variables were not normally distributed besides each group had a small sample size, the characteristics of the sample were described using the median (25-75th percentile) and non-parametric analyses were performed. In comparing the overweight or older adult group with the young non-overweight adult group, depending on whether continuous or categorical variables were being analyzed the Mann-Whitney tests (e.g., age, body mass, waist circumference) or the Chi-squared tests (e.g., sex) were used.

Correlations between descriptive characteristics (e.g., age) and time spent at MVI while doing RT at 70% and 80% of 1-RM were performed using the Spearman correlation tests. Comparisons of the proportion of time spent at moderate to vigorous intensity among the three groups when doing the RT at 70% of 1-RM and 80% of 1-RM was evaluated by using the Wilcoxon tests. A linear regression was performed to identify variables that could help to predict time and proportion of time spent at moderate to vigorous intensity while doing RT. Finally, logistic regression was applied to predict variables associated with reaching a minimum of 75% of time spent at moderate to vigorous intensity while doing RT. All statistics were performed using SPSS version 17.

CHAPTER-4: RESULTS

Descriptive Information

As shown in Table 4, there were many differences when comparing the young non-overweight adult group with the other two groups. As per study design, the young non-overweight adults were significantly younger than the older adult group and weighed less than the overweight adult group ($p \leq 0.01$). The older adult group was significantly different from the young non-overweight adult group in characteristics such as age, BMI, waist circumference, predicted HRmax ($p \leq 0.01$), systolic blood pressure, and maximum hand grip strength (all $p \leq 0.05$). Meanwhile, the overweight adult group was significantly different from the young non-overweight adult group in characteristics such as age, greater body mass, BMI, waist circumference, and predicted HRmax (all $p \leq 0.05$). Even though the recruitment was not stratified by sex, there were a near equal proportion of men and women in each group.

Upon collecting self-reported physical activity levels (Table 5), most of the information was not significantly different between the non-overweight young adult group when compared to the overweight adult group or the older adult group. The only difference was that the time spent at moderate intensity was substantially greater among the young non-overweight adults compared to the overweight adults ($p=0.03$). Also, the years of experience doing RT was significantly greater in the older adult group compared with the young non-overweight adult group ($p \leq 0.01$).

Table 4: General Characteristics

	Young Non-Overweight Adults N= 20	Overweight Adults N= 20	Older Adults N= 20
Age (years)	22.0 (21.0-24.7)	30.0 (24.0-43.0)**	64.5 (60.0-70.0)**
Gender (men)	10 (50.0)	12 (60.0)	11 (55.0)
Body Mass (kg)	70.7 (64.5-77.2)	89.3 (78.9-107.0)**	70.1 (62.2-73.9)
Body Mass Index (kg/m^2)	23.5 (22.0-24.4)	29.7 (28.8-32.9)**	23.7 (22.2-26.7)**
Waist Circumference (cm)	79.5 (73.3-85.9)	99.0 (92.2-110.5)**	88.2 (81.0-92.2)**
Resting Heart Rate (bpm)	60.0 (51.2-68.7)	63.5 (53.2-70.0)	60.0 (55.2-66.0)
Predicted HRmax Using 220-age (bpm)	191.5 (189.2-193.0)	187.0 (178.5-191.0)**	163.5 (160.0-167.0)**
Systolic BP (mmHg)	116.2 (110.5-127.5)	128.5 (112.7-137.1)	128.5 (121.75-137.13)*
Diastolic BP (mmHg)	68.7 (60.7-73.7)	72.5 (66.5-80.8)	74.2 (63.7-81.7)
Maximum Hand Grip (kg)	38.2 (32.7-44.6)	40.5 (25.4-55.0)	31.5 (25.6-37.1)**

Data presented as median (25-75 percentile), or N (%)
BP- Blood Pressure
*$p \leq 0.05$
**$p \leq 0.01$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group
A Chi-Square test was used to test differences in gender between the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Table 5: Self-Reported Physical Activity Levels

	Young Non-Overweight Adults	Overweight Adults	Older Adults
PA Frequency (times/week)	5.0 (4.2-6.7)	4.0 (3.0-5.4)	5.0 (3.9-5.9)
PA Weekly Time (min)	380.0 (271.9-450.0)	307.5 (165.0-545.6)	325.0 (274.4-440.6)
Duration of Current PA level (months)	36.0 (12.0-57.0)	18.0 (3.5-57.5)	42.0 (16.2-174.0)
Time Moderate Intensity (min/week)	135.0 (92.5-262.5)	60.0 (0.0-142.0)*	137.5 (37.5-236.2)
Time Vigorous Intensity (min/week)	190.0 (120.0-270.0)	180.0 (120.0-262.5)	180.0 (58.1-240.0)
Years Doing RT (years)	4.5 (2.0-6.7)	3.5 (0.3-8.0)	12.5 (4.2-27.5)**
RT (days/week)	3.5 (2.5-4.0)	3.0 (2.0-3.5)	3.0 (1.6-3.0)

Data presented as median (25-75th percentiles)
PA- Physical Activity
HR- Heart Rate
RT-Resistance Training
*$p \leq 0.05$
**$p \leq 0.01$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Body weight is normally associated with muscle strength [190]. In an effort to further understand this relationship, strength relative to body weight was evaluated and is presented in Table 6. No difference was observed between the young non-overweight adult group and the overweight adult group on any of the tested exercises. However, five exercises were performed with a lower relative load with the older adults compared with the young non-overweight adults despite no difference in body mass between the two groups ($p \leq 0.05$).

Table 6: Relative 1-RM (Load/ Body Weight)

	Young Non-Overweight Adults	Overweight Adults	Older Adults
Relative Chest Press	1.0 (0.7-1.0)	0.9 (0.6-1.3)	0.7 (0.6-0.8)**
Relative Squats	1.0 (0.8-1.4)	0.9 (0.6-1.4)	0.7 (0.6-0.9)*
Relative Lunges	0.5 (0.4-0.7)	0.4 (0.2-0.6)	0.4 (0.2-0.4)**
Relative Lat Pull Down	0.9 (0.6-1.1)	0.9 (0.5-1.0)	0.7 (0.6-0.8)
Relative Leg Extension	0.9 (0.6-1.1)	0.9 (0.5-1.0)	0.7 (0.6-0.8)
Relative Shoulder Press	0.8 (0.6-1.0)	0.6 (0.5– 1.1)	0.4 (0.3-0.7)**
Relative Leg Curl	0.8 (0.7-0.9)	0.7 (0.5-0.8)	0.6 (0.4-0.7)**

Data presented as median (25-75th percentiles)
*$p \leq 0.05$
**$p \leq 0.01$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Time Spent at Moderate Vigorous Intensity

Together, the median workout time for all participants was 49.5 minutes (47.2-51.9), out of which 40.6 (28.4-46.2) minutes and 39.5 (28.1-46.3) minutes were spent at moderate to vigorous intensity at 70% of 1-RM and 80% of 1-RM, respectively (Table 7). One of the objectives of this study was to identify if the proportion of time spent in moderate to vigorous intensity while doing RT sessions (70% of 1-RM and a session at 80% 1-RM) was significantly different in the overweight adult group and the older adult group when compared with the young non-overweight adults. In a careful look at the duration of the workout, the time spent at moderate to vigorous intensity, and the percentage of time spent at moderate to vigorous intensity, there was no difference between the young non-overweight adults and the overweight adults for both 70% and 80% of the 1-RM exercise sessions. On the other hand, the older adult group spent less time and less percentage of time at moderate to vigorous intensity at both RT sessions compared with the young non-overweight adult group ($p \leq 0.05$). Because no difference in proportion of time spent in moderate to vigorous intensity was observed between the two exercise sessions, the remaining of the results were recorded based on the first exercise session (70% of 1-RM).

The minimum proportion of HRR considered to be moderate intensity is 40% [14]. When combining the results from all the participants, median (25-75th) %HRR while performing the RT session using 70% of 1-RM was 52.7% of HRR (43.3-59.7); it was 53.4% of HRR (44.4-60.8) when performing the RT session at 80% of 1-RM. The older adult group presented a lower median proportion of HRR during both RT sessions ($p \leq 0.05$) when compared with the young non-overweight adult group.

Similar findings were observed when using 55% of predicted HRmax (220-age) instead of 40% HRR as the cutoff for moderate intensity. For example, when combining the results from all the participants, 97% and 96% of workout time was spent at moderate to vigorous intensity when doing the RT at 70% of 1-RM and 80% of 1-RM when using 55% of predicted HRmax.

When only evaluating the proportion of time spent at vigorous intensity, 25% and 31% of the time was spent at vigorous intensity while performing RT at 70% of 1-RM and 80% of 1-RM, respectively. No significant difference for that variable was observed between the young non-overweight adult group with either the overweight adult group or the older adult group.

In a further analysis, it was evaluated if the collected variables from all the participants were associated with the proportion of time spent at moderate to vigorous intensity and vigorous intensity while doing RT session at 70% of 1-RM and 80%-1RM. The bivariate correlations revealed that 13 variables were significantly associated with the proportion of time spent at moderate to vigorous intensity during the second visit (70% of 1-RM): squats 1-RM ($r=0.53$; $p\leq0.01$), leg curl 1-RM ($r=0.52$; $p\leq0.01$), total volume of exercise ($r=0.52$; $p\leq0.01$), chest press 1-RM ($r=0.51$; $p\leq0.01$), shoulder press 1-RM ($r=0.48$; $p\leq0.01$), leg extension 1-RM ($r=0.47$; $p\leq0.01$), lat pull down ($r=0.43$; $p\leq0.01$), HRR ($r=0.39$; $p\leq0.01$), age ($r=-0.39$; $p\leq0.01$), weight ($r=0.39$; $p\leq0.01$), lunge 1-RM ($r=0.37$; $p\leq0.01$), BMI ($r=0.33$; $p\leq0.01$), and hand grip strength ($r=0.26$; $p\leq0.05$).

Table 7: Intensity While Doing Resistance Training Sessions

	Total	Young Non-Overweight Adults	Overweight Adults	Older Adults
Workout Time (min)	49.5 (47.2-51.9)	49.8 (47.6-52.2)	48.8 (47.5-50.9)	50.5 (46.3-53.7)
		70% of 1-RM		
Time MVI (min)	40.6 (28.4-46.2)	42.1 (34.5-47.5)	44.5 (34.7-47.1)	24.0 (11.2-40.1)**
% Time MVI	82.3 (56.1-94.7)	82.6 (69.2-94.6)	92.5 (73.3-99.1)	51.5 (22.0-86.6)**
% Time VI	25.0 (12.9-48.0)	28.9 (18.1-41.1)	31.6 (16.2-51.8)	13.0 (3.7-36.0)
HR (bpm)	124.8 (111.0-135.8)	130.6 (123.135.9)	132.7 (120.8-140.5)	102.6 (93.9-115.1)
HRR (%)	52.7 (43.3-59.7)	53.3 (48.6-57.9)	58.0 (48.6-61.8)	43.0 (30.2-55.1)*
		80% of 1-RM		
Time MVI (min)	39.5 (28.1-46.3)	39.4 (31.1-46.8)	43.7 (38.3-50.1)	27.3 (17.0-43.0)**
% Time MVI	82.0 (59.2-98.0)	81.0 (60.7-96.1)	94.5 (73.8-99.9)	59.4 (31.1-92.3)*
% Time VI	31.0 (12.9-49.3)	34.0 (17.8-42.4)	37.0 (22.7-70.4)	13.0 (8.4-36.4)
HR (bpm)	124.6 (112.3-137.7)	131.2 (122.4-139.5)	136.9 (119.6-145.9)	105.9 (97.6-116.2)
HRR (%)	53.4 (44.4-60.8)	54.9 (45.9-59.5)	56.9 (48.4-67.5)	44.2 (35.5-57.0)**

1-RM – One Repetition Maximum
MVI- Moderate Vigorous Intensity
VI- Vigorous Intensity
*$p \leq 0.05$
**$p \leq 0.01$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Regression Models to Predict Time Spent at Moderate to Vigorous Intensity

Variables that were associated with the proportion of time spent at moderate to vigorous intensity in bivariate analyses were entered in a linear regression model using a stepwise approach. The analysis revealed that age and leg curl 1-RM were the only variables included in the model explaining 38.5% of the proportion of time spent at moderate to vigorous intensity when performing a RT session at 70% of 1-RM. Based on that analysis, the equation to predict how much time is likely to be spent at moderate to vigorous intensity in similar individuals doing RT at 70% of 1-RM was: 67.96 + 0.48 [leg curl 1-RM (kg)] -0.49 [age (years)]. When linear regressions were done for each group, in addition to age and leg curl 1-RM, gender was a significant variable in the model, but only in the older adult group. The proportion of time spent at moderate to vigorous intensity in older men was 81.1% compared with 31.6% in older women ($P=0.01$). Further analyses were done to help understand the difference in proportion of time spent in moderate to vigorous intensity while doing RT between older men and older women. Table 8 presents some characteristics of the older adult group based on sex. BMI and hand grip were significantly lower among the women than among the men ($p \leq 0.01$). In terms of strength, men lifted more weight relative to their body weight in only two of seven exercises ($p \leq 0.01$).

A logistic regression model was performed to verify which variables could predict spending a minimum of 75% of time at moderate to vigorous intensity. The final model showed that age was the only significant predictor ($p \leq 0.03$). In the young non-overweight adult group, 75% of the participants spent a minimum of 75% of the time at moderate to vigorous intensity during the RT session at 70% of 1-RM. These proportions were 85% in the overweight adult group, but only 35% in the older adult group. Similar results were observed when doing the analyses of the RT session at 80% of 1-RM (55%, 75%, and 35%). The difference was only significant between the young non-overweight adult group and the older adult group (p=0.03) in which only older men reached 75% of the time spent at moderate to vigorous intensity.

Table 8: Comparison between Older Men and Older Women

	Older Men N=11	**Older Women N=9**
General Characteristics		
Age (years)	68.0 (60.0-72.0)	63.0 (60.0-68.0)
Body Mass (kg)	73.5 (70.1-84.9)	63.1 (50.7-70.1)
Body Mass Index (kg/m^2)	23.9 (22.8-27.8)	23.0 (19.8-26.1)**
Maximum Hand Grip (kg)	35.8 (29.5-39.0)	26.5 (19.7-31.5)**
Relative Strength		
Relative Chest Press	0.7 (0.7-0.9)	0.7 (0.6-0.8)
Relative Squats	0.7 (0.6-0.8)	0.7 (0.5-0.9)
Relative Lunges	0.4 (0.2-0.5)	0.3 (0.2-0.4)
Relative Lat Pull Down	0.8 (0.7-0.9)	0.6 (0.5-0.7)**
Relative Leg Extension	0.8 (0.7-0.9)	0.6 (0.5-0.7)**
Relative Shoulder Press	0.5 (0.4-0.7)	0.4 (0.2-0.6)
Relative Leg Curl	0.6 (0.5-0.7)	0.6 (0.4-0.7)

Data presented as median (25-75th percentiles)
**$p \leq 0.01$
Mann-Whitney tests were used to compare men and women

Volume of Exercise

The volume of exercise for the two RT sessions was calculated in metric tons. The results are presented in Figure 1. During both RT sessions, participants in the older adult group performed less volume than those in the young non-overweight adult group ($p \leq 0.01$) while no difference was observed between the young non-overweight adults and the overweight adults.

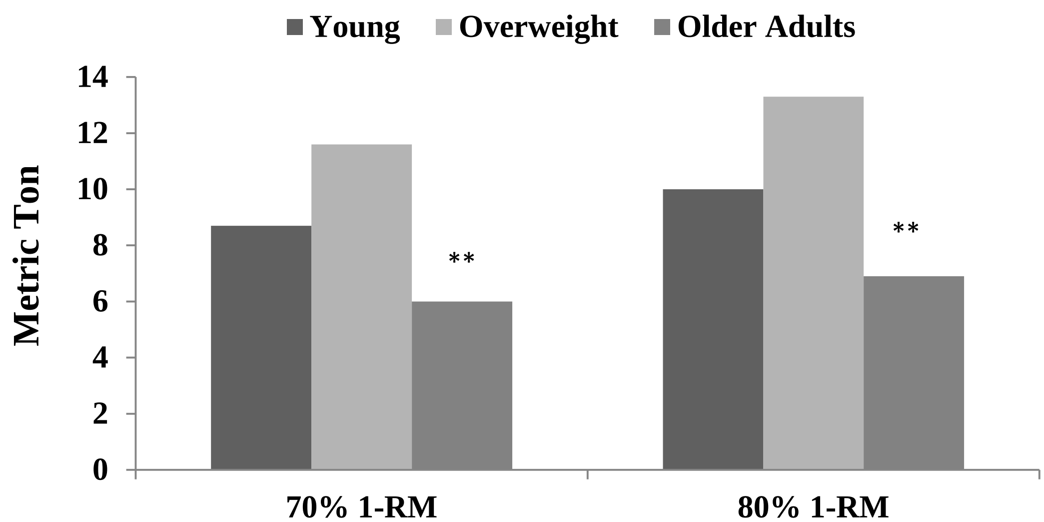


Figure 1: Volume of Exercise at Different Exercise Sessions
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group
**$p \leq 0.01$

Length of Bouts Spent at Moderate to Vigorous Intensity

Based on CPAG recommendations [1] , the researchers carefully evaluated the longest bouts and the average length of bouts spent at moderate to vigorous intensity (Table 9). When the results for all the participants were combined, the median longest bout was 10.4 minutes and 12.0 minutes for the RT session done at 70% and 80% of 1-RM, respectively. On the other hand, the median bout length was 2.2 minutes for both RT sessions.

Table 9: Duration of Bouts while Doing Resistance Training

	Total	Young Non-Overweight Adults	Overweight Adults	Older Adults
Median Bout Length at 70% of 1-RM (min)	2.2 (1.2-6.1)	2.6 (1.6-4.2)	5.0 (1.5-39.2)	1.1 (0.7-2.7)**
Longest Bout at 70% of 1-RM (min)	10.4 (5.2-39.1)	13.5 (7.7-27.3)	16.7 (8.4-44.4)	3.6 (2.0- 15.2)**
Median Bout Length at 80% of 1-RM (min)	2.2 (1.2-13.8)	2.6 (1.3-7.7)	7.6 (1.8-41.6)	1.2 (0.8-4.8)
Longest Bout at 80% of 1-RM (min)	12.0 (5.2-39.1)	12.3 (5.2-37.7)	26.7 (9.0-50.1)	7.5 (2.3-20.2)

Data presented as median (25-75th percentiles)
**$p \leq 0.01$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Evaluation of Each Exercise

Five volunteers from each of the three groups had their HR evaluated in every exercise (Table 10). Overall, the participants spent the highest proportion of time at moderate to vigorous intensity doing lat pull down 100.0% (80.0-100.0), leg extension 100.0% (50.0-100.0), and shoulder press 100.0% (40.0-100.0). The only difference observed was in the leg curl exercise, in which the overweight adult group spent significantly more time at moderate to vigorous intensity compared with the young non-overweight adult group ($p \leq 0.05$). These volunteers were also examined to evaluate the proportion of HRR and the amount of time spend in moderate to vigorous intensity when using two different equations to estimate HRmax for upper body exercises (Table 11). These proportions were calculated using the traditional 220-age equation to predict HRmax and then again by using the Hill et al. equation. No significant difference was observed between the two methods in estimating HRmax when evaluating the proportion of HRR or time spent in moderate to vigorous intensity for any upper body exercises. The %HRR using the equation 220-age to predict maximum HR for the other exercise is also presented.

Table 10: Proportion of Time Spent at Moderate to Vigorous Intensity

	Total N = 15	Young Non-Overweight Adults N=5	Overweight Adults N=5	Older Adults N=5
Squat	71.4 (37.5-100.0)	48.1 (37.5-78.5)	93.7 (51.9-100.0)	83.3 (7.1-100.0)
Chest Press	53.8 (0.0-100.0)	40.5 (0.0-81.2)	75.0 (42.5-100.0)	53.8 (0.0-100.0)
Lunges	94.5 (82.1-100.0)	88.9 (82.1-100.0)	100.0 (70.0-100.0)	93.7 (63.6-100.0)
Lat Pull Down	100.0 (80.0-100.0)	91.6 (75.0-100.0)	100.0 (85.0-100.0)	80.0 (16.6-100.0)
Leg Extension	100.0 (50.0-100.0)	90.0 (53.3-100.0)	90.0 (57.5-100.0)	100.0 (7.1-100.0)
Shoulder Press	100.0 (40.0-100.0)	100.0 (58.3-100.0)	92.8 (58.9-100.0)	100.0 (16.7-100.0)
Leg Curl	85.7 (60.0-100.0)	83.3 (62.5-89.3)	100.0 (100.0-100.0)*	60.0 (8.3-100.0)
Plank	71.4 (57.1-90.0)	69.0 (51.2-78.7)	78.5 (60.7-96.4)	70.0 (27.8-100.0)
Total	72.1 (62.5-98.0)	66.5 (61.6-83)	85.9 (72.5-98.1)	64.2 (21.1-100.0)

Data presented as median (25-75th percentiles)
*$p \leq 0.05$
Mann-Whitney tests were used to compare the Young Non-Overweight Adult Group with either the Overweight Adult Group or the Older Adult Group

Table 21: Percentage of HRR and Time Spent at Moderate to Vigorous Intensity

	%HRR Using 220-age to predict Max HR[84]	%HRR Using the Hill formula to predict Max HR in upper body exercises [188]	% time in MVI Using 220-age to predict Max HR [84]	% time in MVI Using the Hill formula to predict Max HR in upper body exercises [188]
Squat	0.47 (0.40-0.62)			
Chest Press	0.46 (0.42-0.64)	0.42 (0.42-0.64)	0.75 (0.42-1.00)	0.92 (0.81-1.00)
Lunges	0.65 (0.56-0.76)			
Lat Pull Down	0.52 (0.50-0.52)	0.53 (0.53-0.64)	1.00 (0.85-1.00)	1.00 (0.91-1.00)
Leg Extension	0.52 (0.44-0.63)			
Shoulder Press	0.55 (0.46-0.57)	0.53 (0.42-0.60)	0.93 (0.59-1.00)	1.00 (0.92-1.00)
Leg Curl	0.54 (0.45-0.55)			
Plank	0.42 (0.40-0.51)			

HRR- Heart Rate Reserve
MVI- Moderate to Vigorous Intensity
Data presented as median (25-75th percentiles)
Wilcoxon tests were used to compare proportion of HRR and time spent at MVI between the two formulas for each exercise

CHAPTER 5: DISCUSSION

One of the objectives of the study was to identify what was the time spent at moderate to vigorous intensity while doing RT in overweight adults and older adults. Another objective was to evaluate if the proportion of time spent at moderate to vigorous intensity while doing a RT session was different in these two groups when compared with the young non-overweight adults. The participants spent 82.4% of the time in moderate to vigorous intensity when doing the RT at 70% of 1-RM and 81.0% of the time in moderate to vigorous intensity when doing the RT at 80% of 1-RM. During both RT sessions, no difference was observed in the proportion of time spent at moderate to vigorous intensity between the young non-overweight adult group and the overweight adult group. On the other hand, the older adults had a lower proportion of time spent at moderate to vigorous intensity for both RT sessions compared with the young non-overweight adults. However, older men were more likely to reach moderate to vigorous intensity compared with older women.

No significant difference was observed in the proportion of time spent at moderate to vigorous intensity between the RT session performed with 70% of 1-RM and that with 80% of 1-RM. One of the reasons could be that the volume of exercise was not sufficiently different to see any difference in the cardiovascular response. As a result, we recommend doing 70% of 1-RM to reach moderate to vigorous intensity because it causes less fatigue and has a lower volume.

Proportion of Time Spent at Moderate to Vigorous Intensity

The young non-overweight adult group spent 82.6% of their session time at moderate to vigorous intensity, whereas the overweight adult group spent 92.5% of their time at moderate to vigorous intensity when doing RT at 70% of 1-RM. This means that if the duration of a RT session is 50 minutes, as observed in our study, young non-overweight adults and overweight adults would be reaching moderate to vigorous intensity for 41 minutes and 46 minutes, respectively. In order to reach the CPAG aerobic component, young non-overweight adults and overweight adults could do three RT sessions at 70% of 1-RM for about 60 minutes per session every week.

When evaluating the whole sample, the proportion of time spent at moderate to vigorous intensity was greater (82.3%) when compared with the proportion of time (52.0%) observed in an earlier study that had been previously done in our laboratory settings [157]. We had previously reported that RT upper body exercises did not increase HR as much as RT lower body exercises and the difference may be the result of a less number of upper body exercises in this study [157]. A greater muscle mass is recruited when doing lower body exercises and this also may have had an impact on our results [191]. Similarly, we included one multi-joint exercise, lunges, that uses a large muscle group, which is known to increase exercise intensity [192]. In addition, resting time between exercises was shorter in the current study compared with our pilot study (30 seconds compared with 60 to 90 seconds) [157].

Even if the proportion of time spent at moderate to vigorous intensity was relatively high while doing RT, we believe that even a higher proportion of time spent at a minimum of moderate to vigorous intensity could be observed. For example, the four exercises that reached the highest proportion of time in moderate to vigorous intensity (lunges, lat pull down, leg extension, and shoulder press) could be done twice in one training session. Another option would be to repeat the same program in a circuit training pattern and reduce the resting interval. Circuit training is a type of RT program that aims at increasing strength and aerobic capacity [193, 194], mostly using multi-joint RT and callisthenic exercises [195]. During circuit RT, multiple laps are performed by using a small number of exercises (e.g., <10 exercises) with minimal or no rest between the exercises, but involves a short rest interval between laps [194].

A recent study reported that HR could be increased significantly by using circuit RT [196]. In four rounds of eight different exercises, nine physically active men did RT interval training using 75% of 1-RM; their HR was significantly higher than in an aerobic training session [196]. The researchers suggest that a RT program performed in a circuit training fashion could be as beneficial as aerobic training for those who have less time to gain benefits of both resistance and cardiovascular training in young non-overweight adults. Another study conducted by Peinado et.al (2010) evaluated exercise intensity in 14 men and 12 women aged 22 ±2 years old while doing seven exercises (sitting bench press, leg press, lat pull down, shoulder press, hamstring curl, biceps curl, triceps extension) performed in a circuit training manner [156]. Six different intensities of RT programs were compared: 40%, 50%, 60%, 70%, 80%, and 85% of 1-RM [156]. The participants were monitored for HR and energy expenditure. During each workout, the participants performed all seven exercises three times. They had a 10 second rest between exercises, with a five minute break between circuit laps. The tempo of each movement was 2:0:2 (eccentric: rest: concentric). The researchers observed differences between men and women at low intensities (≤ 60% of 1-RM), but at higher intensities (70%, 80%, and 85% of 1-RM) no difference was detected. The findings mirror our study results, in which we evaluated the cardiovascular response using 70% and 80% of 1-RM. We observed no difference in the HR responses between men and women.

Although studies reporting the benefits of circuit training mentioned HR and VO_2 while doing RT, to our knowledge we are the first to look into whether moderate to vigorous intensity can be reached while doing RT. This could potentially replace or help to reach aerobic exercise to reach the CPAG aerobic component. Peinado et al. (2010) reported that their participants were doing an average of 51.0% of HRR while performing RT [156], which would be considered moderate intensity. In our case, 53.3% was the median value in the young non-overweight adult group, which had a similar age range, when doing RT at 70% of 1-RM. Using regression models, Peinado et al. (2010) found that HR during the exercise session, work load, and body weight, were the factors predicting the intensity of the exercise session for men while HRmax and workload during the RT session were identified for women. In our study, strength (i.e., leg curl 1-RM) was the best predictor of the proportion of time spent at moderate to vigorous intensity with no differences between men and women in the young group. Because the workload is based on 1-RM, we could say that there are some similarities between Peinado's study and ours.

When looking at all of our participants, we observed that age and 1-RM leg curl were predictors of time and proportion of time spent in moderate to vigorous intensity. Physiologically, it is possible to explain why age is a predictor. In our study, the older adult group reached a smaller proportion of time in moderate to vigorous intensity compared to the young non-overweight adult group (51.5% vs. 82.6%). Among the reasons for this, the older adults were not lifting as much volume (31% less; Figure 1) compared with the young non-overweight adults. For example, the volume of exercise was a median of 6.0 metric tons in the older adult group compared with 8.7 metric tons in the young non-overweight adult group. This was expected because the volume is a result of maximal strength and it is well known that maximal muscle strength is reduced with age [197].

In addition, the literature suggests that older adults might not perform their true 1-RM when evaluating it in only one session, especially for older women [198]. In fact, one study has indicated that older adults need two to three sessions of 1-RM testing before reaching their true maximum [199]. It is possible that the 1-RM in older adults was underestimated, and, as a consequence, older adults might have done their RT sessions at a lower percentage than the expected 70% and 80%, which partly explains why their HR did not reach a higher proportion of moderate to vigorous intensity. Nonetheless, we chose this method because all our participants had a history of RT (average of 12.5 years in older adults). It was, therefore, assumed that they would be familiar with RT exercises and would reach their true 1-RM in one session. It is possible that evaluating 1-RM two to three times would have contributed to a higher volume workout and possibly increased the time spent at moderate to vigorous intensity in older adults, especially if 1-RM would have been increased for the leg curl exercise because the 1-RM leg curl was one of the predictors of time spent at moderate to vigorous intensity while doing RT. In the current study, the difference between the 1-RM in leg curl of the young non-overweight adult group and the older adult group was 35%; 57.9kg (43.6-67.3) in the young non-overweight adult group versus 37.6kg (27.3-51.4) in the older adult group ($p \leq 0.01$). Moreover, the relative 1-RM for the older adult group was lower compared to the young non-overweight adult group for six of eight RT exercises, meaning that for the same body weight, older adults lifted less load compared to younger adults, probably because of a lower muscle quality [200]. Physiologically, this reduction in muscle quality can be explained by the fact that the muscle unit undergoes a deterioration with aging that impairs the excitation/contraction coupling. A decrease in fiber recruitment results [201] change in the sinoatrial node cells or cardiac output associated with aging could also explain why HR was not as elevated in the older adults as in the young non-overweight adults [202].

As mentioned earlier, leg-curl 1-RM was a predictor of time and proportion of time spent in moderate to vigorous intensity. No physiological reason was found why leg curl 1-RM was an important predictor compared to other RT exercises. In fact, many other 1-RM tests were associated with proportion of time spent in moderate to vigorous intensity when evaluated in bivariate analyses. Squat 1-RM, shoulder press 1-RM, chest press 1-RM, lat pull-down 1-RM, and lunge 1-RM were also significantly associated with the proportion of time spent in moderate to vigorous intensity. Also, all 1-RM measures were significantly associated with each other. It is possible that maximum strength in general is associated with the proportion of time spent in moderate to vigorous intensity and leg curl 1-RM being simply the variable entering the model when controlled for other variables.

Even if the proportion of time spent at moderate to vigorous intensity during RT was lower in the older adult group compared with the young non-overweight adult group, it is important to note that seven of 20 older adult men reached moderate to vigorous intensity at least 75% of the time when doing RT at 70% of 1-RM. In addition, older men reaching moderate to vigorous intensity at least 75% of the time while doing the RT at 70% of 1-RM had a greater average leg curl 1-RM compared with the older men not reaching that intensity for a minimum of 75% (46.1 kg versus 33.6 kg). This implies that older men are more likely to reach moderate to vigorous intensity for a minimum of 75% of the RT session than older women, especially if they have a greater leg curl 1-RM. When comparing the older men and the older women in our study, 81.1% of the time was spent at moderate to vigorous intensity while doing RT for men compared with 31.6% (P=0.02) for women. Such a difference between men and women was only observed in older adults. Older women have less leg muscle strength than older men, and the decline in muscle quality with age is steeper in women compared with men [203]. The leg muscle quality, with such contractile properties of muscle or angle of pennation of muscle fibers, declines with age. This decline is more pervasive in women than in men. This surely had an effect on the results of our study.

Table 6 shows 1-RM for every exercise the groups performed. Further analyses by gender have shown that in some exercises older men presented a greater relative 1-RM than older women (Table 8), but this was not observed between men and women in the other groups. One of the differences in relative 1-RM between older men and older women was the relative 1-RM for leg curl. The difference in relative leg curl 1-RM again can partially explain why older men achieved greater proportion of time at moderate to vigorous intensity during RT sessions when compared to older women.

It was hypothesized that no difference would be observed between the overweight adult group and the young non-overweight adult group in the proportion of time spent at moderate to vigorous intensity while doing RT. We confirmed our hypothesis; no difference was observed between the two groups. The overweight adult group increased their HR to the same level as the young non-overweight adults at both RT sessions despite being significantly older ($p \leq 0.01$). However, the overweight adult group displayed a higher 1-RM for leg curls which is also a predictor of the proportion of time spent at moderate to vigorous intensity and probably compensated for the median difference of eight years in age. This is not surprising as it is well known that overweight individuals have more absolute muscle strength compared with their leaner counterparts [204]. In other words, if someone is overweight, even being somewhat older, he or she might be able to compensate by having a greater 1-RM on leg curls to reach a high proportion of moderate to vigorous intensity when doing RT.

Oxygen consumption was not measured in our study, but we acknowledge that some studies have reported that oxygen consumption does not increase at the same proportion as HR while doing RT as observed when doing aerobic exercise [155, 205]. For example, Jansen et al. (2007) reported that their 12 participants were at 61.0% of their HR while doing RT, compared to only 26.5% of VO_2max [155]. In addition, it is known that HRmax is not strongly associated with VO_2max [206]. These studies indicate that VO_2 might not increase proportionally with HR when doing RT compared to doing aerobic activities. The results also suggest that the energy expenditure could be overestimated when doing RT if estimated with HR. However, %HRR as used to estimate intensity, as was done in our study, is associated with %VO_2R [206]. In addition, in our sample, 28% of the workout time was spent at vigorous intensity (≥60%HRR [14]) and the median percentage of HR was 124.8 bpm (111.0-135.8) during the RT at 70% of 1-RM, which represented 53.3% of HRR, and, thus, 13.3% above the cutoff for moderate to vigorous intensity. As a result, it is likely that the participants' oxygen consumption reached the parameters of moderate to vigorous intensity while doing our RT program. Future studies in this area should measure oxygen consumption while doing RT to confirm that VO_2 reaches the intended intensity.

Choice of Exercises

Based on HR, some exercises were better than others to increase the proportion of time spent at moderate to vigorous intensity (Table 10). Overall, when performing lat pull down, leg extension, and shoulder press, the median proportion of time spent at moderate to vigorous intensity was 100%. For lunges, participants were at moderate to vigorous intensity for 94.5% of the time. Statistical analyses were performed to compare the proportion of time spent at moderate to vigorous intensity within each exercise among different groups in the study. The only difference observed was that the overweight adult group spent a greater proportion of time at moderate to vigorous intensity while performing leg curl.

It is known that large muscle groups and multi-joint exercises recruit more muscle fiber, and, therefore, utilize more oxygen when achieving work [207, 208]. This could explain why these movements were associated with a greater proportion of time spent at moderate to vigorous intensity. For example, one study has indicated a direct relationship between the size of the active muscles and the magnitude of the increase in VO_2 and HR [209]. However, exercises such squat and chest press also require a large muscle group and the proportion of time spent at moderate to vigorous intensity was lower (71.4% and 53.8%) than exercises using large muscle groups. Also, shoulder press, an exercise that requires a small muscle group, had a high proportion of time spent at moderate to vigorous intensity. Some literature supports that upper body exercises have more cardiovascular response, such as an increase in HR and blood pressure, than in lower body exercises due to a greater increase in peripheral resistance [210, 211]. Based on our findings and the current literature, more studies are needed to explain why some RT exercises are associated with greater exercise intensity.

Bouts of Moderate to Vigorous Intensity

There is evidence in the literature suggesting that sporadic bouts (<10-minutes) and non-sporadic bouts (≥10-minutes) of moderate to vigorous intensity are both associated with health benefits [4, 5, 212]. To our knowledge, there has been no study that has measured the bout length at moderate to vigorous intensity while doing RT. The median length of bout in our sample was 2.2 minutes for both RT sessions. This implies that the majority of the participants were using the aerobic pathway to create energy, and, thus, RT has the potential to target and possibly improve the aerobic capacity. In examining the data, the longest bout length in the young non-overweight adult group and the overweight adult group was greater than 10-minutes; however, a huge variation was observed with 25% of the sample having their longest bout being 5.2 minutes or lower, and 25% of the sample having their longest bout being 39.1 minutes, when evaluating the whole sample doing 70% of 1-RM. Correlations were performed to understand what variable could be associated with longer bouts performed at moderate to vigorous intensity. It seems the more strength a person has (measured by 1-RM), the more a participant is likely to sustain a bout of RT at moderate to vigorous intensity. The researchers also tested BMI, age, and experience doing RT, but there were no significant correlations. Even if we were to argue that bouts of moderate to vigorous intensity shorter than 10-minutes are as valuable as longer bouts at that intensity , our results show that it is possible to reach 10-minute bouts of moderate to vigorous intensity while doing RT. In other words, not only can RT reach moderate to vigorous intensity, this intensity can be potentially sustained for a number of minutes. The duration of bouts could be influenced by resting intervals between the sets, as well as between the exercises. Reducing these rest intervals could increase the length of bouts at moderate to vigorous intensity [212].

The older adult group performed shorter bout lengths at moderate to vigorous intensity compared with the young non-overweight adult group during both sessions. This might be explained by the fact that older adults are probably closer to their lactate threshold or using their anaerobic pathways to produce energy at that intensity, and, therefore, they accumulate fatigue sooner and maintain the exercise intensity for a shorter period of time. This is supported by Wiswell et al. (2000) who reported that absolute work rate at lactate threshold declines with age [213].

Implications for the Canadian Physical Activity Guidelines

For all adults, the current CPAG recommendations suggest doing a minimum of 150 minutes of aerobic exercises at moderate to vigorous intensity along with two days of RT [1]. Only 15% of Canadians are reaching the aerobic component of these guidelines [2]. We explored whether moderate to vigorous intensity could be reached while doing RT. As new research suggests, it could replace some or all of the CPAG aerobic components if it is accepted that 10-minute bouts are not needed to optimize health benefits and if further studies show that similar health and functional benefits can be achieved by using this form of exercise. Based on our results, a 60 minute RT program three times a week would reduce the weekly exercise time to 183 minutes compared to 250 minutes (150 minutes of aerobic exercise + two days of RT of about 50 minutes each), a 27% reduction in time. This difference could even be larger (34%) for overweight adults where 92% of their time doing RT was spent at moderate to vigorous intensity. For older adults, the situation is different for men and women. While older men can reach enough proportion of time (81.1%) at moderate to vigorous intensity to contribute significantly to the CPAG aerobic component, it is not the case for older women. According to our study, only older women would not spend enough proportion of time at moderate to vigorous intensity to fully benefit from such training because they would have to do more than 250 minutes of RT each week to achieve the 150 minutes of aerobic activities the target intensity. However, it is possible that overweight or obese older adults could reach a greater proportion of time spent at moderate to vigorous intensity or that some older women would prefer doing 250 minutes of RT instead of 150 of aerobic exercises along with the prescribed two days of RT.

This study shows that doing only RT to reach the CPAG could be envisioned as a new way to promote physical activity if access to RT facilities is provided. Besides traditional fitness facilities, outdoor fitness parks [214] and callisthenic exercises could be feasible options, especially since there is no cost associated with these options [215]. Underlining the current literature that suggests RT is beneficial in inducing changes that include an increase in resting metabolic rate [216] and excess oxygen consumption [217, 218], this suggested approach could be particularly useful for overweight adults who want to change enhance their physical fitness. Based on the fit-and-fat concept of improved health without weight loss, doing RT to reach the CPAG aerobic component could be a new and important way for many people to improve their health and functional abilities [219].

Limitations

Although the research findings of this study are interesting and have public health implications, some limitations still need to be pointed out. The participants in the study were selected only if they were already doing some form of RT. Consequently, if such a person had less experience working with weights he or she conceivably would not have achieved their true 1-RM in the first session tests. Thus, it is possible that such a participant would have been trained in the subsequent sessions with loads lower than 70% or 80% of their maximal capacity. Another limitation of this study is that maximal HR was predicted and not objectively measured. In addition, since there are many factors that can be changed in a RT session (e.g., sets, repetitions, rest, exercise tempo), it is possible that other RT exercises or other elements of the RT could result in more time at moderate to vigorous intensity. Another limitation is the fact that we did not measure the cardiorespiratory fitness level of the participants nor the oxygen consumption during the sessions. This would have helped to identify the true maximal HR and the relationship between HR and oxygen consumption while doing the workout and would have helped to fully indicate the fitness level of our participants.

Next Steps

In the future, studies should aim at exploring the best RT program design to sustain moderate to vigorous intensity for a greater proportion of time, especially in the case of older women. Moreover, a randomized controlled trial is now needed to test whether it is possible to reach the CPAG by only doing RT and obtain similar health outcomes and see how that compares to the traditional CPAG approach (150 minutes of aerobic activity at moderate to vigorous intensity in 10-minute bouts + two days of RT).

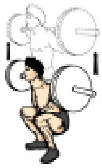
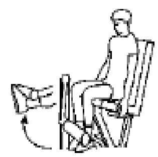
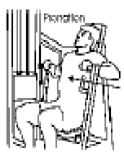
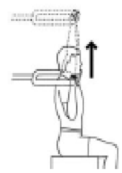
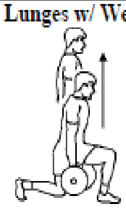
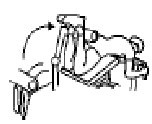
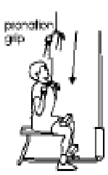
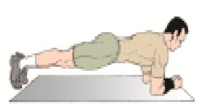
Conclusion

In conclusion, our study shows that it is possible to reach moderate to vigorous intensity when doing RT for young non-overweight adults, overweight adults, and older adults. While no difference in the proportion of time spent at moderate to vigorous intensity was observed between the young non-overweight adult group and the overweight adult group, the older adults reached moderate to vigorous intensity for a smaller proportion of time during the workout. However, a significantly lower proportion of older women reached moderate to vigorous intensity compared to the older men ($p \leq 0.01$). Nevertheless, our results suggest that most Canadian adults and older men could save a substantial amount of time in reaching the CPAG by doing only RT instead of a combination of aerobic and RT exercises.

APPENDIX-I

1-RM Testing: Visit #1

Evaluator:___________________________________ **Date:**______

Exercise	Repetitions (1 minute rest)	Weight Lifted	Exercise	Repetitions (1 minute rest)	Weight Lifted
#1) Squat 			#5 Leg extension 		
#2) Chest Press 			#6) Shoulder Raises 		
#3) Lunges w/ Weight 			#7) Leg Curl 		
#4) Lat Pull Down 			#8) Plank 		
					(Until Failure)

Is the participant reaching the submaximal 1-RM for all exercises, or functional maximum? ____________________

If functional, what were the limiting factors?

____

What exercises were affected?

____

APENDIX-II

Canadian Physical Activity Guidelines – Resistance Training Summary of Results

Hello______,

Thank you again for participating in our study! Your contribution is greatly appreciated and highly valuable to the overall findings. You will receive information on the results on the study as soon as they are available. The following document consists of your personal results.

On the following page you will find the current Canadian Physical Activity Guidelines as set out by the Canadian Society of Exercise Physiology and ParticipACTION. You will notice that they encourage people to participate in aerobic exercise at a 'moderate to vigorous' level of intensity To determine if you are reaching the Canadian Physical Activity Guidelines, we use maximal heart rate. Maximal heart rate is the maximum pace at which your heart can beat (per minute) in order to sufficiently supply blood to the needed areas of your body and is estimated as 220-age.

Based on your results, in order to reach.

- Moderate intensity when you train, your heart rate should be between __beats per minute (bpm) and __bpm, which corresponds to 55-69% of your maximal heart rate (**HRMax**).

- Vigorous intensity when you train, your heart rate should be anywhere above ____ bpm, which corresponds to ≥70% of your **HRMax**.

On behalf of everyone involved in the study, I would like to thank you once again for choosing to participate. Hopefully you are able to take the following information and continue a beneficial resistance training program. If you have any concerns with your personal measures, please contact your family doctor. For any questions directly involved with the study, contact myself at (XXXXXXX or XXXXX @XX.XX

Sincerely,

Personal Measures	
Height (m): **Weight (kg):** **Body Mass Index (kg/m²):** The optimal BMI is between 18.5 and 25.0 to avoid health related conditions. **Waist circumference (cm):** To maintain a low risk of poor health, your waist circumference should be lower than 88 cm for women and lower than 102 cm for men. **Body Fat Percentage:** A range of 10-22% for men and 20-32% for women is considered as satisfactory for health. **Hand Grip Strength (Kg W): (R), (L)** Handgrip strength is a good indicator of both overall strength and health. A measure of 48-51 is average for males, and a measure of 26-29 is average for females.	**Blood Pressure (mmHg):** Optimal blood pressure is below 120/80 mmHg to avoid heart diseases. It's important to note that we only measured your blood pressure at one point in time. You might want to take it several times in a week to see a more accurate, consistent pattern. **Maximum Heart Rate (beats per min):** This is the predicted maximum beats per minute that your heart will go. The more you age the more this number will naturally decrease. In other words, someone age 80 with a heart rate at 130 bpm for a given exercise is working "harder" than a 30 year old individual whose heart rate reaches 130 bpm. **Heart Rate at Rest (bpm):** The lower is the better as the heart will need to pump fewer times in a minute to deliver the required blood. The average for an adult is 73 bpm.

Should you have any concerns regarding any of the information, please consult your doctor.

Results: Maximal Weight That Can Be Lifted Once(lbs)	
Squat:	**Leg Extension:**
Chest Press:	**Shoulder Raise:**
Lunge:	**Leg Curl:**
Lat Pull Down:	**Longest Held Plank (Abdomen):**

This information could be valuable if you are or become a member in a fitness facility. We suggest bringing it to a staff member so he or she can adjust your resistance program accordingly.

REFERENCES

1. Tremblay, M.S., et al., *New Canadian physical activity guidelines.* Appl Physiol Nutr Metab, 2011. **36**(1): p. 36-46; 47-58.
2. Colley, R.C., et al., *Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey*. Health Rep, 2011. **22**(1): p. 7-14.
3. Prince, S.A., et al., *A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review*. Int J Behav Nutr Phys Act, 2008. **5**: p. 56.
4. Ayabe, M., et al., *Accumulation of short bouts of non-exercise daily physical activity is associated with lower visceral fat in Japanese female adults.* Int J Sports Med, 2013. **34**(1): p. 62-7.
5. Loprinzi, P.D. and B.J. Cardinal, *Association between biologic outcomes and objectively measured physical activity accumulated in >/= 10-minute bouts and <10-minute bouts.* Am J Health Promot, 2013. **27**(3): p. 143-51.
6. Mahar, M.T., *Impact of short bouts of physical activity on attention-to-task in elementary school children.* Prev Med, 2011. **52** (1): p. S60-4.
7. Mark, A.E. and I. Janssen, *Influence of bouts of physical activity on overweight in youth.* Am J Prev Med, 2009. **36**(5): p. 416-21.
8. Barr-Anderson, D.J., et al., *Integration of short bouts of physical activity into organizational routine a systematic review of the literature.* Am J Prev Med. **40**(1): p. 76-93.

9. Holman, R.M., V. Carson, and I. Janssen, *Does the fractionalization of daily physical activity (sporadic vs. bouts) impact cardiometabolic risk factors in children and youth?* PLoS One, 2011. **6**(10): p. e25733.

10. Salmon, J., et al., *Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference.* Health Psychol, 2003. **22**(2): p. 178-88.

11. Weyer, C., et al., *Implications of the traditional and the new ACSM physical activity recommendations on weight reduction in dietary treated obese subjects.* Int J Obes Relat Metab Disord, 1998. **22**(11): p. 1071-8.

12. Warburton, D.E., et al., *A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults.* Int J Behav Nutr Phys Act, 2010. **7**: p. 39.

13. Paterson, D.H. and D.E. Warburton, *Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines.* Int J Behav Nutr Phys Act, 2010. **7**: p. 38.

14. Warburton, D.E., C.W. Nicol, and S.S. Bredin, *Prescribing exercise as preventive therapy.* CMAJ, 2006. **174**(7): p. 961-74.

15. Feichtinger, R.G., et al., *Low aerobic mitochondrial energy metabolism in poorly- or undifferentiated neuroblastoma.* BMC Cancer, 2010. **10**: p. 149.

16. Yokota, T., et al., *Systemic oxidative stress is associated with lower aerobic capacity and impaired skeletal muscle energy metabolism in patients with metabolic syndrome.* Diabetes Care, 2013. **36**(5): p. 1341-6.

17. Rooks, D.S., C.B. Silverman, and F.G. Kantrowitz, *The effects of progressive strength training and aerobic exercise on muscle strength and cardiovascular fitness in women with fibromyalgia: a pilot study.* Arthritis Rheum, 2002. **47**(1): p. 22-8.

18. Kilpatrick, M.W., et al., *Heart rate and metabolic responses to moderate-intensity aerobic exercise: a comparison of graded walking and ungraded jogging at a constant perceived exertion.* J Sports Sci, 2009. **27**(5): p. 509-16.

19. Nikolai, A.L., et al., *Cardiovascular and metabolic responses to water aerobics exercise in middle-age and older adults.* J Phys Act Health, 2009. **6**(3): p. 333-8.

20. Penedo, F.J. and J.R. Dahn, *Exercise and well-being: a review of mental and physical health benefits associated with physical activity*. Curr Opin Psychiatry, 2005. **18**(2): p. 189-93.

21. Thompson, P.D., et al., *ACSM's New Preparticipation Health Screening Recommendations from ACSM's Guidelines for Exercise Testing and Prescription, Ninth Edition.* Current Sports Medicine Reports, 2013. **12**(4): p. 215-217.

22. Pescatello, L., (2014). *ACSM’s Guidelines for Exercise Testing and Prescription,* 9th Ed. Philadephia, US: Wolters Kluwer/Lippincott Williams & Wilkins Health.

23. Azevedo, L.F., et al., *Exercise intensity optimization for men with high cardiorespiratory fitness.* J Sports Sci, 2011. **29**(6): p. 555-61.

24. Evans, H.J., G. Parfitt, and R.G. Eston, *The perceptually regulated exercise test is sensitive to increases in maximal oxygen uptake.* Eur J Appl Physiol. **113**(5): p. 1233-9.

25. Borg, G., (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.

26. Swain. D., *ACSM's Guidelines for Exercise Testing and Prescription*. 7th ed. Philadephia, US: Wolters Kluwer/ Lippincott Williams & Wilkins.

27. Levinger, I., et al., *The reliability of the 1RM strength test for untrained middle-aged individuals.* J Sci Med Sport, 2009. **12**(2): p. 310-6.

28. Caspersen, C.J., K.E. Powell, and G.M. Christenson, *Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research.* Public Health Rep, 1985. **100**(2): p. 126-31.

29. Thompson, P.D., et al., *Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity).* Circulation, 2003. **107**(24): p. 3109-16.

30. U.S. Department of Health and Human Services (1996). *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: US. Retrieved on April 01, 2015 from http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf.

31. Kraemer, W.J., N.A. Ratamess, and D.N. French, *Resistance training for health and performance.* Curr Sports Med Rep, 2002. **1**(3): p. 165-71.

32. Brogardh, C. and J. Lexell, *Effects of cardiorespiratory fitness and muscle-resistance training after stroke.* PMR, 2012. **4**(11): p. 901-7; quiz 907.

33. Chantler, I., C.P. Szabo, and K. Green, *Muscular strength changes in hospitalized anorexic patients after an eight week resistance training program.* Int J Sports Med, 2006. **27**(8): p. 660-5.

34. Campbell, W.W., et al., *Resistance training preserves fat-free mass without impacting changes in protein metabolism after weight loss in older women.* Obesity (Silver Spring), 2009. **17**(7): p. 1332-9.

35. Chomistek, A.K., et al., *Physical activity, genes for physical fitness, and risk of coronary heart disease.* Med Sci Sports Exerc, 2013. **45**(4): p. 691-7.

36. Chomistek, A.K., et al., *Relationship of sedentary behavior and physical activity to incident cardiovascular disease: results from the Women's Health Initiative.* J Am Coll Cardiol, 2013. **61**(23): p. 2346-54.

37. Takken, T., et al., *Recommendations for physical activity, recreation sport, and exercise training in paediatric patients with congenital heart disease: a report from the Exercise, Basic & Translational Research Section of the European Association of Cardiovascular Prevention and Rehabilitation, the European Congenital Heart and Lung Exercise Group, and the Association for European Paediatric Cardiology.* Eur J Prev Cardiol, 2012. **19**(5): p. 1034-65.

38. Fletcher, G.F., et al., *Statement on exercise: benefits and recommendations for physical activity programs for all Americans. A statement for health professionals by the Committee on Exercise and Cardiac Rehabilitation of the Council on Clinical Cardiology, American Heart Association.* Circulation, 1996. **94**(4): p. 857-62.

39. Foley, L., et al., *Self-report use-of-time tools for the assessment of physical activity and sedentary behaviour in young people: systematic review.* Obes Rev, 2012. **13**(8): p. 711-22.

40. Warburton, D.E., C.W. Nicol, and S.S. Bredin, *Health benefits of physical activity: the evidence.* CMAJ, 2006. **174**(6): p. 801-9.

41. Puetz, T.W., S.S. Flowers, and P.J. O'Connor, *A randomized controlled trial of the effect of aerobic exercise training on feelings of energy and fatigue in sedentary young adults with persistent fatigue.* Psychother Psychosom, 2008. **77**(3): p. 167-74.

42. von Thiele Schwarz, U. and H. Hasson, *Employee self-rated productivity and objective organizational production levels: effects of worksite health interventions involving reduced work hours and physical exercise.* J Occup Environ Med, 2011. **53**(8): p. 838-44.

43. *American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults.* Med Sci Sports Exerc, 1998. **30**(6): p. 975-91.

44. Feigenbaum, M.S. and M.L. Pollock, *Prescription of resistance training for health and disease.* Med Sci Sports Exerc, 1999. **31**(1): p. 38-45.

45. Garber, C.E., et al., *American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise.* Med Sci Sports Exerc, 2011. **43**(7): p. 1334-59.

46. Whelton, S.P., et al., *Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials.* Ann Intern Med, 2002. **136**(7): p. 493-503.

47. Kingsley, J.D., et al., *The effects of a 12-week strength-training program on strength and functionality in women with fibromyalgia.* Arch Phys Med Rehabil, 2005. **86**(9): p. 1713-21.

48. Centre for Disease Control and Prevention (2015),*Home and Recreational Safety-Falls-Older Adults*. Retreived on April 30, 2015 from http://www.cdc.gov/HomeandRecreationalSafety/Falls/adultfalls.html.

49. Gligoroska, J.P. and S. Manchevska, *The effect of physical activity on cognition - physiological mechanisms.* Mater Sociomed, 2012. **24**(3): p. 198-202.

50. Koltyn, K.F., *Analgesia following exercise: a review.* Sports Med, 2000. **29**(2): p. 85-98.

51. Craft, L.L. and F.M. Perna, *The Benefits of Exercise for the Clinically Depressed.* Prim Care Companion J Clin Psychiatry, 2004. **6**(3): p. 104-111.

52. Broman-Fulks, J.J., et al., *Effects of aerobic exercise on anxiety sensitivity.* Behav Res Ther, 2004. **42**(2): p. 125-36.

53. Carek, P.J., S.E. Laibstain, and S.M. Carek, *Exercise for the treatment of depression and anxiety.* Int J Psychiatry Med, 2011. **41**(1): p. 15-28.

54. Martinsen, E.W., *Physical activity in the prevention and treatment of anxiety and depression.* Nord J Psychiatry, 2008. **62 Suppl 47**: p. 25-9.

55. Schmalz, D.L., et al., *A longitudinal assessment of the links between physical activity and self-esteem in early adolescent non-Hispanic females.* J Adolesc Health, 2007. **41**(6): p. 559-65.

56. Pretty, J., et al., *The mental and physical health outcomes of green exercise.* Int J Environ Health Res, 2005. **15**(5): p. 319-37.

57. Erickson, K.I., et al., *Exercise training increases size of hippocampus and improves memory.* Proc Natl Acad Sci U S A, 2011. **108**(7): p. 3017-22.

58. Chinn, D.J., et al., *Barriers to physical activity and socioeconomic position: implications for health promotion.* J Epidemiol Community Health, 1999. **53**(3): p. 191-2.

59. Johnson, C.A., et al., *Perceived barriers to exercise and weight control practices in community women.* Women Health, 1990. **16**(3-4): p. 177-91.

60. Church, T.S., et al., *Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity*. PLoS One, 2011. **6**(5): p. e19657.

61. Kim, Y., et al., *Association between various sedentary behaviours and all-cause, cardiovascular disease and cancer mortality: the Multiethnic Cohort Study*. Int J Epidemiol, 2013. **42**(4): p. 1040-56.

62. Brownson, R.C., T.K. Boehmer, and D.A. Luke, *Declining rates of physical activity in the United States: what are the contributors?* Annu Rev Public Health, 2005. **26**: p. 421-43.

63. Ball, K., D. Crawford, and N. Owen, *Too fat to exercise? Obesity as a barrier to physical activity*. Aust N Z J Public Health, 2000. **24**(3): p. 331-3.

64. Gibala, M.J., et al., *Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance*. J Physiol, 2006. **575**: p. 901-11.

65. Burgomaster, K.A., et al., *Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans*. J Physiol, 2008. **586**(1): p. 151-60.

66. Kravitz, L., *The fitness professional's complete guide to circuits and intervals*. Idea Today, 1996. **14**(1): p. 32-43.

67. Daussin, F.N., et al., *Effect of interval versus continuous training on cardiorespiratory and mitochondrial functions: relationship to aerobic performance improvements in sedentary subjects*. Am J Physiol Regul Integr Comp Physiol, 2008. **295**(1): p. R264-72.

68. Gibala, M.J. and S.L. McGee, *Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain?* Exerc Sport Sci Rev, 2008. **36**(2): p. 58-63.

69. Gist, N.H., et al., *Sprint interval training effects on aerobic capacity: a systematic review and meta-analysis.* Sports Med, 2014. **44**(2): p. 269-79.

70. Cocks, M., et. al., (2013). *Sprint interval and endurance training are equally effective in increasing muscle microvascular density and eNOS content in sedentary males.* The Journal of Physiology, **591**(3): p. 641–656.

71. Tjonna, A.E., et al., *Aerobic interval training versus continuous moderate exercise as a treatment for the metabolic syndrome: a pilot study.* Circulation, 2008. **118**(4): p. 346-54.

72. Gibala, M.J., et al., *Physiological adaptations to low-volume, high-intensity interval training in health and disease.* J Physiol, 2012. **590**: p. 1077-84.

73. Dunstan, D.W., et al., *High-intensity resistance training improves glycemic control in older patients with type 2 diabetes.* Diabetes Care, 2002. **25**(10): p. 1729-36.

74. Gillen, J.B., et al., *Acute high-intensity interval exercise reduces the postprandial glucose response and prevalence of hyperglycaemia in patients with type 2 diabetes.* Diabetes Obes Metab, 2012. **14**(6): p. 575-7.

75. Lunt, H., et al., *High intensity interval training in a real world setting: a randomized controlled feasibility study in overweight inactive adults, measuring change in maximal oxygen uptake.* PLoS One, 2014. **9**(1): p. e83256.

76. Plotnikoff, R.C., et al., *Awareness of Canada's Physical Activity Guide to Healthy Active Living in a large community sample.* Am J Health Promot, 2011. **25**(5): p. 294-7.

77. Bauman, A., C.L. Craig, and C. Cameron, *Low levels of recall among adult Canadians of the CSEP/Health Canada physical activity guidelines.* Can J Appl Physiol, 2005. **30**(2): p. 246-52.

78. Arts, F.J. and H. Kuipers, *The relation between power output, oxygen uptake and heart rate in male athletes.* Int J Sports Med, 1994. **15**(5): p. 228-31.

79. Hawley, J.A. and T.D. Noakes, *Peak power output predicts maximal oxygen uptake and performance time in trained cyclists.* Eur J Appl Physiol Occup Physiol, 1992. **65**(1): p. 79-83.

80. Fletcher, G.F., et al., *Exercise standards. A statement for healthcare professionals from the American Heart Association. Writing Group.* Circulation, 1995. **91**(2): p. 580-615.

81. Colberg, S.R., D.P. Swain, and A.I. Vinik, *Use of heart rate reserve and rating of perceived exertion to prescribe exercise intensity in diabetic autonomic neuropathy.* Diabetes Care, 2003. **26**(4): p. 986-90.

82. Cunha, F.A., et al., *The relationship between oxygen uptake reserve and heart rate reserve is affected by intensity and duration during aerobic exercise at constant work rate.* Appl Physiol Nutr Metab, 2011. **36**(6): p. 839-47.

83. Wilmore, J.H. and W.L. Haskell, *Use of the heart rate-energy expenditure relationship in the individualized prescription of exercise.* Am J Clin Nutr, 1971. **24**(9): p. 1186-92.

84. Landwehr, et. al., *The Surprising History of the HRmax=220-age equation.* The American Society of Exercise Physiologists, 2002. **5**(2): p. 1-10.

85. Price, M., et al., *Oxygen uptake during upper body and lower body Wingate anaerobic tests.* Appl Physiol Nutr Metab, 2014. **39**(12): p. 1345-51.

86. Swain, D.P. and B.C. Leutholtz, *Heart rate reserve is equivalent to %VO2 reserve, not to %VO2max.* Med Sci Sports Exerc, 1997. **29**(3): p. 410-4.

87. da Cunha, F.A., T. Farinatti Pde, and A.W. Midgley, *Methodological and practical application issues in exercise prescription using the heart rate reserve and oxygen uptake reserve methods.* J Sci Med Sport, 2011. **14**(1): p. 46-57.

88. Colley, R.C. and M.S. Tremblay, *Moderate and vigorous physical activity intensity cut-points for the Actical accelerometer.* J Sports Sci, 2011. **29**(8): p. 783-9.

89. Tudor-Locke, C., et al., *Pedometer-determined step count guidelines for classifying walking intensity in a young ostensibly healthy population.* Can J Appl Physiol, 2005. **30**(6): p. 666-76.

90. Jacobi, D., et al., *Physical activity-related energy expenditure with the RT3 and TriTrac accelerometers in overweight adults.* Obesity (Silver Spring), 2007. **15**(4): p. 950-6.

91. Pober, D.M., et al., *Development of novel techniques to classify physical activity mode using accelerometers.* Med Sci Sports Exerc, 2006. **38**(9): p. 1626-34.

92. Leenders, N.Y., et al., *Evaluation of methods to assess physical activity in free-living conditions.* Med Sci Sports Exerc, 2001. **33**(7): p. 1233-40.

93. Maturi, M.S., P. Afshary, and P. Abedi, *Effect of physical activity intervention based on a pedometer on physical activity level and anthropometric measures after*

childbirth: a randomized controlled trial. BMC Pregnancy Childbirth, 2011. **11**: p. 103.

94. Hasson, R.E., et al., *Validity of the Omron HJ-112 pedometer during treadmill walking.* Med Sci Sports Exerc, 2009. **41**(4): p. 805-9.

95. Bravata, D.M., et al., *Using pedometers to increase physical activity and improve health: a systematic review.* JAMA, 2007. **298**(19): p. 2296-304.

96. Richardson, C.R., et al., *A meta-analysis of pedometer-based walking interventions and weight loss.* Ann Fam Med, 2008. **6**(1): p. 69-77.

97. Michie, S., et al., *Effective techniques in healthy eating and physical activity interventions: a meta-regression.* Health Psychol, 2009. **28**(6): p. 690-701.

98. Marshall, A.L., et al., *Population-based randomized controlled trial of a stage-targeted physical activity intervention.* Ann Behav Med, 2003. **25**(3): p. 194-202.

99. Tudor-Locke, C., et al., *How many steps/day are enough? For adults.* Int J Behav Nutr Phys Act. **8**: p. 79.

100. Bryner, R.W., et al., *Effects of resistance vs. aerobic training combined with an 800 calorie liquid diet on lean body mass and resting metabolic rate.* J Am Coll Nutr, 1999. **18**(2): p. 115-21.

101. Nelson, M.E., et al., *Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association.* Circulation, 2007. **116**(9): p. 1094-105.

102. Hopkins, P.M., *Skeletal muscle physiology*. Continuing Education in Anaesthesia, Critical Care & Pain, 2006. **6**(1): p. 1-6.

103. Miyatake, N., et al., *Re-evaluation of exercise intensity for overweight Japanese men by ventilatory threshold.* Diabetes Obes Metab, 2005. **7**(6): p. 762-5.

104. Swain, D.P., *Energy cost calculations for exercise prescription: an update.* Sports Med, 2000. **30**(1): p. 17-22.

105. Cao, Z.B., et al., *Predicting VO(2max) with an objectively measured physical activity in Japanese men.* Eur J Appl Physiol, 2010. **109**(3): p. 465-72.

106. Hoffmann, U., et al., *Skeletal muscle VO(2) kinetics from cardio-pulmonary measurements: assessing distortions through O(2) transport by means of stochastic work-rate signals and circulatory modelling.* Eur J Appl Physiol, 2013. **113**(7): p. 1745-54.

107. Cunha, F.A., et al., *How long does it take to achieve steady state for an accurate assessment of resting VO(2) in healthy men?* Eur J Appl Physiol, 2013. **113**(6): p. 1441-7.

108. Brawner, C.A., S.J. Keteyian, and J.K. Ehrman, *The relationship of heart rate reserve to VO2 reserve in patients with heart disease.* Med Sci Sports Exerc, 2002. **34**(3): p. 418-22.

109. Dishman, R.K., *Prescribing exercise intensity for healthy adults using perceived exertion.* Med Sci Sports Exerc, 1994. **26**(9): p. 1087-94.

110. Jette, M., K. Sidney, and G. Blumchen, *Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity.* Clin Cardiol, 1990. **13**(8): p. 555-65.

111. Swain, D.P., et al., *Relationship between % heart rate reserve and % VO2 reserve in treadmill exercise.* Med Sci Sports Exerc, 1998. **30**(2): p. 318-21.

112. Swain, D.P. and B.A. Franklin, *VO(2) reserve and the minimal intensity for improving cardiorespiratory fitness.* Med Sci Sports Exerc, 2002. **34**(1): p. 152-7.

113. Lucia, A., et al., *Determinants of VO(2) kinetics at high power outputs during a ramp exercise protocol.* Med Sci Sports Exerc, 2002. **34**(2): p. 326-31.

114. Moreira, C., et al., *Comparison of different VO(2max) equations in the ability to discriminate the metabolic risk in Portuguese adolescents.* J Sci Med Sport, 2011. **14**(1): p. 79-84.

115. Sperlich, B., et al., *High-intensity interval training improves VO(2peak), maximal lactate accumulation, time trial and competition performance in 9-11-year-old swimmers.* Eur J Appl Physiol, 2010. **110**(5): p. 1029-36.

116. Foster, C., et al., *A new approach to monitoring exercise training.* J Strength Cond Res, 2001. **15**(1): p. 109-15.

117. Persinger, R., et al., *Consistency of the talk test for exercise prescription.* Med Sci Sports Exerc, 2004. **36**(9): p. 1632-6.

118. Bouchard, D.R., et al., *Pilot study: can older inactive adults learn how to reach the required intensity of physical activity guideline?* Clin Interv Aging, 2013. **8**: p. 501-8.

119. Stratford, P.W., et al., *The relationship between self-report and performance-related measures: questioning the content validity of timed tests.* Arthritis Rheum, 2003. **49**(4): p. 535-40.

120. Woolf-May, K., et al., *The efficacy of accumulated short bouts versus single daily bouts of brisk walking in improving aerobic fitness and blood lipid profiles.* Health Educ Res, 1999. **14**(6): p. 803-15.

121. DeBusk, R.F., et al., *Training effects of long versus short bouts of exercise in healthy subjects.* Am J Cardiol, 1990. **65**(15): p. 1010-3.

122. McGuire, K.A. and R. Ross, *Incidental physical activity is positively associated with cardiorespiratory fitness.* Med Sci Sports Exerc, 2011. **43**(11): p. 2189-94.

123. Allison, K.R., J.J. Dwyer, and S. Makin, *Perceived barriers to physical activity among high school students.* Prev Med, 1999. **28**(6): p. 608-15.

124. Booth, M.L., et al., *Physical activity preferences, preferred sources of assistance, and perceived barriers to increased activity among physically inactive Australians.* Prev Med, 1997. **26**(1): p. 131-7.

125. Pollock, M.L. and W.J. Evans, *Resistance training for health and disease: introduction.* Med Sci Sports Exerc, 1999. **31**(1): p. 10-1.

126. Borg, P., et al., *Effects of walking or resistance training on weight loss maintenance in obese, middle-aged men: a randomized trial.* Int J Obes Relat Metab Disord, 2002. **26**(5): p. 676-83.

127. Donnelly, J.E., et al., *American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults.* Med Sci Sports Exerc, 2009. **41**(2): p. 459-71.

128. Jurca, R., et al., *Association of muscular strength with incidence of metabolic syndrome in men.* Med Sci Sports Exerc, 2005. **37**(11): p. 1849-55.

129. Artero, E.G., et al., *Effects of muscular strength on cardiovascular risk factors and prognosis.* J Cardiopulm Rehabil Prev, 2012. **32**(6): p. 351-8.

130. Drewnowski, A. and W.J. Evans, *Nutrition, physical activity, and quality of life in older adults: summary.* J Gerontol A Biol Sci Med Sci, 2001. **56 Spec No 2**: p. 89-94.

131. Gordon, N.F., et al., *Physical activity and exercise recommendations for stroke survivors: an American Heart Association scientific statement from the Council on Clinical Cardiology, Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention; the Council on Cardiovascular Nursing; the Council on Nutrition, Physical Activity, and Metabolism; and the Stroke Council.* Circulation, 2004. **109**(16): p. 2031-41.

132. Liu, C.J. and N.K. Latham, *Progressive resistance strength training for improving physical function in older adults.* Cochrane Database Systemic Review, 2009(3): p. CD002759.

133. Hunter, G.R., D. Seelhorst, and S. Snyder, *Comparison of metabolic and heart rate responses to super slow vs. traditional resistance training.* J Strength Cond Res, 2003. **17**(1): p. 76-81.

134. Judge, J.O., et al., *Balance improvements in older women: effects of exercise training.* Phys Ther, 1993. **73**(4): p. 254-62; discussion 263-5.

135. Liu-Ambrose, T.Y., et al., *Both resistance and agility training increase cortical bone density in 75- to 85-year-old women with low bone mass: a 6-month randomized controlled trial.* J Clin Densitom, 2004. **7**(4): p. 390-8.

136. Anderson, K. and D.G. Behm, *The impact of instability resistance training on balance and stability.* Sports Med, 2005. **35**(1): p. 43-53.

137. Asikainen, T.M., et al., *Effect of brisk walking in 1 or 2 daily bouts and moderate resistance training on lower-extremity muscle strength, balance, and walking performance in women who recently went through menopause: a randomized, controlled trial.* Phys Ther, 2006. **86**(7): p. 912-23.

138. Wedge, F., *The impact of resistance training on balance and functional ability of a patient with multiple system atrophy*. J Geriatr Phys Ther, 2008. **31**(2): p. 79-83.

139. Balsamo, S., et al., *Resistance training versus weight-bearing aquatic exercise: a cross-sectional analysis of bone mineral density in postmenopausal women.* Rev Bras Reumatol, 2013. **53**(2): p. 193-198.

140. Moghadasi, M. and S. Siavashpour, *The effect of 12 weeks of resistance training on hormones of bone formation in young sedentary women.* Eur J Appl Physiol, 2013. **113**(1): p. 25-32.

141. Winett, R.A. and R.N. Carpinelli, *Potential health-related benefits of resistance training.* Prev Med, 2001. **33**(5): p. 503-13.

142. Haltom, R.W., et al., *Circuit weight training and its effects on excess postexercise oxygen consumption.* Med Sci Sports Exerc, 1999. **31**(11): p. 1613-8.

143. Borsheim, E. and R. Bahr, *Effect of exercise intensity, duration and mode on post-exercise oxygen consumption.* Sports Med, 2003. **33**(14): p. 1037-60.

144. Bird, S., K. Tarpenning, and F. Marino, *Designing Resistance Training Programmes to Enhance Muscular Fitness.* Sports Med, 2005. **35**(10): p. 841-851.

145. Haddock, B.L. and L.D. Wilkin, *Resistance training volume and post exercise energy expenditure*. Int J Sports Med, 2006. **27**(2): p. 143-8.

146. Mazzetti, S., et al., *Effect of explosive versus slow contractions and exercise intensity on energy expenditure.* Med Sci Sports Exerc, 2007. **39**(8): p. 1291-301.

147. Shepstone, T.N., et al., *Short-term high- vs. low-velocity isokinetic lengthening training results in greater hypertrophy of the elbow flexors in young men.* J Appl Physiol (1985), 2005. **98**(5): p. 1768-76.

148. Farinatti, P.T. and A.G. Castinheiras Neto, *The effect of between-set rest intervals on the oxygen uptake during and after resistance exercise sessions performed with large- and small-muscle mass.* J Strength Cond Res, 2011. **25**(11): p. 3181-90.

149. Farinatti, P.T., et. al., *Influence of exercise order on the number of repetitions, oxygen uptake, and rate of perceived exertion during strength training in younger and older women.* J Strength Cond Res, 2013. **27**(3): p. 776-85.

150. Baker, J.S., et. al., *Interaction among Skeletal Muscle Metabolic Energy Systems during Intense Exercise.* J Nutr and Met. 2010: p. 13.

151. Gastin, P.B., *Energy system interaction and relative contribution during maximal exercise.* Sports Med, 2001. **31**(10): p. 725-41.

152. Wong, J. and S. Wong, *Trends in lifestyle cardiovascular risk factors in women: analysis from the Canadian National Population Health Survey.* Int J Nurs Stud, 2002. **39**(2): p. 229-42.

153. Pollock, M.L., et al., *AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine.* Circulation, 2000. **101**(7): p. 828-33.

154. Romero-Arenas, S., et al., *Effects of high-resistance circuit training in an elderly population.* Exp Gerontol, 2013. **48**(3): p. 334-40.

155. Jansen, R., D. Schmidtbleicher, and J. Cabri, *Cardiopulmonary responses during high intensity weight training in male handball players.* Sportverletz Sportschaden, 2007. **21**(1): p. 15-9.

156. Peinado, P.J., et al., *Aerobic Energy Expenditure and Intensity Prediction During a Specific Circuit Weight Training: A Pilot Study*. Journal of Human Sport & Exercise, 2010. **5**(2): p. 134.

157. Hrubeniuk, T., Prokop, N., Myrie, S., Sénéchal, M., & Bouchard, D.R *Can Resistance Training Contribute to the Aerobic Components of the Canadian Physical Activity Guidelines?* . International Journal of Exercise Science, 2014. **4**: p. 278-285.

158. American Heart Association. *Target Heart Rates*. 2013. Accessed on 2014 September 22; Available from: http://www.heart.org/HEARTORG/GettingHealthy/PhysicalActivity/FitnessBasics/Target-Heart-Rates_UCM_434341_Article.jsp.

159. World Health Organization. Obesity and overweight. Accessed on May 08, 2015; Available on http://www.who.int/mediacentre/factsheets/fs311/en/

160. Noble, R.E., *Waist-to-hip ratio versus BMI as predictors of cardiac risk in obese adult women.* West J Med, 2001. **174**(4): p. 240-1.

161. Dagan, S.S., et al., *Waist circumference vs body mass index in association with cardiorespiratory fitness in healthy men and women: a cross sectional analysis of 403 subjects.* Nutr J. **12**: p. 12.

162. Tjepkema, M.S., M. *Adult obesity in Canada*. Measured height and weight, 2005. Accessed on January 18, 2014; Available from: http://www.statcan.gc.ca/pub/82-620-m/2005001/article/adults-adultes/8060-eng.htm

163. Statistics Canada (2013, February 11). *Overweight and Obese Adults (Self-Reported), 2011*. Accessed on May 12, 2015 from http://www.statcan.gc.ca/pub/82-625-x/2012001/article/11664-eng.htm.

164. Nelson, M.E., et al., *Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association.* Med Sci Sports Exerc, 2007. **39**(8): p. 1435-45.

165. Shin, N.R., et al., *An increase in the Akkermansia spp. population induced by metformin treatment improves glucose homeostasis in diet-induced obese mice.* Gut, 2013.

166. Wiener, J.M. and J. Tilly, *Population ageing in the United States of America: implications for public programmes.* Int J Epidemiol, 2002. **31**(4): p. 776-81.

167. Association, A.P., *Fighting Ageism*, in *Geropsychologists are striving to stop negative age stereotypes and meet the growing mental health needs of older adults*, M. Dittmann, Editor. 2003.

168. Statistics Canada (2012). *Overview of the Census 2011*. Retrieved on May 01, 2015 from http://www12.statcan.gc.ca/census-recensement/2011/ref/overview-apercu/98-302-XIE.pdf.

169. Manton, K.G., E. Stallard, and L. Corder, *Changes in the age dependence of mortality and disability: cohort and other determinants.* Demography, 1997. **34**(1): p. 135-57.

170. Sherrer, Y.S., et al., *The development of disability in rheumatoid arthritis.* Arthritis Rheum, 1986. **29**(4): p. 494-500.

171. World Health Organisation (2014, December 1). *Disability and health*. Retrieved on May 13, 2015, from http://www.who.int/topics/disabilities/en/.

172. Rosso, A.L., et al., *Mobility, disability, and social engagement in older adults.* J Aging Health, 2013. **25**(4): p. 617-37.

173. Freedman, V.A., L.G. Martin, and R.F. Schoeni, *Recent trends in disability and functioning among older adults in the United States: a systematic review*. JAMA, 2002. **288**(24): p. 3137-46.

174. Roma, M.F., et al., *Effects of resistance training and aerobic exercise in elderly people concerning physical fitness and ability: a prospective clinical trial.* Einstein (Sao Paulo), 2013. **11**(2): p. 153-7.

175. Stefanov, T., et al., *Effects of supervised vs non-supervised combined aerobic and resistance exercise programme on cardiometabolic risk factors.* Cent Eur J Public Health, 2013. **21**(1): p. 8-16.

176. Jette, A.M., et al., *Home-based resistance training: predictors of participation and adherence.* Gerontologist, 1998. **38**(4): p. 412-21.

177. Littbrand, H., et al., *A high-intensity functional weight-bearing exercise program for older people dependent in activities of daily living and living in residential care facilities: evaluation of the applicability with focus on cognitive function.* Phys Ther, 2006. **86**(4): p. 489-98.

178. Craig, C.L., et al., *International physical activity questionnaire: 12-country reliability and validity*. Med Sci Sports Exerc, 2003. **35**(8): p. 1381-95.

179. van der Ploeg, H.P., et al., *Reliability and validity of the international physical activity questionnaire for assessing walking.* Res Q Exerc Sport, 2010. **81**(1): p. 97-101.

180. Marcus, B.H., J.T. Ciccolo, and C.N. Sciamanna, *Using electronic/computer interventions to promote physical activity*. Br J Sports Med, 2009. **43**(2): p. 102-5.

181. Canadian Society for Exercise Physiology (2004). *The Canadian Physical Acitvity, Fitness and Lifestyle Approach: CSEP- health & fitness program's health -related*

appraisal and counselling stratgey. 3rd edition. Ottawa, Ontario: Canadian Society for Exercise Physiology.

182. Gadzik, J., *"How much should I weigh?"--Quetelet's equation, upper weight limits, and BMI prime.* Conn Med, 2006. **70**(2): p. 81-8.

183. Health, N.I.o., *The Practical Guide: Identification, Evaluation, and Treatment of Overweight and Obesity in Adults.* 2000.

184. Swain, D. P., et. al., (2014). *ACSM's guidelines for exercise testing and prescription.*7th Ed. Philadelphia, US: Wolters Kluwer Health/Lippincott Williams & Wilkins.

185. Pickering, T.G., et al., *Recommendations for blood pressure measurement in humans: an AHA scientific statement from the Council on High Blood Pressure Research Professional and Public Education Subcommittee.* J Clin Hypertens (Greenwich), 2005. **7**(2): p. 102-9.

186. Baechle, T.R., et. al., (2008). *Essentials of strength training and conditioning*. 3rd Ed. Champaign, IL: Human Kinetics. xiv, p. 641.

187. Bauman, A., et al., *The descriptive epidemiology of sitting. A 20-country comparison using the International Physical Activity Questionnaire (IPAQ).* Am J Prev Med, 2011. **41**(2): p. 228-35.

188. Hill, M., C. Talbot, and M. Price, *Predicted maximal heart rate for upper body exercise testing.* Clin Physiol Funct Imaging, 2014.

189. Bout. 2015. In *Merriam-Webster*.com. Retrieved on May 10, 2015 from http://www.merriam-webster.com/dictionary/bout.

190. Chen, L., et al., *Relationship between muscle mass and muscle strength, and the impact of comorbidities: a population-based, cross-sectional study of older adults in the United States*. BMC Geriatr. **13**: p. 74.

191. Kraemer, W.J., et al., *American College of Sports Medicine position stand. Progression models in resistance training for healthy adults*. Med Sci Sports Exerc, 2002. **34**(2): p. 364-80.

192. Ratamess, N., et al., *American College of Sports Medicine position stand. Progression models in resistance training for healthy adults*. Med Sci Sports Exerc, 2009. **41**(3): p. 687-708.

193. Garbutt, G., et al., *Physiological and spinal responses to circuit weight-training*. Ergonomics, 1994. **37**(1): p. 117-25.

194. Maiorana, A., et al., *Combined aerobic and resistance exercise training improves functional capacity and strength in CHF*. J Appl Physiol (1985), 2000. **88**(5): p. 1565-70.

195. Paoli, A., et al., *Effects of three distinct protocols of fitness training on body composition, strength and blood lactate*. J Sports Med Phys Fitness, 2010. **50**(1): p. 43-51.

196. Falcone, P.H., et al., *Caloric Expenditure of Aerobic, Resistance or Combined High-Intensity Interval Training Using a Hydraulic Resistance System in Healthy Men*. Journal of Strength and Conditioning Research, 2014. **29**(3): p. 779 - 785.

197. Shephard, R.J., *Exercise, immune function and HIV infection*. Journal of Sports Medicine and Physical Fitness, 1998. **38**(2): p. 101-10.

198. Gerage, A.M., et al., *Cardiovascular adaptations to resistance training in elderly postmenopausal women.* Int J Sports Med, 2013. **34**(9): p. 806-13.

199. Phillips, W.T. and J.R. Ziuraitis, *Energy cost of single-set resistance training in older adults.* J Strength Cond Res, 2004. **18**(3): p. 606-9.

200. Goodpaster, B.H., et al., *The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study.* J Gerontol A Biol Sci Med Sci, 2006. **61**(10): p. 1059-64.

201. Williams, G.N., M.J. Higgins, and M.D. Lewek, *Aging skeletal muscle: physiologic changes and the effects of training.* Phys Ther, 2002. **82**(1): p. 62-8.

202. Haqqani, H.M. and J.M. Kalman, *Aging and sinoatrial node dysfunction: musings on the not-so-funny side.* Circulation, 2007. **115**(10): p. 1178-9.

203. Lynch, N.A., et al., *Muscle quality. I. Age-associated differences between arm and leg muscle groups.* J Appl Physiol (1985), 1999. **86**(1): p. 188-94.

204. Fogelholm, M., et al., *Physical fitness in adolescents with normal weight and overweight.* Scand J Med Sci Sports, 2008. **18**(2): p. 162-70.

205. Fletcher, G.F., et al., *Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association.* Circulation, 2001. **104**(14): p. 1694-740.

206. Lounana, J., et al., *Relationship between %HRmax, %HR reserve, %VO2max, and %VO2 reserve in elite cyclists.* Med Sci Sports Exerc, 2007. **39**(2): p. 350-7.

207. Hambrecht, R., et al., *Effects of exercise training on left ventricular function and peripheral resistance in patients with chronic heart failure: A randomized trial.* JAMA, 2000. **283**(23): p. 3095-101.

208. Miller, M.B., et al., *The effect of a short-term high-intensity circuit training program on work capacity, body composition, and blood profiles in sedentary obese men: a pilot study.* Biomed Res Int, 2014. **2014**: p. 191797.

209. Mitchell, J.H., W.L. Haskell, and P.B. Raven, *Classification of sports.* Med Sci Sports Exerc, 1994. **26**(10 Suppl): p. S242-5.

210. Volianitis, S. and N.H. Secher, *Arm blood flow and metabolism during arm and combined arm and leg exercise in humans.* J Physiol, 2002. **544**(Pt 3): p. 977-84.

211. Volianitis, S., et al., *Arterial blood pressure and carotid baroreflex function during arm and combined arm and leg exercise in humans.* Acta Physiol Scand, 2004. **181**(3): p. 289-95.

212. Veloso, J., et al., *Effects of rest interval between exercise sets on blood pressure after resistance exercises.* Arq Bras Cardiol, 2010. **94**(4): p. 512-8.

213. Wiswell, R.A., et al., *Maximal aerobic power, lactate threshold, and running performance in master athletes.* Med Sci Sports Exerc, 2000. **32**(6): p. 1165-70.

214. Cohen, D.A., et al., *Impact and cost-effectiveness of family Fitness Zones: a natural experiment in urban public parks.* Health Place, 2012. **18**(1): p. 39-45.

215. Chow, H.W., *Outdoor fitness equipment in parks: a qualitative study from older adults' perceptions.* BMC Public Health, 2013. **13**: p. 1216.

216. Olson, T.P., et al., *Moderate resistance training and vascular health in overweight women.* Med Sci Sports Exerc, 2006. **38**(9): p. 1558-64.

217. Braun, W.A., W.E. Hawthorne, and M.M. Markofski, *Acute EPOC response in women to circuit training and treadmill exercise of matched oxygen consumption.* Eur J Appl Physiol, 2005. **94**(5-6): p. 500-4.

218. Burleson, M.A., Jr., et al., *Effect of weight training exercise and treadmill exercise on post-exercise oxygen consumption.* Med Sci Sports Exerc, 1998. **30**(4): p. 518-22.

219. Duncan, G.E., *The "fit but fat" concept revisited: population-based estimates using NHANES.* Int J Behav Nutr Phys Act, 2010. **7**: p. 47.