EFFECTS OF EQUAL VOLUME HIGH-REPETITION RESISTANCE TRAINING
WITH DIFFERENT WORKOUT FREQUENCY ON MUSCLE MASS AND MUSCLE
PERFORMANCE IN POSTMENOPAUSAL WOMEN

A Thesis
Submitted to the Faculty of Graduate Studies and Research
In Partial Fulfillment of the Requirements
For the Degree of

Master of Science
in
Kinesiology and Health Studies
University of Regina

By
Karolina Grzyb
Regina, Saskatchewan
March 2019

Copyright © 2019: K. Grzyb
Karolina Grzyb, candidate for the degree of Master of Science in Kinesiology & Health Studies, has presented a thesis titled, "Effects of Equal Volume High-Repetition Resistance Training With Different Workout Frequency on Muscle Mass and Muscle Performance in Postmenopausal Women," in an oral examination held on January 15, 2019. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

External Examiner: *Dr. Nicholas Burd, University of Illinois at Urbana-Champaign

Supervisor: Dr. Darren Candow, Faculty of Kinesiology & Health Studies

Committee Member: Dr. Patrick Neary, Faculty of Kinesiology & Health Studies

Committee Member: **Dr. Brad Schoenfeld, Faculty of Kinesiology & Health Studies

Chair of Defense: Dr. Lisa Watson, Faculty of Graduate Studies & Research

*via ZOOM Conference
**Not present at defense
Abstract

The purpose was to examine the effects of equal volume, high-repetition resistance training (HRRT) to volitional fatigue, with different workout frequency, on muscle mass and muscle performance in healthy postmenopausal women. After matching participants for age, weight and years post-menopause, postmenopausal women were randomized to perform HRRT two days per week (HRRT-2; 60.8 ± 5.5 years, 72.1 ± 16.4 kg, 160.2 ± 3.9 cm; 3 sets of 20-30 repetitions/set to volitional fatigue for elbow and knee flexion and extension) or three days per week (HRRT-3; 61.8 ± 4.6 years, 67.6 ± 13.6 kg, 160.7 ± 4.4 cm; 2 sets of 20-30 repetitions/set to volitional fatigue per exercise) for 8 weeks. Prior and following training, assessments were made for muscle thickness of the elbow and knee flexors and extensors (B-mode ultrasound), muscle strength (1-repetition maximum for elbow and knee flexion and extension), and muscle endurance (maximum number of repetitions performed at 50% baseline 1-repetition maximum for elbow and knee flexion and extension). There was a significant increase over time for all measures of muscle thickness, muscle strength, and muscle endurance (p < 0.001), with no differences between groups. Equal volume, HRRT (independent of training frequency), is an effective intervention for improving muscle mass and muscle performance in postmenopausal women.

Keywords: aging, resistance training, muscle, frequency, hypertrophy
Acknowledgements

I would first like to express my sincere gratitude to my thesis supervisor Dr. Darren Candow for the continuous support, encouragement, patience, and immense knowledge. I could not have imagined having a better advisor and mentor for my Masters. I would like to thank my committee members, Dr. Patrick Neary and Dr. Brad Schoenfeld, and my external examiner, Dr. Nicholas Burd, for the insightful comments and guidance. I would like to thank my study participants for their time and commitment with the study. I would like to thank Patrick Bernat and Sara Butchart for the help and support throughout the study. I would also like to thank my parents, my fiancé and my fiancé’s family for the encouragement and for being by my side on every step of the study.
# Table of Contents

Abstract .................................................................................................................. ii
Acknowledgements ............................................................................................... iii
Table of Contents ................................................................................................. iv
List of Figures ....................................................................................................... vi
List of Tables ....................................................................................................... vii
List of Abbreviations ........................................................................................... viii
1 Introduction ....................................................................................................... 1
2 Literature Review .............................................................................................. 3
   2.1 Muscle protein turnover ............................................................................ 3
   2.2 Hormones .................................................................................................... 4
   2.3 Satellite cells ............................................................................................... 6
3 High-Repetition Resistance Training ................................................................. 7
   3.1 Frequency of training ................................................................................ 8
4 Research Purpose and Hypothesis ..................................................................... 9
5 Methods ............................................................................................................. 10
   5.1 Participants ............................................................................................... 10
   5.2 Research Design ....................................................................................... 11
   5.3 High-Repetition Resistance Training ....................................................... 11
   5.4 Primary Dependent Variables ................................................................. 12
      5.4.1 Muscle thickness .............................................................................. 12
      5.4.2 Muscle strength and endurance ...................................................... 14
      5.4.3 Dietary records ............................................................................... 15
5.4.4 Adverse event assessment ......................................................... 16

5.5 Statistical Analyses ........................................................................ 16

6 Results ................................................................................................ 16

6.1 Muscle Thickness ........................................................................... 21

6.2 Muscle Strength ............................................................................... 23

6.3 Relative Strength ........................................................................... 25

6.4 Muscle Endurance .......................................................................... 27

6.5 Training Volume .............................................................................. 29

6.6 Diet .................................................................................................. 31

7 Discussion .......................................................................................... 33

References .............................................................................................. 37

Appendix A: Godin Leisure-Time Exercise Questionnaire ....................... 45

Appendix B: PAR-Q+ ............................................................................. 47

Appendix C: PARMED-X ........................................................................ 51

Appendix D: Participant Information and Consent Form ......................... 55

Appendix E: 3-Day Food Record .............................................................. 60

Appendix F: Study Adverse Event Form .................................................. 66
List of Figures

1 Summary of recruitment, allocation and analyses……………………………………... 18
# List of Tables

1 Baseline data .................................................................................................................. 20

2 Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Thickness  
(cm) .................................................................................................................................. 22

3 Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Strength  
(kg) .................................................................................................................................. 24

4 Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Relative Strength  
(kg /cm) ............................................................................................................................ 26

5 Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Endurance  
(number of repetitions performed) .................................................................................... 28

6 Training volume (kg) and average number of repetitions (Average Repetitions)  
performed per set over 8 weeks of training ................................................................. 30

7 Mean Absolute Changes (95% CI) From Baseline to 8 weeks for average total calories  
(kcal / day) and average macronutrient (grams / day) ............................................... 32
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-RM</td>
<td>One Repetition Maximum</td>
</tr>
<tr>
<td>4E-BP1</td>
<td>4E Binding Protein</td>
</tr>
<tr>
<td>Akt</td>
<td>Protein Kinase B</td>
</tr>
<tr>
<td>ATPase</td>
<td>Adenosine Triphosphate Synthase</td>
</tr>
<tr>
<td>DHEA</td>
<td>Dehydroepiandrosterone</td>
</tr>
<tr>
<td>eIF4E</td>
<td>Eukaryotic Translation Initiation Factor 4E</td>
</tr>
<tr>
<td>eIF4F</td>
<td>Eukaryotic Translation Initiation Factor 4F</td>
</tr>
<tr>
<td>eIF4G</td>
<td>Eukaryotic Translation Initiation Factor 4 Gamma Protein</td>
</tr>
<tr>
<td>GH</td>
<td>Growth Hormone</td>
</tr>
<tr>
<td>HHRT</td>
<td>High-repetition resistance training</td>
</tr>
<tr>
<td>IGF-1</td>
<td>Insulin-like Growth Factor 1</td>
</tr>
<tr>
<td>IL-10</td>
<td>Interleukin-10 Cytokine</td>
</tr>
<tr>
<td>IL-6</td>
<td>Interleukin-6 Cytokine</td>
</tr>
<tr>
<td>MPB</td>
<td>Muscle Protein Breakdown</td>
</tr>
<tr>
<td>MPS</td>
<td>Muscle Protein Synthesis</td>
</tr>
<tr>
<td>mRNA</td>
<td>Messenger Ribonucleic Acid</td>
</tr>
<tr>
<td>mTOR</td>
<td>Mammalian Target of Rapamycin</td>
</tr>
<tr>
<td>mTORC1</td>
<td>Raptor Mammalian Target of Rapamycin</td>
</tr>
<tr>
<td>mTORC2</td>
<td>Rictor Mammalian Target of Rapamycin</td>
</tr>
<tr>
<td>p70S6K</td>
<td>70-kDA S6 Protein Kinase</td>
</tr>
<tr>
<td>RT</td>
<td>Resistance Training</td>
</tr>
</tbody>
</table>
1 Introduction

Sarcopenia has recently been defined as a muscle disease (ICD-10-MC Diagnosis Code) characterized by low muscle strength, muscle mass and functionality (Cruz-Jentoft et al., 2018). Typically, adults lose between 1-2% of their total muscle mass per year after the age of 50, which corresponds to a 1.5% decrease in maximal strength (for review see Van Kan, 2009). Postmenopausal women may experience accelerated muscle and strength loss, possibly due to a decrease in estrogen production and estrogen receptor concentration in skeletal muscle (Maltais, Desroches, & Dionne, 2009; Wiik, Ekman, Johansson, Jansson & Esbjörnsson, 2009). Progesterone levels decrease in postmenopausal women is mainly associated with functional capacity and muscle performance (Joe and Ramirez, 2001).

While the exact mechanisms explaining sarcopenia remain to be elucidated, one main contributing factor involves muscle protein kinetics (Breen & Phillips, 2011). Specifically, there is an attenuated muscle protein synthetic response to resistance training (i.e. aging anabolic resistance; Breen & Phillips, 2011). Therefore, from a healthy aging perspective, the design of effective resistance training interventions which can help overcome aging anabolic resistance and improve muscle mass and muscle performance are important.

The American College of Sports Medicine (ACSM) recommends that resistance training should be performed at training intensities ≥ 70% one repetition maximum (1-RM) to achieve significant muscle accretion (Ratamess, Alvar, Evetoch, and Housh, 2009). Unfortunately, aging adults may not be able to train at high intensities due to possible co-morbidities associated with aging (i.e. arthritis, osteoporosis, joint pain) (Bemben, Fetters, Bemben, Nabavi, & Koh, 2000; Loenneke and Pujol, 2011). Emerging research indicates that high-repetition resistance training (HRRT; ≥ 20 repetitions/set) to volitional fatigue may be an effective strategy for improving some
indices of muscle biology. For example, young adults (n = 15-18; age = 21 ± 1 years) who performed HRRT (3-4 sets of knee extension exercise; ~20-30 repetitions/set to volitional fatigue) experienced significant increases in the rates of muscle protein synthesis (≤ 24 hours; Burd et al., 2010) and muscle size and strength over 10 weeks of training (Mitchell et al., 2012). Additional work from the same laboratory showed that HRRT (n = 49; 23 ± 1 years, 3 sets of 20-25 repetitions to volitional fatigue; whole-body routine, 4 days per week for 12 weeks) significantly increased lean tissue mass, muscle cross-sectional area, and muscle strength in resistance-trained young males (Morton et al., 2016). Furthermore, postmenopausal women (n = 12; age = 57 ± 4.7 years) who performed unilateral HRRT (3 sets of elbow and knee flexion and extension, ~ 21 repetitions/set to volitional fatigue) experienced significant gains in upper body strength and muscle size after 10 weeks of training (Weisgarber, Candow & Farthing, 2015). While it is difficult to compare results across studies that use different methodologies, HRRT (~ 20-30 repetitions/set to volitional fatigue) appears to be effective for increasing muscle mass and muscle performance.

In addition to high-repetition, the volume and frequency of resistance training may also be important contributing factors for increasing muscle hypertrophy and muscle performance. For example, Schoenfeld, Ogborn and Krieger (2016a) performed a systematic review and meta-analysis on the effects of resistance training frequency and concluded that increased frequency of training led to greater muscle accretion (p = 0.002). However, when resistance training volume (load x sets x repetitions) was equated across studies, there was no influence from training frequency on muscle hypertrophy (Grgic, Schoenfeld & Latella, 2018a). Regarding muscle strength, Grgic et al. (2018) showed that increasing the frequency of training from 1 to 3 days per week had a significant accumulative effect (p = 0.003). Similar to muscle hypertrophy, when
resistance training volume was equated across studies, frequency of training had no greater effect on strength (p = 0.421).

The resistance training guidelines by the ACSM suggests that untrained individuals should train each muscle group 2-3 days per week (Garber et al., 2011; ACSM, 2009). Interestingly, young untrained adults who performed equal-volume resistance training 2 or 3 days per week (2-3 sets of 10 repetitions) for 6 weeks experienced similar gains in muscle hypertrophy and strength (Candow & Burke, 2007). However, the effects of equal volume HRRT, with different workout frequency, in postmenopausal women are unknown. Therefore, the purpose of this thesis was to determine the effects of equal volume HRRT (20-30 repetitions/set to volitional fatigue) with different workout frequency (2 vs. 3 days per week) on muscle hypertrophy, muscle strength and endurance in postmenopausal females.

2 Literature Review

2.1 Muscle protein turnover

The constant and simultaneous synthesis and breakdown of skeletal muscle proteins is referred to as muscle protein turnover (Breen & Phillips, 2011). Muscle hypertrophy will occur when the rates of muscle protein synthesis (MPS) are greater than the rates of muscle protein breakdown (MPB) (Breen & Phillips, 2011). The cellular mechanisms helping explain muscle protein turnover include gene transcription, cell signalling, and enzymes involved in various proteolytic pathways (Burd, Tang, Moore, & Phillips, 2009).

The mammalian target of rapamycin (mTOR) pathway is considered the main governing regulator of messenger ribonucleic acid (mRNA) translation and subsequent MPS (Little & Phillips, 2009; Schoenfeld, 2010) and has been shown to play a key role in the regulation of mRNA translation and MPS for muscle hypertrophy (Bemben et al., 2000). There are two different mTOR
complexes – raptor mammalian target of rapamycin (mTORC1), the predominant multi-protein complex regulator of translation initiation, and rictor mammalian target of rapamycin (mTORC2) – involved in the regulation of actin cytoskeletons. Resistance training elevates the phosphorylation of translational repressor 4E binding protein (4E-BP1), which dissociates from eukaryotic translation initiation factor 4E (eIF4E) that subsequently associates with eukaryotic translation initiation factor 4 gamma protein (eIF4G). This association assists in the recruitment of other translation initiation factors to assembly the eukaryotic translation initiation factor 4F (eIF4F) complex and start cap-dependent translation (Ogasawara et al., 2013). Further, as a response of the mechanical stimulus of type II muscle fibers during resistance training, the mTOR pathways is activated, and it contributes to the progression of protein translation trough the phosphorylation of 70-kDa S6 protein kinase (p70S6K) (Camera, Smiles & Hawley, 2016). In addition to the regulation of translation initiation and MPS for muscle hypertrophy, mTOR plays important roles in processes such as ribosome biogenesis, nutrient metabolism, autophagy, and myoblast fusion (Sarbassov, Ali and Sabatini, 2005). Insufficient stimulation of mTOR following resistance training may be a contributing factor of sarcopenia. For example, following an acute bout of resistance training, up-regulation of MPS and associated translational signalling through the mTORC1 pathways were significantly reduced in aging adults compared to younger adults (Fry et al., 2011).

2.2 Hormones

The age-related decrease in anabolic factors (e.g. growth hormone, androgens, estrogens) and increase in catabolic factors (e.g. cytokines) may have a negative effect on aging muscle biology (Morley et al., 2001). Growth hormone (GH) is released in response to acute exercise from the pituitary gland and it stimulates the production of insulin-like growth factor 1 (IGF-1) in the
liver and skeletal muscle. After resistance training, there is an increase in the gene expression of muscle IGF-1 stimulated by GH. IGF-1 stimulates the mTOR pathway, binding to a receptor in the outer membrane of the muscle cell that sends a signal to the muscle cell nucleus (Brown, 2007). Subsequently, there is an increase in transcription, translation and protein synthesis. Furthermore, IGF-1 reduces the gene expression of myostatin, which inhibits myogenesis, and stimulates the proliferation and differentiation of satellite cells (Candow et al., 2012; Koopman & van Loon, 2009).

Dehydroepiandrosterone (DHEA) is a hormone secreted by the adrenal glands. It acts as an androgen precursor and can be transformed into different sex steroids, such as testosterone and estrogen. DHEA has multifunctional purposes and is associated with increased bone formation, muscle accretion and decreased fat mass as well as improved glucose metabolism (Labrie et al., 2005).

Another major anabolic hormone is testosterone, which is known to increase MPS and decrease proteolysis, as well as act on the muscular system by binding to intracellular androgen receptors, which subsequently translocate to the nucleus and mediate gene expression (Schoenfeld, 2013). In addition to this direct interaction with the muscle cell, testosterone has a powerful anabolic effect by inducing the release of growth hormone (GH) from the pituitary gland (Fleck & Kraemer, 2014).

During and after menopause, estrogen levels in women decrease, leading to a reduced anabolic profile (Karakelides & Nair, 2005). Skeletal muscle has estrogen receptors mainly on type II muscle fibers, which are reduced in postmenopausal women. Along with the sarcopenic loss of type II muscle fibers, low levels of estrogen may accelerate the decrease in muscle mass and strength in aging females (Brown, 2008).
Serum levels of cytokines are increased in response to concentric and eccentric muscle contractions and are involved in the tissue remodelling in response to muscular damage. Interleukin-6 cytokine (IL-6) is produced during acute RT and is responsible for the regulation of satellite cell-mediated hypertrophic muscle growth. Interleukin-10 cytokine (IL-10) is also produced during and after RT, and it plays a role in inflammation (Izquierdo et al., 2009).

2.3 Satellite cells

Satellite cells are characterized as stem cells within skeletal muscle, located peripherally between the basal lamina and the sarcolemma (Lieber, 2002). These cells are precursors to myoblasts and can be found in 3 different stages: quiescence, proliferation, and differentiation (Lieber, 2002). Quiescent satellite cells respond to muscle trauma by reinitiating the cell cycle through mitotic activity to proliferate and differentiate into a muscle cell (Brack & Rando, 2007; Hawke & Garry, 2001; Scharner & Zammit, 2011; Lieber, 2002). When the nucleus receives molecular signals to increase cell size, the cell stimulates the proliferation of satellite cells in order to increase the number of nuclei, potentially contributing to muscle hypertrophy (Brown, 2007). A study by Kadi, Charifi, Denis and Lexell (2004) demonstrated that the biological process of aging decreases satellite cell concentration by approximately 40%, especially in type II muscle fibers (Snijders, Verdijk & van Loon, 2009; Verdijk, Koopman & Schaart, 2007). During the aging process there is a reduction in muscle regenerative capacity (Lightfoot, McCormick, Nye & McArdle, 2014). This aging-dependent satellite cell dysregulation can be caused intrinsically (e.g. genetic mutations) and/or extrinsically (e.g. local/systemic environment) (Brack & Rando, 2007). Moreover, the apoptosis rate of satellite cells in aging muscle increases substantially, impairing muscular regenerative processes (Brack & Rando, 2007). Furthermore, age-related decreases in serum levels of immune cells and growth factors are closely associated with the reduced activity
of satellite cells on aging individuals (Hawke & Garry, 2001). Although satellite cell activity and function decreases with aging, resistance training is an effective lifestyle intervention for improving satellite cell quantity in aging individuals, especially women (Roth et al., 2001; Mackey et al., 2006).

3 High-Repetition Resistance Training

A greater volume of muscle contractions may be required to achieve significant muscle accretion and strength gains in aging individuals (Breen & Phillips, 2011). Training protocols that utilize high-repetitions across multiple sets, especially to volitional fatigue, are effective for increasing the rates of muscle protein synthesis, muscle mass and strength (for reviews see Ralston, Kilgore, Wyatt, & Baker, 2017; Schoenfeld, Grgic, Ogborn & Krieger, 2017). Volitional fatigue can be achieved by performing uninterrupted muscle contractions using high repetitions. Mechanistically, volitional fatigue may be caused by reduced muscle fiber conduction velocity (Sale, 1987), disabled muscle excitation-contraction action via metabolic acidosis, reduced calcium release by the sarcoplasmic reticulum, low energy status or altered activity of ATPase (Green, 1986). To sustain and/or intensify muscle force production, there is an increase in motor unit activation, according to Henneman’s size principle (Henneman, Somjen & Carpenter, 1965). This principle proposes that the size of the motor neuron determines its threshold, predicting the frequency of cell stimulation and the order of recruitment. The order of motor unit recruitment is systematic, with type I fibers recruited first followed by type II fibers as force demands increase (Henneman et al., 1965; Moore et al., 2004; Neumann, 2010).

Type II motor units are primarily recruited to maintain force production during fatiguing exercise (Mitchell et al., 2012) and are typically associated with higher phosphorylation rates of mTOR signaling proteins (Edström & Ekblom, 1972; Fujita et al., 2007; Koopman, Zorenc,
Gransier, Cameron-Smith, & van Loon, 2006). Interestingly, HRRT to volitional fatigue increases type I and type II recruitment which may help explain the observed increases in muscle mass and strength. For example, Burd et al. (2010) showed that HRRT (4 sets of knee extension, ~ 24 repetitions/set) in young males increased mTOR; phosphorylation of Akt, p70S6K, and 4E-BP1; myogenic factors (myogenic differentiation factor D mRNA, myogenin mRNA, paired box protein Pax-7), and rates of myofibrillar protein synthesis. Furthermore, Mitchell et al., (2012) showed that 10 weeks of HHRT (3 sets of knee extension, ~ 20-30 repetitions/set; 3 days per week) significantly increased muscle cross-sectional area and strength over time in young adults. Additional work from the same laboratory showed that HRRT (3 sets of 20-25 repetitions; whole-body routine, 4 days per week for 12 weeks) significantly increased lean tissue mass, muscle cross-sectional area, and muscle strength in resistance-trained young males (Morton et al., 2016). Finally, in aging postmenopausal women (n = 12; age = 57 ± 4.7 years), HRRT (3 sets of elbow and knee flexion and extension, ~ 21 repetitions/set to volitional fatigue) for 10 weeks resulted in significant gains in upper-body strength and muscle mass (Weisgarber et al., 2015). Results across studies indicate that HHRT performed to volitional fatigue increases muscle size and strength. Since sarcopenia is characterized by the loss of muscle mass and strength, HRRT may be an effective intervention to help overcome aging anabolic resistance and improve muscle mass and muscle performance.

3.1 Frequency of training

In addition to high-repetition, the volume and frequency of resistance training may also be important contributing factors for increasing muscle hypertrophy and muscle performance. For example, Schoenfeld et al. (2016a) performed a systematic review and meta-analysis on the effects of resistance training frequency and concluded that increased frequency of training led to greater
muscle accretion (p = 0.002). However, when resistance training volume (load x sets x repetitions) was equated across studies, there was no influence from training frequency on muscle hypertrophy (Grgic et al., 2018a). Regarding muscle strength, Grgic et al. (2018) showed that increasing the frequency of training from 1 to 3 days per week had a significant accumulative effect (p = 0.003). Similar to muscle hypertrophy, when resistance training volume was equated across studies, frequency of training had no greater effect on strength (p = 0.421).

The resistance training guidelines by the American College of Sports Medicine suggests that untrained individuals should train each muscle groups 2-3 days per week (Garber et al., 2011; ACSM, 2009). Interesting, young untrained adults who performed equal-volume resistance training 2 or 3 days per week (2-3 sets of 10 repetitions) for 6 weeks experienced similar gains in muscle hypertrophy and strength (Candow & Burke, 2007). However, the effects of equal volume HRRT, with different workout frequency, in postmenopausal women are unknown.

4 Research Purpose and Hypothesis

The purpose of this thesis was to determine the effects of equal volume HRRT (20-30 repetitions/set to volitional fatigue) with different workout frequency (2 vs. 3 days per week) on muscle hypertrophy, muscle strength and endurance in postmenopausal females. It was hypothesized that training to volitional fatigue 2 or 3 days per week would produce similar gains in muscle mass, strength and endurance.

5 Methods

5.1 Participants

An a priori power analysis (G*Power v. 3.1.5.1) indicated that 34 participants were required for the study. This calculation was based on a moderate effect size (Cohen’s $f = 0.25$), an
alpha level of 0.05, a β-value of 0.8 employing a repeated measures, within-between interactions, ANOVA statistical approach (Faul, Erdfelder, Lang, & Buchner, 2007). Post-menopausal females (≥ 50 years of age) who were not engaged in supervised resistance training for ≥ 6 months prior to the start of the study were recruited to participate. Females were postmenopausal for at least 1 year (defined as having their last menstrual cycle ≥ 1 year prior to the start of the study). Recruitment occurred through the University of Regina e-mail server list. Participants were required to fill out a leisure time exercise questionnaire (Appendix A), which indicated the average number of times that strenuous (i.e. heart beats rapidly), moderate (i.e. not exhausting), and mild exercise (i.e. minimal effort) was performed per week (Godin & Shephard, 1985). Participants also filled out a Physical Activity Readiness Questionnaire (PAR-Q+; Appendix B), which assessed their readiness for participation in resistance training. This questionnaire included questions related to heart conditions, angina at rest or during physical exercise, balance, and bone or joint problems that may affect exercise performance. If the participant indicated any of the above conditions, they were required to get medical clearance before starting the study (PARMED-X; Appendix C). Participants were excluded if they had taken medications (i.e. bisphosphonates, hormone replacement therapy, selective estrogen receptor modulators, parathyroid hormone, calcitonin ) or creatine monohydrate ≤ 12 months prior to the start of the study; if they had a history of fragility fractures; diseases that are known to affect muscle biology (i.e. Crohn’s Disease); if they suffered from severe osteoarthritis or if they planned to travel during the study period for greater than 2 weeks duration at a time. Participants were instructed not to change their diet or engage in additional physical activity that was not part of their normal daily routine or consume non-steroidal anti-inflammatory drugs during the study, as these interventions can affect muscle protein synthesis (Trappe et al., 2002). The study was approved by the Research Ethics Board at the
University of Regina (REB 2018-027). Participants were informed of the risks and purposes of the study before written consent was obtained (Appendix D).

5.2 Research Design

The study was a repeated measures design. After being matched for age, body mass and years post-menopause, participants were randomized on a 1:1 basis to one of two groups: HRRT for 2 days per week (HRRT-2; Monday/Thursday, Tuesday/Friday or Wednesday/Saturday) or HRRT for 3 days per week (HRRT-3; Monday/Wednesday/ Friday or Tuesday/Thursday/Saturday). The primary dependent variables measured at baseline and after the intervention included: (1) muscle thickness (elbow and knee flexors and extensors), (2) muscle strength (1-RM for elbow and knee flexion and extension), and (3) muscle endurance (number of repetitions performed for 1 set using 50% baseline 1-RM for elbow and knee flexion and extension). In addition, participants were required to complete a 3-day food diary (Appendix E) at baseline and during the last week of training to determine whether total energy (kcal) and macronutrient intake changed over time.

5.3 High-Repetition Resistance Training

Prior to the start of HRRT, participants became familiar with the machine-based resistance training equipment (Pulse Exercise Systems Inc., Winnipeg, Canada) in the Aging Muscle and Bone Health Laboratory, University of Regina. During the familiarization training sessions, participants were properly shown how to breathe, use the equipment, and perform repetitions to volitional fatigue. Participants were instructed to perform the concentric phase in 2 seconds, pause for 1 second, then perform the eccentric phase in 2 seconds, in accordance to a metronome (60 beats per minute). An important aspect of the study was that all repetitions were directly supervised.
and performed to volitional fatigue (defined as the inability to perform the concentric phase of a muscle contraction).

During the first familiarization session, participants performed 1 set of HRRT (20-30 repetitions to volitional fatigue) for each exercise in order (knee extension, elbow extension, knee flexion, elbow flexion). In the second familiarization session, 2 sets were performed and during the final familiarization session, participants in the HRRT-2 group performed 2 sets while participants in HRRT-3 group performed 3 sets for each exercise. At least 48 hours separated each familiarization session.

During the 8 weeks of training, participants in the HRRT-2 group exercised on Monday and Thursday, Tuesday and Friday, or Wednesday and Saturday, and performed 3 sets of 20-30 repetitions to volitional fatigue for knee extension, elbow extension, knee flexion, and elbow flexion. Participants in the HHRT-3 group exercised on Monday, Wednesday and Friday or Tuesday, Thursday and Saturday, and performed 2 sets of 20-30 repetitions to volitional fatigue for each exercise. If required, loads were adjusted accordingly per set and/or session to maintain the required 20-30 repetition range. Participants were provided with verbal encouragement to achieve volitional fatigue. Rest period between sets was 2 minutes. Training logs were completed to determine the average training volume (weight x sets x repetitions) per set and the average number of repetitions performed per set.

5.4 Primary Dependent Variables

5.4.1 Muscle thickness. Muscle thickness (right side) of the elbow and knee flexors and extensors was measured using B-mode ultrasound (LOGIQ e, GE Medical Systems). For elbow flexor and extensor muscle thickness, a small mark was drawn on the lateral side of the arm to indicate 65% of the distance down from the acromion process to the olecranon process (Farthing
A tape measure was wrapped around the arm at the 65% mark and used as a reference, while another mark was placed on the bulk of the elbow flexors and extensors where the center of the ultrasound probe was placed. To measure elbow flexor muscle thickness, each participant placed their right arm flat on a table with the belly of the bicep facing upwards and the forearm supinated. To measure elbow extensor muscle thickness, participants stood with their back facing the researcher and elbows relaxed and extended.

For knee flexor and extensor muscle thickness, a small mark was drawn on the lateral side of the leg to indicate 70% of the distance down from the greater trochanter to the lateral epicondyle of the tibia (Abe et al., 2001). A tape measure was wrapped around the leg at the 70% mark and was used to mark another reference point on the bulk of the vastus lateralis (knee extensor) and biceps femoris (knee flexor) where the center of the ultrasound was placed. To measure knee flexor muscle thickness, each participant was prone on the table with both legs extended and relaxed. To measure knee extensor muscle thickness, each participant was placed on a table in a seated position with the leg extended and relaxed.

An 8-MHz scanning transducer head was placed perpendicular to the muscle area. Water-soluble transmission gel (EcoGel 200, Eco-Med Pharmaceutical Inc., Mississauga, Ontario, Canada) was placed on the measurement site to provide acoustic contact with the surface of the muscle. When the image was produced on the screen, the image was frozen. A cursor was then enabled to quantify muscle thickness (cm) at three sites: proximal, mid, and distal, as determined by divisions (1 cm) on the monitor. Muscle thickness measurements were determined from the monitor screen by measuring the distance from the bottom of the subcutaneous adipose layer to the surface of the humerus for elbow flexor and extensor muscle thickness, and to the surface of the femur for knee flexor and extensor muscle thickness. All measurements were taken twice at
each site and averaged to give a muscle thickness value. For each muscle group, markings on the skin were taken using overhead transparency film to ensure that identical sites were measured at baseline and after 8 weeks of training. The reproducibility (coefficient of variation [CV]; intraclass correlation coefficient [ICC]) of muscle thickness measurements was as follows: elbow flexors (CV: 9.2%; ICC: 0.50), elbow extensors (CV: 8.2%; ICC: 0.76), knee extensors (CV: 5.9%; ICC: 0.82) and knee flexors (CV: 6.3%; ICC: 0.82).

The same researcher performed all measurements. Baseline and post-testing muscle thickness measurements were performed prior to assessing 1-RM strength and endurance. Post-testing muscle thickness measurements were performed ≥ 48 hours after the last training session.

5.4.2 Muscle strength and endurance. Muscle strength was assessed using a 1-repetition maximum (1-RM) standard testing procedure in the Aging Muscle and Bone Health Laboratory at the University of Regina. At least 72 hours following the last familiarization training session, baseline 1-RM strength testing was performed for knee extension, elbow extension, knee flexion, and elbow flexion. Following a 5 minute warm-up on a stationary cycle ergometer at a self-selected intensity, participants performed two warm-up sets of each exercise to be tested in the following order: 1 set of 10 repetitions using a load determined by each participant to be comfortable and 1 set of 5 repetitions using a heavier weight. Two-minutes after the warm-up sets, the load was progressively increased for each subsequent 1-RM attempt. Participants rested (passively) at least 2 minutes between 1-RM attempts. Five minutes of passive rest separated each 1-RM assessment. The same researcher performed all measurements.

To measure knee extension 1-RM, participants were positioned in a bilateral, seated knee extension machine so that the knees aligned with the axis of the machine and the lower part of the legs touched the padded lever arm. Following a demonstration, participants were instructed keep
their back firmly against the seat and to not lift their buttocks off the seat during the lift. Participants were instructed to extend their legs until full extension.

To measure elbow extension 1-RM, participants were positioned in a bilateral, seated elbow extension machine with both feet on the floor. Following a demonstration, participants were instructed to push the weight away from their body until full extension of the elbow was achieved.

To measure knee flexion 1-RM, participants were positioned in a bilateral, seated knee flexion machine so that the knees were aligned with the axis of the machine and the back of the lower part of the legs touched the padded lever arm. Following a demonstration, participants were instructed to curl the weight to the point where an estimated 90° angle at the knee was achieved. Participants were instructed to keep their back firmly against the back pad and to not lift their buttocks off the seat during the lift.

To measure elbow flexion 1-RM, participants were positioned in a bilateral, seated elbow flexion machine with both feet on the floor. Following a demonstration, participants were instructed to curl the weight towards their body so that a 90° angle at the elbow was achieved.

Seat position was recorded for each participant to ensure consistency between familiarization, baseline and post-testing. Muscle endurance was assessed at least 48 hours after muscle strength was assessed so the recovery period was appropriate. To measure muscle endurance, participants performed 1 set to volitional fatigue using 50% baseline 1-RM for each exercise. Five minutes of passive rest separated each muscle endurance assessment between different muscle groups.

5.4.3 Dietary records. In order to determine whether habitual dietary intake changed over time and to assess possible differences in macronutrient and caloric intake between groups, a 3-day dietary food record (Appendix E) was collected at the beginning and during the last week of
HRRT. Participants were instructed to record all food and beverage consumption during 2 weekdays and 1 weekend day. Food records were analyzed using MyFitnessPal, which provided daily calorie, carbohydrate, protein, and fat intake.

5.4.4 Adverse event assessment. In the case of an adverse event, participants were required to complete an adverse event form (Appendix F), which provided details on the type of adverse event, the severity (i.e. mild, moderate, severe, or life threatening), the frequency, and the relationship to the intervention (i.e. not related, unlikely, possible, probable, and definite).

5.5 Statistical Analyses

A 2 (group: HRRT-2 vs. HRRT-3) x 2 (time: pre- vs. post-training) analysis of variance (ANOVA), with repeated measures on the second factor was performed to determine differences between groups over time for the dependent variables of muscle thickness, muscle strength, relative strength (kg/cm), muscle endurance and diet. A one-factor ANOVA was used to assess baseline data, training volume variables between groups over time, and absolute change scores ($\Delta = post\ mean - pre\ mean$). Baseline and training volume data are presented as means (standard deviation). All other data are presented as absolute change scores and their 95% confidence intervals. Significance was set at an alpha level of $p < 0.05$. Effect size was determined by partial eta squared ($\eta^2$). Statistical analyses were performed using IBM® SPSS® Statistics, v. 24.

6 RESULTS

A summary of participant recruitment, allocation and analyses is shown in Figure 1. Of the seventy participants who initially volunteered, twenty-five did not meet inclusion criteria and three participants could not commit to the study expectations. Forty-two participants were randomized and started the familiarization phase of the study with one participant subsequently withdrawing because of time constraints. Therefore, forty-one participants started the HRRT
portion of the study. Two participants then withdrew because of time constraints, and one participant withdrew because of health issues unrelated to the study, leaving thirty-eight participants who completed the study. One participant in the HRRT-2 group stopped performing elbow flexion after eight training sessions and elbow extension after thirteen training sessions because of a previous shoulder injury. Another participant in the HRRT-2 group did not perform five sets of elbow flexion and two sets of elbow extension because of wrist pain due to a previous surgery. One participant in the HRRT-3 group did not perform six sets of elbow flexion and two sets of elbow extension because of shoulder calcification. Three participants, two in the HRRT-2 group and one in the HRRT-3 group, did not perform five sets of knee extension and one set of elbow flexion because of episodic headaches during the exercise tasks. One participant in the HRRT-2 groups stopped performing knee extension after seven training sessions because of recurring headaches from the exercise. Participants attended all training sessions and provided 3-day food records at the beginning and end of the study.
Figure 1. Summary of recruitment, allocation and analyses.
Baseline data are presented in Table 1. There were no differences between groups for any baseline measurement except carbohydrate intake. The HRRT-3 group consumed significantly more carbohydrate than the HRRT-2 group (F [1, 37] = 9.00, p = 0.005). There was no change over time for body mass (F [1, 36] = 1.73, p = 0.197; 2 day: - 0.46 kg [-1.07, 0.14], 3 day: - 0.23 kg [-1.16, 0.71]).
Table 1. Baseline data

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (yrs)</strong></td>
<td>60.89 (5.57)</td>
<td>61.84 (4.64)</td>
<td>0.573</td>
</tr>
<tr>
<td><strong>Mass (kg)</strong></td>
<td>72.15 (16.46)</td>
<td>67.65 (13.65)</td>
<td>0.366</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>160.27 (3.91)</td>
<td>160.78 (4.43)</td>
<td>0.706</td>
</tr>
<tr>
<td><strong>Physical activity score</strong></td>
<td>54.38 (37.05)</td>
<td>51.42 (28.21)</td>
<td>0.785</td>
</tr>
<tr>
<td><strong>Muscle Thickness (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexors</td>
<td>4.00 (0.58)</td>
<td>3.80 (0.37)</td>
<td>0.222</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>3.82 (0.73)</td>
<td>3.90 (0.55)</td>
<td>0.707</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>4.10 (0.66)</td>
<td>4.08 (0.53)</td>
<td>0.890</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>4.28 (0.59)</td>
<td>4.22 (0.54)</td>
<td>0.740</td>
</tr>
<tr>
<td>Upper body</td>
<td>7.83 (1.24)</td>
<td>7.71 (0.69)</td>
<td>0.718</td>
</tr>
<tr>
<td>Lower body</td>
<td>8.39 (1.15)</td>
<td>8.30 (0.93)</td>
<td>0.794</td>
</tr>
<tr>
<td>Total body</td>
<td>16.22 (2.5)</td>
<td>16.01 (1.40)</td>
<td>0.734</td>
</tr>
<tr>
<td><strong>Strength (kg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>13.63 (5.88)</td>
<td>13.32 (7.05)</td>
<td>0.885</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>21.65 (6.48)</td>
<td>19.97 (5.05)</td>
<td>0.385</td>
</tr>
<tr>
<td>Knee extension</td>
<td>58.71 (13.59)</td>
<td>56.93 (10.31)</td>
<td>0.656</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>48.44 (10.82)</td>
<td>44.49 (6.87)</td>
<td>0.188</td>
</tr>
<tr>
<td>Upper body</td>
<td>35.29 (11.36)</td>
<td>33.30 (10.96)</td>
<td>0.591</td>
</tr>
<tr>
<td>Lower body</td>
<td>108.37 (23.76)</td>
<td>101.43 (15.96)</td>
<td>0.298</td>
</tr>
<tr>
<td>Total body</td>
<td>142.40 (34.84)</td>
<td>134.73 (24.29)</td>
<td>0.437</td>
</tr>
<tr>
<td><strong>Relative Strength (kg/cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexors</td>
<td>3.44 (1.56)</td>
<td>3.50 (1.77)</td>
<td>0.915</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>5.90 (2.46)</td>
<td>5.19 (1.50)</td>
<td>0.299</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>14.59 (4.17)</td>
<td>14.05 (2.46)</td>
<td>0.475</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>11.49 (3.10)</td>
<td>10.72 (2.37)</td>
<td>0.391</td>
</tr>
<tr>
<td>Upper body</td>
<td>9.34 (3.82)</td>
<td>8.70 (2.85)</td>
<td>0.563</td>
</tr>
<tr>
<td>Lower body</td>
<td>26.36 (6.92)</td>
<td>24.77 (4.46)</td>
<td>0.406</td>
</tr>
<tr>
<td>Total body</td>
<td>35.38 (10.24)</td>
<td>33.47 (6.13)</td>
<td>0.490</td>
</tr>
<tr>
<td><strong>Endurance (repetitions)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>28.05 (21.97)</td>
<td>26.29 (15.04)</td>
<td>0.785</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>38.83 (20.56)</td>
<td>53.64 (35.5)</td>
<td>0.138</td>
</tr>
<tr>
<td>Knee extension</td>
<td>16.72 (5.02)</td>
<td>15.58 (4.41)</td>
<td>0.484</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>32.72 (15.65)</td>
<td>37.64 (14.14)</td>
<td>0.396</td>
</tr>
<tr>
<td>Upper body</td>
<td>66.88 (31.83)</td>
<td>79.94 (41.84)</td>
<td>0.305</td>
</tr>
<tr>
<td>Lower body</td>
<td>48.36 (16.00)</td>
<td>53.23 (16.26)</td>
<td>0.373</td>
</tr>
<tr>
<td>Total body</td>
<td>115.10 (42.22)</td>
<td>133.17 (52.92)</td>
<td>0.263</td>
</tr>
<tr>
<td><strong>Diet</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calories (kcal/day)</td>
<td>1753.85 (462.38)</td>
<td>1932.00 (376.50)</td>
<td>0.201</td>
</tr>
<tr>
<td>Carbohydrate (g/day)</td>
<td>179.24 (50.90)</td>
<td>226.57 (46.22)</td>
<td>0.005*</td>
</tr>
<tr>
<td>Fat (g/day)</td>
<td>77.07 (27.82)</td>
<td>77.21 (26.42)</td>
<td>0.987</td>
</tr>
<tr>
<td>Protein (g/day)</td>
<td>80.59 (34.35)</td>
<td>76.52 (21.12)</td>
<td>0.663</td>
</tr>
</tbody>
</table>

Values are means (standard deviation).
* Different at baseline.
6.1 Muscle Thickness

There was a significant increase over time (Table 2) for the elbow flexors ($F [1, 36] = 74.05, \eta^2 = 0.67$), elbow extensors ($F [1, 36] = 98.16, \eta^2 = 0.73$), elbow flexors and extensors combined ($F [1, 36] = 105.44, \eta^2 = 0.74$), knee flexors ($F [1, 36] = 100.92, \eta^2 = 0.56$), knee extensors ($F [1, 36] = 87.80, \eta^2 = 0.70$), knee flexors and extensors combined ($F [1, 36] = 125.85, \eta^2 = 0.78$), and elbow and knee flexors and extensors combined ($F [1, 36] = 128.56, \eta^2 = 0.78$), with no differences between groups.
Table 2. Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Thickness (cm).

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Exercise p-value</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexors</td>
<td>1.26 (0.77, 1.75)</td>
<td>1.55 (1.07, 2.03)</td>
<td>&lt; 0.001*</td>
<td>0.388</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>1.91 (1.35, 2.47)</td>
<td>1.59 (1.10, 2.07)</td>
<td>&lt; 0.001*</td>
<td>0.361</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>1.15 (0.67, 1.63)</td>
<td>1.61 (1.21, 2.00)</td>
<td>&lt; 0.001*</td>
<td>0.131</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>1.29 (0.88, 1.69)</td>
<td>1.45 (1.04, 1.85)</td>
<td>&lt; 0.001*</td>
<td>0.561</td>
</tr>
<tr>
<td>Upper body</td>
<td>3.18 (2.15, 4.21)</td>
<td>3.14 (2.35, 3.93)</td>
<td>&lt; 0.001*</td>
<td>0.947</td>
</tr>
<tr>
<td>Lower body</td>
<td>2.44 (1.68, 3.21)</td>
<td>3.06 (2.37, 3.75)</td>
<td>&lt; 0.001*</td>
<td>0.218</td>
</tr>
<tr>
<td>Total body</td>
<td>5.63 (3.93, 7.33)</td>
<td>6.20 (4.81, 7.59)</td>
<td>&lt; 0.001*</td>
<td>0.585</td>
</tr>
</tbody>
</table>

* Time main effect (p < 0.05) 
Upper body = Elbow flexors and elbow extensors 
Lower body = Knee flexors and knee extensors 
Total body = Elbow and knee flexors and extensors
6.2 Muscle Strength

Both groups experienced a similar increase in strength over time (Table 3) for elbow flexion ($F[1, 35] = 31.27, \eta^2 = 0.47$), elbow extension ($F[1, 35] = 91.65, \eta^2 = 0.72$), elbow flexion and extension combined ($F[1, 35] = 118.27, \eta^2 = 0.77$), knee flexion ($F[1, 36] = 29.51, \eta^2 = 0.45$), knee extension ($F[1, 36] = 27.12, \eta^2 = 0.43$), knee flexion and extension combined ($F[1, 36] = 13.82, \eta^2 = 0.27$), and elbow and knee flexion and extension combined ($F[1, 36] = 29.62 \text{ cm}, \eta^2 = 0.45$), with no differences between groups.
Table 3. Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Strength (kg).

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Exercise p-value</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexion</td>
<td>4.60 (1.91, 7.29)</td>
<td>3.21 (1.88, 4.54)</td>
<td>&lt; 0.001*</td>
<td>0.327</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>4.73 (2.91, 6.55)</td>
<td>6.10 (4.54, 7.65)</td>
<td>&lt; 0.001*</td>
<td>0.236</td>
</tr>
<tr>
<td>Knee extension</td>
<td>2.75 (-8.14, 13.64)</td>
<td>9.09 (4.53, 13.65)</td>
<td>&lt; 0.001*</td>
<td>0.608</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>8.49 (3.15, 13.82)</td>
<td>7.89 (4.48, 11.31)</td>
<td>&lt; 0.001*</td>
<td>0.844</td>
</tr>
<tr>
<td>Upper body</td>
<td>9.34 (6.27, 12.41)</td>
<td>9.31 (7.33, 11.30)</td>
<td>&lt; 0.001*</td>
<td>0.988</td>
</tr>
<tr>
<td>Lower body</td>
<td>11.24 (-3.41, 25.90)</td>
<td>16.98 (10.71, 23.26)</td>
<td>&lt; 0.001*</td>
<td>0.454</td>
</tr>
<tr>
<td>Total body</td>
<td>20.58 (3.64, 37.5)</td>
<td>26.3 (19.03, 33.57)</td>
<td>&lt; 0.001*</td>
<td>0.424</td>
</tr>
</tbody>
</table>

* Time main effect (p < 0.05)
Upper body = Elbow flexion and elbow extension
Lower body = Knee flexion and knee extension
Total body = Elbow and knee flexion and extension
6.3 Relative Strength

There was a decrease over time (Table 4) for the elbow extensors (F [1, 35] = 9.93, \(\eta^2 = 0.22\)), elbow flexors and extensors combined (F [1, 35] = 7.33, \(\eta^2 = 0.17\)), knee flexors (F [1, 36] = 11.45, \(\eta^2 = 0.24\)), knee extensors (F [1, 36] = 17.75, \(\eta^2 = 0.33\)), knee flexors and extensors combined (F [1, 36] = 18.56, \(\eta^2 = 0.34\)), elbow and knee flexors and extensors combined (F [1, 36] = 19.84 cm, \(\eta^2 = 0.35\)), with no change for the elbow flexors (p = 0.351). There were no differences between groups.
Table 4. Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Relative Strength (kg /cm).

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Exercise p-value</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexors</td>
<td>0.03 (-0.59, 0.67)</td>
<td>-0.34 (-0.63, -0.55)</td>
<td>0.351</td>
<td>0.247</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>-1.24 (-2.15, -0.32)</td>
<td>-0.37 (-0.97, 0.22)</td>
<td>0.003*</td>
<td>0.101</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>-2.90 (-5.56, -0.24)</td>
<td>-2.45 (-3.61, -1.26)</td>
<td>&lt; 0.001*</td>
<td>0.647</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>-1.30 (-2.57, -0.44)</td>
<td>-1.44 (-2.59, -0.29)</td>
<td>0.002*</td>
<td>0.867</td>
</tr>
<tr>
<td>Upper body</td>
<td>-1.20 (-2.54, 0.13)</td>
<td>-0.72 (-1.44, -0.01)</td>
<td>0.010*</td>
<td>0.505</td>
</tr>
<tr>
<td>Lower body</td>
<td>-4.21 (-7.69, -0.72)</td>
<td>-3.89 (-5.76, -2.03)</td>
<td>&lt; 0.001*</td>
<td>0.868</td>
</tr>
<tr>
<td>Total body</td>
<td>-5.25 (-9.72, -0.77)</td>
<td>-4.62 (-6.81, -2.43)</td>
<td>&lt; 0.001*</td>
<td>0.696</td>
</tr>
</tbody>
</table>

* Time main effect (p < 0.05)

Upper body = Elbow flexors and elbow extensors
Lower body = Knee flexors and knee extensors
Total body = Elbow and knee flexors and extensors
6.4 Muscle Endurance

There was a significant increase in muscular endurance (number of repetitions performed) over time (Table 5) for elbow flexion (F [1, 33] = 16.86, $\eta^2 = 0.33$), elbow extension (F [1, 33] = 9.75, $\eta^2 = 0.22$), elbow flexion and extension combined (F [1, 33] = 17.62, $\eta^2 = 0.34$), knee flexion (F [1, 34] = 24.81, $\eta^2 = 0.42$), knee extension (F [1, 34] = 20.65, $\eta^2 = 0.38$), knee flexion and extension combined (F [1, 34] = 28.94, $\eta^2 = 0.46$), and elbow and knee flexion and extension combined (F [1, 34] = 37.60, $p < 0.001$, $\eta^2 = 0.52$), with no differences between groups.
Table 5. Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Muscle Endurance (number of repetitions performed).

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Exercise p-value</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexion</td>
<td>11.21 (-0.73, 23.15)</td>
<td>17.78 (6.78, 28.79)</td>
<td>&lt; 0.001*</td>
<td>0.401</td>
</tr>
<tr>
<td>Elbow extension</td>
<td>12.94 (0.93, 24.95)</td>
<td>13.00 (-3.04, 29.04)</td>
<td>0.004*</td>
<td>0.881</td>
</tr>
<tr>
<td>Knee extension</td>
<td>3.78 (-0.75, 8.33)</td>
<td>6.89 (3.37, 10.41)</td>
<td>&lt; 0.001*</td>
<td>0.283</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>40.00 (22.45, 57.54)</td>
<td>42.86 (11.61, 73.75)</td>
<td>&lt; 0.001*</td>
<td>0.664</td>
</tr>
<tr>
<td>Upper body</td>
<td>29.05 (13.03, 45.07)</td>
<td>34.41 (6.16, 62.66)</td>
<td>&lt; 0.001*</td>
<td>0.725</td>
</tr>
<tr>
<td>Lower body</td>
<td>43.78 (24.32, 63.20)</td>
<td>55.41 (20.33, 90.49)</td>
<td>&lt; 0.001*</td>
<td>0.533</td>
</tr>
<tr>
<td>Total endurance</td>
<td>75.77 (50.12, 101.42)</td>
<td>89.82 (42.46, 137.17)</td>
<td>&lt; 0.001*</td>
<td>0.401</td>
</tr>
</tbody>
</table>

* Time main effect (p < 0.05)
Upper body = Elbow flexors and elbow extensors
Lower body = knee flexors and knee extensors
Total body = elbow and knee flexors and extensors
6.5 Training Volume

There were no differences between groups in training volume (Table 6) for the elbow flexors ($F \[1, 37\] = 0.016$), elbow extensors ($F \[1, 37\] = 3.36$), elbow flexors and extensors combined ($F \[1, 37\] = 0.69$), knee flexors ($F \[1, 37\] = 0.66$), knee extensors ($F \[1, 37\] = 0.48$), knee flexors and extensors combined ($F \[1, 37\] = 0.04$), or elbow and knee flexors and extensors combined ($F \[1, 37\] = 0.01$).

There was a group x time interaction for the average number of repetitions performed per set for the knee flexors and extensors combined with the HRRT-3 group performing more repetitions than the HRRT-2 group ($F \[1, 37\] = 5.37$; Table 6). There were no differences between groups for the elbow flexors ($F \[1, 37\] = 0.001$), elbow extensors ($F \[1, 37\] = 2.38$), elbow flexors and extensors combined ($F \[1, 37\] = 0.28$), knee flexors ($F \[1, 37\] = 4.07$), knee extensors ($F \[1, 37\] = 3.04$), or for the elbow and knee flexors and extensors combined ($F \[1, 37\] = 2.57$).
Table 6. Training volume (kg) and average number of repetitions (Ave Reps) performed per set over 8 weeks of training.

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training Volume</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexors</td>
<td>8121.69 (3737.45)</td>
<td>7966.31 (3865.21)</td>
<td>0.900</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>15130.86 (3374.48)</td>
<td>16960.94 (2745.77)</td>
<td>0.075</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>21767.82 (8139.60)</td>
<td>23388.39 (6122.79)</td>
<td>0.492</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>41010.76 (12684.84)</td>
<td>38254.60 (7450.86)</td>
<td>0.420</td>
</tr>
<tr>
<td>Upper body</td>
<td>23252.55 (6851.37)</td>
<td>24927.26 (5452.75)</td>
<td>0.410</td>
</tr>
<tr>
<td>Lower body</td>
<td>62778.58 (19604.89)</td>
<td>61643.00 (11144.80)</td>
<td>0.828</td>
</tr>
<tr>
<td>Total body</td>
<td>86031.14 (24805.05)</td>
<td>86570.26 (13597.48)</td>
<td>0.934</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ave Reps</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow flexors</td>
<td>22.10 (4.73)</td>
<td>22.11 (1.92)</td>
<td>0.996</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>23.58 (1.89)</td>
<td>24.41 (1.36)</td>
<td>0.131</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>23.68 (4.09)</td>
<td>25.40 (1.31)</td>
<td>0.090</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>26.70 (1.65)</td>
<td>27.83 (1.80)</td>
<td>0.051</td>
</tr>
<tr>
<td>Upper body</td>
<td>45.69 (6.42)</td>
<td>46.53 (2.31)</td>
<td>0.598</td>
</tr>
<tr>
<td>Lower body</td>
<td>50.39 (4.73)</td>
<td>53.24 (2.53)</td>
<td>0.026*</td>
</tr>
<tr>
<td>Total body</td>
<td>96.08 (9.03)</td>
<td>99.77 (4.32)</td>
<td>0.117</td>
</tr>
</tbody>
</table>

Values are means (standard deviation).
* HRRT-3 greater than HRRT-2
Upper body = Elbow flexors/extensors
Lower body = Knee flexors/extensors
Total body = Elbow and knee flexors/extensors
6.6 Diet

There was a group x time interaction for total calories, fat, and protein (Table 7). The HRRT-2 group consumed less total calories $F[1, 36] = 7.33, \eta^2 = 0.16$, fat $F[1, 36] = 10.125, \eta^2 = 0.22$ and protein $F[1, 36] = 6.87, \eta^2 = 0.16$ over time, with no change in the HRRT-3 group. There were no other differences.
Table 7. Mean Absolute Changes (95% CI) From Baseline to 8 weeks for Average Total Calories (kcal / day) and Average Macronutrient (grams / day).

<table>
<thead>
<tr>
<th></th>
<th>HRRT-2</th>
<th>HRRT-3</th>
<th>Exercise p-value</th>
<th>Interaction p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total calories</td>
<td>-317.29 (-499.13, -135.46)</td>
<td>80.49 (-168.71, 329.69)</td>
<td>0.116</td>
<td>0.010**</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>-15.24 (-36.48, 5.99)</td>
<td>-0.49 (-36.96, 35.97)</td>
<td>0.439</td>
<td>0.467</td>
</tr>
<tr>
<td>Fats</td>
<td>-20.31 (-30.06, -10.57)</td>
<td>2.78 (-8.94, 14.52)</td>
<td>0.021*</td>
<td>0.003**</td>
</tr>
<tr>
<td>Protein</td>
<td>-22.28 (-39.79, -4.76)</td>
<td>6.31 (-8.42, 21.05)</td>
<td>0.152</td>
<td>0.013**</td>
</tr>
</tbody>
</table>

* Time main effect (p < 0.05)
** HRRT-2 different than HRRT-3 group
7 DISCUSSION

This was the first study to compare the effects of equal volume HRRT, with different workout frequency, on muscle mass and muscle performance in postmenopausal women. Results showed that HRRT, independent of training frequency, was effective for improving muscle hypertrophy, muscle strength and endurance. From a healthy aging perspective, these results are important as the reduction in muscle mass and strength with aging decreases the ability to perform activities of daily living (Manini & Clark, 2013) and improvements in muscle size and muscle performance may lead to greater functionality over time (Chalé et al., 2012).

Results from the present study support the growing body of literature that HRRT is a very effective intervention for improving indices of muscle biology and performance. For example, Burd et al. (2010) showed that an acute bout of HRRT (4 sets of knee extension, ~ 24 repetitions/set to volitional fatigue) in young males significantly increased the rates of myofibrillar muscle protein synthesis for up to 24 hours post-exercise. Furthermore, Mitchell et al. (2012) showed that 10 weeks of HRRT (3 sets of knee extension, 20-30 repetitions/set to volitional fatigue) increased muscle cross-section area and strength over time in young males. Additional work from the same laboratory showed that HRRT (3 sets of 20-25 repetitions to volitional fatigue; whole-body routine, 4 days per week for 12 weeks) significantly increased lean tissue mass, muscle cross-sectional area, and muscle strength in resistance-trained young males (Morton et al., 2016). Finally, postmenopausal women who performed unilateral HRRT (3 sets of elbow and knee flexor and extensor exercise, ~ 21 repetitions/set to volitional fatigue) experienced significant gains in upper body strength and muscle size after 10 weeks of training (Weisgarber et al., 2015). While it is difficult to compare results across studies that use different methodologies, HRRT (~ 20-30
repetitions/set to volitional fatigue) is an effective intervention to increases muscle mass and muscle performance.

While the mechanisms explaining the significant increase in muscle mass and muscle performance from HRRT remain to be elucidated, it is plausible that muscle fiber recruitment patterns may be involved (Burd et al., 2009; Schoenfeld, Wilson, Lowery & Krieger, 2016b). Hennemann’s ‘size principle’ of neuromuscular adaptation to resistance training indicates a hierarchy of muscle fiber recruitment, with Type I fibers being recruited first followed by Type II fibers (Henneman et al., 1965). There is speculation that HRRT performed to volitional fatigue may cause greater time-under-tension of activated muscle fibers and promote earlier recruitment of Type I and Type II fibers, leading to improvements in muscle hypertrophy and muscle performance (Schoenfeld et al. 2016b). Unfortunately, muscle biopsies were not performed in the present study which negates the ability to determine the effects of HHRT on muscle fiber morphology.

Results showed that the frequency of equal-volume HRRT did not influence muscle accretion or muscle performance, which is in agreement with several recent meta-analyses and reviews. For example, Grgic et al. (2018) reviewed 22 studies and concluded that the frequency of equal-volume resistance training had no greater effect on strength (p = 0.421), even when repetitions were performed to volitional fatigue. Ralston, Kilgore, Wyatt, Buchan and Baker (2018) also concluded that training frequency (1 -3 days/week) had no effect on muscle strength when training volume was equal across 12 studies (p = 0.078). Additional work by Grgic, Schoenfeld and Latella (2018a) showed that training frequency had no influence on muscle hypertrophy when training volume was equal across 10 studies reviewed.
There was a significant increase in muscle thickness and strength but a decrease in relative strength (kg / cm) over time for all muscle groups, except the elbow flexors. The decrease in relative strength indirectly suggests that the change in muscle thickness was larger than the change in muscle strength. Therefore, HRRT may have a greater stimulatory effect (relative basis) on muscle accretion compared to strength. In a recent meta-analysis by Schoenfeld, Grgic, Ogborn and Krieger (2017), HRRT (low-load) to volitional fatigue increased muscle hypertrophy to the same extent as heavy-load, lower repetition training (Effect Size: 0.03 ± 0.05; 95% CI [-0.08, 0.14]; p = 0.56). However, HRRT was unable to produce the same strength gains as lower-repetition (heavy-load) training. Future research should directly compare the effects of longer term (> 8 weeks) high-repetition (low-load) resistance training vs. lower-repetition (heavy-load) training in postmenopausal women.

There were several additional limitations to this study not previously mentioned. First, results only apply to postmenopausal women. Second, participant’s motivation and activities of daily living may have influenced the results. Third, participants were instructed not to change their diet or engage in additional physical activity that was not part of their normal routine during the study. Changes in these parameters could have influenced the results. Finally, muscle fiber area/recruitment, myogenic transcription factors, muscle protein kinetics, satellite cells or hormonal properties were not measured.

In conclusion, equal volume HRRT, performed two or three days per week, is an effective intervention to increase muscle hypertrophy, muscle strength and endurance in postmenopausal women. These results are important because improvements in muscle hypertrophy and muscle performance lead to greater functionality and quality of life. From a lifestyle and knowledge
translation perspective, postmenopausal women can expect the same muscle benefits by either training with a greater volume two days per week or less volume three days per week.
References


Appendix A: Godin Leisure-Time Exercise Questionnaire

Godin Leisure-Time Exercise Questionnaire

INSTRUCTIONS
In this excerpt from the Godin Leisure-Time Exercise Questionnaire, the individual is asked to complete a self-explanatory, brief four-item query of usual leisure-time exercise habits.

CALCULATIONS
For the first question, weekly frequencies of strenuous, moderate, and light activities are multiplied by nine, five, and three, respectively. Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:

Weekly leisure activity score = \((9 \times \text{Strenuous}) + (5 \times \text{Moderate}) + (3 \times \text{Light})\)

The second question is used to calculate the frequency of weekly leisure-time activities pursued “long enough to work up a sweat” (see questionnaire).

EXAMPLE

Strenuous = 3 times/wk
Moderate = 6 times/wk
Light = 14 times/wk

Total leisure activity score = \((9 \times 3) + (5 \times 6) + (3 \times 14) = 27 + 30 + 42 = 99\)

Godin Leisure-Time Exercise Questionnaire

1. During a typical 7-Day period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time (write on each line the appropriate number).

<table>
<thead>
<tr>
<th>Times Per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week</td>
</tr>
</tbody>
</table>

a) STRENUEOUS EXERCISE
(HEART BEATS RAPIDLY)
(e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling)
b) MODERATE EXERCISE
(NOT EXHAUSTING)
(e.g., fast walking, baseball, tennis, easy bicycling,
volleyball, badminton, easy swimming, alpine skiing,
popular and folk dancing)

(c) MILD EXERCISE
(MINIMAL EFFORT)
(e.g., yoga, archery, fishing from river bank, bowling,
horseshoes, golf, snow-mobiling, easy walking)

2. During a typical 7-Day period (a week), in your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?

<table>
<thead>
<tr>
<th>OFTEN</th>
<th>SOMETIMES</th>
<th>NEVER/RARELY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2.</td>
<td>3.</td>
</tr>
</tbody>
</table>
Appendix B: PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

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

SECTION 1 - GENERAL HEALTH

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.

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

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

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

✓  Start becoming much more physically active – start slowly and build up gradually.

✓  Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).

✓  You may take part in a health and fitness appraisal.

✓  If you have any further questions, contact a qualified exercise professional such as a

   CSEP Certified Exercise Physiologist’ (CSEP-CEP) or CSEP Certified Personal Trainer’
   (CSEP-CPT).

✓  If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity,

   please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort
   exercise.

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

✗ Delay becoming more active if:

✓  You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better.

✓  You are pregnant – talk to your health care practitioner, your physician, a qualified exercise

   professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR

✓  Your health changes – please answer the questions on Section 2 of this document and/or talk to

   your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with

   any physical activity programme.
### SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th>Question</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Do you have Arthritis, Osteoporosis, or Back Problems?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Do you have Cancer of any kind?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Do you have Heart Disease or Cardiovascular Disease?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3b. Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3c. Do you have chronic heart failure?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3d. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3e. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Do you have any Metabolic Conditions?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4a. Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4b. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4c. Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5. Do you have any Mental Health Problems or Learning Difficulties?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5b. Do you also have back problems affecting nerves or muscles?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>-----</td>
<td>----</td>
</tr>
<tr>
<td>6. Do you have a Respiratory Disease?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure</td>
<td>If yes, answer questions 6a-6d</td>
<td>If no, go to question 7</td>
</tr>
<tr>
<td>6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>6b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>6c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>6d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>7. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>7b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>7c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>8. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>8b. Do you have any impairment in walking or mobility?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>8c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>9. Do you have any other medical condition not listed above or do you live with two chronic conditions?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>9a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>9b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
<tr>
<td>9c. Do you currently live with two chronic conditions?</td>
<td>![Yes/No]</td>
<td>![Yes/No]</td>
</tr>
</tbody>
</table>

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

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

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

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:

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

SECTION 3 - DECLARATION

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

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

NAME ______________________________________________________________________ DATE ______________

SIGNATURE __________________________________________________________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER __________________________________________________________________

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

KEY REFERENCES

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

CSEP approved Sept 12 2011 version
Appendix C: PARMDE-X

PARmed-X

PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION

The PARmed-X is a physical activity-specific checklist to be used by a physician with patients who have had positive responses to the Physical Activity Readiness Questionnaire (PAR-Q). In addition, the Conveyance/Referral Form in the PARmed-X can be used to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. The PAR-Q by itself provides adequate screening for the majority of people. However, some individuals may require a medical evaluation and specific advice (exercise prescription) due to one or more positive responses to the PAR-Q.

Following the participant’s evaluation by a physician, a physical activity plan should be devised in consultation with a physical activity professional (CSEP-Certified Personal Trainer™ or CSEP-Certified Exercise Physiologist™). To assist in this, the following instructions are provided:

PAGE 1: · Sections A, B, C, and D should be completed by the participant BEFORE the examination by the physician. The bottom section is to be completed by the examining physician.

PAGES 2 & 3: · A checklist of medical conditions requiring special consideration and management.

PAGE 4: · Physical Activity & Lifestyle Advice for people who do not require specific instructions or prescribed exercise.
· Physical Activity Readiness Conveyance/Referral Form - an optional tear-off tab for the physician to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

A

PERSONAL INFORMATION:

NAME ____________________________

ADDRESS __________________________

TELEPHONE ____________________________

BIRTHDATE ________ GENDER ________

MEDICAL No. ____________________________

B

PAR-Q. Please indicate the PAR-Q questions to which you answered YES

q 1 Heart condition
q 2 Chest pain during activity
q 3 Chest pain at rest
q 4 Loss of balance, dizziness
q 5 Bone or joint problem
q 6 Blood pressure or heart drugs
q 7 Other reason:

C

RISK FACTORS FOR CARDIOVASCULAR DISEASE:

Check all that apply

q Less than 50 minutes of moderate physical activity most days of the week.
q Currently smoker (tobacco smoking 1 or more times per week).
q High blood pressure reported by physician after repeated measurements.
q High cholesterol level reported by physician.

Please note: Many of these risk factors are modifiable. Please refer to page 4 and discuss with your physician.

D

PHYSICAL ACTIVITY INTENTIONS:

What physical activity do you intend to do?

Physical Activity Readiness Conveyance/Referral:

Based upon a current review of health status, I recommend:

q No physical activity
q Only a medically-supervised exercise program until further medical clearance
q Progressive physical activity:

with avoidance of: ______________________________

with inclusion of: ______________________________

q under the supervision of a CSEP-Certified Exercise Physiologist™
q Unrestricted physical activity—start slowly and build up gradually

This section to be completed by the examining physician

Physical Exam:

HI Wt BP i) /

BP ii) /

Conditions limiting physical activity:

q Cardiovascular q Respiratory q Other
q Musculoskeletal q Abdominal

Tests required:

q ECG q Exercise Test q X-Ray
q Blood q Urinkysis q Other

Further Information:

Attached

To be forwarded

Available on request

© Canadian Society for Exercise Physiology www.cscep.ca
Physical Activity Readiness
Medical Examination
(revised 2002)

**PARmed-X**

**PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION**

Following is a checklist of medical conditions for which a degree of precaution and/or special advice should be considered for those who answered "YES" to one or more questions on the PAR-Q, and people over the age of 69. Conditions are grouped by system. Three categories of precautions are provided. Comments under Advice are general, since details and alternatives require clinical judgement in each individual instance.

<table>
<thead>
<tr>
<th>Absolute Contraindications</th>
<th>Relative Contraindications</th>
<th>Special Prescriptive Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent restriction or temporary restriction until condition is treated, stable, and/or past acute phase.</td>
<td>Highly variable: Value of exercise testing and/or program may exceed risk. Activity may be restricted. Desirable to maximize control of condition. Direct or indirect medical supervision of exercise program may be desirable.</td>
<td>Individualized prescriptive advice generally appropriate: - limitations imposed and/or - special exercises prescribed. May require medical monitoring and/or initial supervision in exercise program.</td>
</tr>
</tbody>
</table>

**Cardiovascular**
- Aortic aneurysm (dissecting)
- Aortic stenosis (severe)
- Congestive heart failure
- Congestive anemia
- Myocardial infarction (acute)
- Myocardial infarction (active or recent)
- Pulmonary or systemic embolism (acute)
- Thromboprophylaxis
- Ventricular tachycardia and other dangerous dysrhythmias (e.g., multi-hostile ventricular activity)

**Infections**
- Acute infections disease (regardless of etiology)
- Subacute/bacterial/complicated infectious diseases (e.g., malaria, others)
- Chronic infections
- HIV

**Metabolic**
- Uncontrolled metabolic disorders (diabetes mellitus, thyrotoxicosis, myxedema)
- Renal, hepatic & other metabolic insufficiency
- Obesity
- Single kidney

**Pregnancy**
- Complicated pregnancy (e.g., low-risk, high-risk, congenital defect, etc.)
- Advanced pregnancy (late 3rd trimester)

**ADVICE**
- Clinical exercise test may be warranted in selected cases, for specific determination of coronary insufficiency and limitations and precautions (if any).
- Slow progression of exercise to levels based on test performance and individual tolerance.
- Consider individual need for initial conditioning program under medical supervision (indirect or direct).
- Intermittent claudication or progressive exercise to tolerance.
- Hypertension: systolic 160-180, diastolic 105+
- Progressive exercise; care with medications (serum electrolytes; post-exercise syncope; etc.)
- Variable as to condition.
- Variable as to status.
- Dietary modification, and initial light exercises with slow progression (walking, swimming, cycling).

**References:**

The PAR-Q and PARmed-X were developed by the British Columbia Ministry of Health. They have been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

No changes permitted. You are encouraged to photocopy the PARmed-X, but only if you use the entire form.

Disponible en français sous le titre
"Évaluation médicale de l’aptitude à l’activité physique (X-AAP)"

Continued on page 3...
### Special Prescriptive Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Advice</th>
</tr>
</thead>
</table>
| Lung      | - chronic pulmonary disorders: special relaxation and breathing exercises.  
- obstructive lung disease: breath control during endurance exercises to tolerance, avoid polluted air  
- chronic bronchitis: avoid hyperventilation during exercise, avoid extremely cold conditions; warm up adequately, utilize appropriate medication.  
- exercise-induced bronchospasm: avoid hyperventilation during exercise, avoid extremely cold conditions; warm up adequately, utilize appropriate medication. |
| Musculoskeletal | - low back conditions (pathological, functional): avoid or minimize exercise that precipitates or exacerbates e.g., forced extreme flexion, extension, and violent holding; correct posture, proper back exercises  
- arthritis—osteo (inflammatory, rheumatoid, gout): treatment, plus judicious blend of rest, splinting and gentle movement  
- arthritis—subacute: progressive increase of active exercise therapy  
- osteoarthritis and above conditions: maintenance of mobility and strength, non-weight bearing exercises to minimize joint trauma (e.g., cycling, aquatic activity, etc.)  
- orthopaedic: highly variable and individualized  
- hernia: minimize straining and isometrics; strengthen abdominal muscles  
- osteoporosis or low bone density: avoid exercise with high risk for fracture such as push-ups, curl-ups, vertical jump and trunk forward flexion; engage in low-impact weight-bearing activities and resistance training |
| CNS       | - convulsive disorder not completely controlled by medication: minimize or avoid exercise in hazardous environments and/or exercising alone (e.g., swimming, mountain climbing, etc.)  
- recent concussion: thorough examination and history of two concussions, review for discontinuation of contact sport if three concussions, depending on duration of unconsciousness, retrogade amnesia, persistent headaches, and other objective evidence of cerebral damage |
| Blood     | - anemia—severe (<10 Gm/dl): control preferred, exercise as tolerated  
- electrolyte disturbances: moderate program |
| Medications | - antihypertensive: moderate program  
- antihypertensive: moderate program  
- beta-blockers: moderate program  
- diuretics: moderate program  
- other: moderate program |
| Other     | - post-exercise syncope: moderate program  
- heat intolerance: protract cool-down with light activities; avoid exercise in extreme heat  
- temporary minor illness: postpone until recovered  
- cancer: if potential metastases, first by cycle ergometry, consider non-weight bearing exercises; exercise at lower end of prescriptive range (40-65% of heart rate reserve), depending on condition and recent treatment (radiation, chemotherapy), monitor hemoglobin and lymphocyte counts; add dynamic lifting exercise to strengthen muscles, using machines rather than weights. |

*Refer to special publications for elaboration as required*
PARmed-X Physical Activity Readiness Conveyance/Referral Form

Based upon a current review of the health status of ____________________________, I recommend:

- No physical activity
- Only a medically-supervised exercise program until further medical clearance
- Progressive physical activity
  - with avoidance of: ____________________________________________
  - with inclusion of: ____________________________________________
  - under the supervision of a CSEP-Certified Exercise Physiologist™
- Unrestricted physical activity — start slowly and build up gradually

__________________________
M.D.

__________________________
(date)

Further Information:
- Attached
- To be forwarded
- Available on request

Physician/clinic stamp:

NOTE: This physical activity clearance is valid for a maximum of six months from the date it is completed and becomes invalid if your medical condition becomes worse.
Appendix D: Participant Information and Consent Form

Research Participant Information and Consent Form

Title of the study: Effects of low-load, high-volume resistance training with different workout frequency on muscle mass and muscle performance in aging females

Researchers: Darren G. Candow, Ph.D. (Principal Investigator), Faculty of Kinesiology and Health Studies, University of Regina, phone: 306-585-4906, email: Darren.Candow@uregina.ca; Karolina Grzyb, MSc student researcher, email: grzyb20k@uregina.ca

24-hour emergency telephone contact: 306-209-0280

INTRODUCTION
You are being invited to participate in this research study because we are interested in investigating the effects of low-load, high-volume resistance training with different workout frequencies (2 vs. 3 days per week) on muscle mass, muscle strength and endurance.

Before you decide to participate, it is important that you understand what the research involves. This consent form will tell you about the study, why the research is being performed, what will happen to you during the study, and the possible benefits, risks, and discomforts.

If you wish to participate, you will be asked to sign this form. Your participation is completely voluntary, so it is up to you to decide whether or not to participate in this study. If you decide to take part in this study, you are free to withdraw at any time without giving any reasons for your decision and your choice not to participate will not affect your relationship with any of the researchers or institutions conducting the research. Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

Why is this study being done?
The purpose of the study is to determine the effects of performing resistance training 2 or 3 days per week on muscle mass, muscle strength and muscle endurance. A total of 40 participants will be involved in this study.

Who can participate in this study?
You can participate if you are postmenopausal for \( \geq 1 \) year and have not been engaged in supervised resistance training for \( \geq 1 \) year prior to the start of the study. In addition, you cannot have taken medications or ergogenic aids (i.e. creatine) that affect muscle biology
12 weeks prior to the start of the study; have a history of fragility fractures; diseases that are known to affect muscle biology (i.e. corticoids); suffer from severe osteoarthritis; have taken bisphosphonates, hormone replacement therapy, selective estrogen receptor modulators, parathyroid hormone, or calcitonin 12 months prior to the start of the study; or plan to travel during the study period for greater than two weeks duration at a time.

What does the study involve?
If you agree to participate in this study, the following will occur:

You will initially be given a leisure time exercise questionnaire, which indicates the average number of times that strenuous (i.e. heart beats rapidly), moderate (i.e. not exhausting), and mild exercise (i.e. minimal effort) is performed per week. You will also be given a questionnaire (Physical Activity Readiness Questionnaire), which assesses whether you are at a health risk for participating in exercise training. If you indicate a possible health risk, you will be given a clearance form (PARMED-X) to be filled out by your family physician before being permitted to participate in this study.

Prior to the start of the study, you will be randomized (i.e. assigned by chance by a computer) into one of two groups: Group 1 will perform resistance training 2 days per week (3 sets per exercise; Monday and Thursday) for 8 weeks. Group 2 will perform resistance training 3 days per week (2 sets per exercise; Monday, Wednesday and Friday) for 8 weeks.

Resistance exercises (leg extension, triceps extension, leg curl, and biceps curl) will be performed in the Aging Muscle and Bone Health Lab at the University of Regina and will take approximately 40 minutes to complete. Two weeks prior to the start of the study, you will be shown how to use the resistance training equipment with proper form and technique and you will participate in three training sessions to get accustomed to the exercises. A warm-up (e.g., stretching and 5 minutes of stationary cycling exercise) will be part of the training session.

Although 100% compliance to the exercise program is the expectation, it is unlikely that all participants will meet this goal. Our hope is that you will be able to attend approximately 90% of the sessions. You are not expected to attend the training sessions on holidays. You are allowed to do other exercises outside of our program if you choose.

Study measurements:

The following measurements will be performed prior to the intervention (i.e. baseline) and after 8 weeks:

- Your muscle thickness will be determined using an ultrasound machine on the right side of your body for the elbow flexors (biceps), elbow extensors (triceps), knee flexors (hamstrings), and knee extensors (quadriceps). This procedure will take approximately 30 minutes.
• Your muscular strength will be determined for each exercise of the resistance training program (leg extension, triceps extension, leg curl, and biceps curl). This procedure will take approximately 20 minutes.

• Your muscle endurance will be determined for each exercise of the resistance training program (leg extension, triceps extension, leg curl, and biceps curl). This procedure will take approximately 20 minutes.

What are the benefits of participating in this study?
You might increase your muscle thickness, strength, and endurance by participating in this study. These benefits are not guaranteed.

What are the possible risks and discomforts?
The resistance training and strength and endurance testing may result in minor muscle pulls and strains. You will be given proper warm-up prior to exercising and be supervised and this will minimize the risk. Adequate rest will be given between training and testing sessions to ensure that your muscles are recovered by the next training session.

What are alternatives to the study?
You do not have to participate in this study to have your muscle mass and muscle performance assessed. You could have your muscle mass estimated through an appointment with the Dr. Paul Schwann Center, Faculty of Kinesiology and Health Studies at the University of Regina and this can be performed by a number of different techniques (i.e. skin folds, bio-electrical impedance analysis). You do not have to participate in this study to increase muscle performance. You can perform alternative exercises (i.e. free-body exercises such as push-ups and wall squats instead of the resistance exercises in this study).

What happens if I decide to withdraw?
Your participation in this research is voluntary. You may withdraw from this study at any time. You do not have to provide a reason. Your relationships with the researchers or the university will not be affected. If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment will be retained for analysis.

What happens if something goes wrong?
In the case of a medical emergency related to the study, you should seek immediate care and, as soon as possible, notify the principal investigator. Inform the medical staff you are participating in a clinical study. Necessary medical treatment will be made available at no cost to you.

What happens after completion of the study?
We will inform you of the overall study results after we have analyzed all data.
What will the study cost me?
You will not be charged for any research-related procedures. You will not be paid for participating in this study. Reimbursement for study-related expenses (e.g. travel, parking, meals) is not available.

Will my participation be kept confidential?
In Saskatchewan, the Health Information Protection Act (HIPA) defines how the privacy of your personal health information must be maintained so that your privacy will be respected. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed.

Who do I contact if I have questions about the study?
If you have questions concerning the study you can contact Dr. Darren Cadow at 306-585-4906 or 306-209-0280 (24 hour cell).

If you have any questions about your rights as a research subject or concerns about this study, you may contact the Chair of the University of Regina Research Ethics Board at (306) 585-4775 or email research.ethics@uregina.ca. Out of town participants may call collect.

Consent statement

- I have read (or someone has read to me) the information in this consent form.
- I understand the purpose and procedures and the possible risks and benefits of the study.
- I have been informed of the alternatives to the study.
- I was given sufficient time to think about it.
- I had the opportunity to ask questions and have received satisfactory answers.
- I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my future relationships at the university.
- I agree to follow the principal investigator's instructions and will tell the principal investigator at once if I feel I have had any unexpected or unusual symptoms.
- I have been informed there is no guarantee that this study will provide any benefits to me.
- I give permission for the use and disclosure of my de-identified personal health information collected for the research purposes described in this form.
- I understand that by signing this document I do not waive any of my legal rights.
- I will be given a signed and dated copy of this consent form.
- I give permission for my family physician to be informed about my participation in this study if need be:
  - [ ] Yes
  - [ ] No
  - [ ] I do not have a family physician
☐ I agree to participate in this study:

Printed name of participant: ___________________________________________

Signature ___________________________ Date_____________________________

Printed name of person obtaining consent: _________________________________

Signature ___________________________ Date_____________________________
Appendix E: 3-Day Food Record

3-Day Food Intake Record

Please keep a record of everything you EAT and DRINK for 3 days – 2 weekdays and 1 weekend day. Include all meals, snacks, and beverages, and the time of day you are eating or drinking. Please pick days that are typical for your current eating patterns.

Please also record the supplements (i.e. vitamins, minerals, protein powders, sport supplements, shakes, etc.) in detail, including the name or supplement, the amount you take, how often you take it, when you started the supplement, and your reason for taking it.

The purpose of filling out these food records is to help better understand WHAT you are eating, WHEN you are eating, and HOW MUCH you are eating. Please be as honest and accurate as you can, as the information you provide will help you better reflect on your eating habits.

FOOD/BEVERAGE RECORDING INSTRUCTIONS:

1. Record all food and beverages consumed during a 24 hour period. Provide the following:
   - Type of Food Eaten: e.g. chicken noodle soup
   - Brand Name: e.g. Campbell’s, Lipton, Weight Watchers
   - Food or Beverage Characteristics:
     - Colour: e.g. green vs. yellow beans; white vs. whole wheat bread
     - Fat Content: % fat (e.g. skim, 1%, 2% or homogenized milk), leanness of meat (e.g. extra lean ground beef), fat claims (e.g. “light”, “low-fat”), was skin removed from poultry?
     - Freshness: e.g. fresh, frozen, canned, or dried?
     - Other Details: e.g. 25% reduced sodium, “diet” products, etc.
   - Time of Day you ate or drank

2. Please MEASURE and describe the amount of food eaten as best as possible. Diet records are only reliable with accurate measurements.
   - Always estimate portion sizes of food after cooking.
   - Use household measures to specify serving sizes.
     - 1 cup = 250mL = 8 fluid oz
     - 1 tablespoon (Tbsp) = 15mL
     - 1 ounce (oz) = 30g
     - 1 teaspoon (tsp) = 5mL
   - Measuring cups (examples): Put cooked pasta or rice into a measuring cup to record the correct amount before placing it on your plate. Measure your cereal out before pouring into a bowl, and don’t forget to measure your milk as well!
   - Teaspoons/tablespoons (examples): Measure out butter, margarine, mayonnaise, salad dressings, ketchup, mustard, ground flaxseed, sugar, milk/cream, and other condiments, seasonings, and toppings before adding to your food or beverages.
   - Count the number of food items if practical: e.g.: 20 grapes, 15 baby carrots, 8 medium-sized shrimp, etc.
   - Fluids: Record amounts in fluid ounces (oz), milliliters (mL), or in cups. Remember 1 cup = 250mL = 8 fl. oz
• **Use food labels to estimate quantities**: Food labels can help you estimate the quantity of food eaten based on weight or volume. For example, write down a 355mL can of pop, 1/2 of a 60g can of tuna, a 37g granola bar, etc.

• **Use your hand to estimate portion sizes quickly**:
  - Whole Thumb = 1 Tablespoon
  - Tip of your Thumb = 1 Teaspoon
  - Palm of Your Hand = 3 oz of meat
  - Fist = 1 cup (250mL)

![Hand Portion Size Illustrations](image)

3. Record if anything was ADDED when preparing the food, such as oil (list specific kind), sauce, butter, margarine, or other condiments or seasonings.

4. For COMBINATION DISHES such as lasagna, casseroles, chili, soups, or stews include a description of the main ingredients. E.g. Lasagna: lean ground beef (1/4 cup per piece), mozzarella cheese (1 oz per piece), cottage cheese (1 oz per piece), 1/2 cup tomato sauce, 2 noodles, 1/4 cup spinach.

5. Include SNACK FOODS eaten. Don’t forget to include candy, chips, cookies, popcorn, ice cream, and beverages such as soft drinks, juice, coffee, or tea.

6. Use the “notes” column to record any additional PRODUCT INFORMATION if available (e.g. 6 crackers – 80 calories, 2.5g fat, 1g fibre, 210mg sodium).

7. Don’t forget to write down any ALCOHOLIC BEVERAGES consumed and how much you drank. This includes all wine, beer, and liquor.

**When in doubt... include more details!**
# Sample 1-Day Food Record

Below is an *example* of how to keep accurate records. Include a detailed description and amounts for each item. Remember to record water, notes on product details, and the times of day you ate.

<table>
<thead>
<tr>
<th>TIME</th>
<th>AMOUNT</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>8am</td>
<td>Large</td>
<td>Coffee</td>
<td>Tim Horton’s</td>
</tr>
<tr>
<td></td>
<td>1 Tbsp</td>
<td>Cream</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 tsp</td>
<td>Sugar</td>
<td></td>
</tr>
<tr>
<td>11am</td>
<td>2 slices</td>
<td>Bread, whole wheat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 oz.</td>
<td>Turkey, lunchmeat</td>
<td>Oven-roasted from deli</td>
</tr>
<tr>
<td></td>
<td>1 Tbsp</td>
<td>Mayo (Hellman’s)</td>
<td>“light”, 4.5g fat per Tbsp</td>
</tr>
<tr>
<td></td>
<td>1 leaf</td>
<td>Romaine Lettuce</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 tsp</td>
<td>Becel Margarine</td>
<td>Salt-free</td>
</tr>
<tr>
<td>11:30pm</td>
<td>2 cups</td>
<td>Water, tap</td>
<td></td>
</tr>
<tr>
<td>2pm</td>
<td>1 medium</td>
<td>Apply (granny smith)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Whole wheat crackers (Premium Plus)</td>
<td>80 cals, 2.5g fat, 210mg sodium (from label)</td>
</tr>
<tr>
<td></td>
<td>1&quot;x1&quot; cube</td>
<td>Marble cheese, 35%MF</td>
<td>Crackerbarrel</td>
</tr>
<tr>
<td>4pm</td>
<td>1 large</td>
<td>Muffin, blueberry</td>
<td>Store-bought</td>
</tr>
<tr>
<td></td>
<td>500mL</td>
<td>Water, tap</td>
<td></td>
</tr>
<tr>
<td>7:30pm</td>
<td>1 patty</td>
<td>Hamburger, BBQ'd (regular ground beef)</td>
<td>M&amp;M Meat Shops (~4oz.)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Hamburger Bun, white bread</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 leaf</td>
<td>Iceburg Lettuce</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 slices</td>
<td>Tomato, raw</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 slice</td>
<td>Red Onion, raw</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Tbsp</td>
<td>Ketchup, Heinz</td>
<td>45 calories per tsp</td>
</tr>
<tr>
<td></td>
<td>1 bottle</td>
<td>Beer (12 oz, 5% alcohol)</td>
<td>Moosehead</td>
</tr>
<tr>
<td>10pm</td>
<td>2 cups</td>
<td>Chocolate ice cream</td>
<td>Chapman’s</td>
</tr>
</tbody>
</table>

Was this a typical day? If not, why? *Usually drink more water (forgot water bottle at home)*
Did you take all of your usual medications and supplements as prescribed?  ✔ Yes  □ No
DAILY FOOD RECORD

Subject Code: ___________________ Date: _______________ □ Weekday or □ Weekend

Please list all food/beverages/water/medications/supplements. Estimate all food/drink amounts accurately.

<table>
<thead>
<tr>
<th>TIME</th>
<th>AMOUNT</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was this a typical day? If not, why? ________________________

Did you take all of your usual medications and supplements as prescribed? □ Yes □ No
# Daily Food Record

Subject Code: ___________________ Date: ___________________  □ Weekday or □ Weekend

Please list all food/beverages/water/medications/supplements. Estimate all food/drink amounts accurately.

<table>
<thead>
<tr>
<th>TIME</th>
<th>AMOUNT</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was this a typical day? If not, why? ___________________

Did you take all of your usual medications and supplements as prescribed? □ Yes □ No
DAILY FOOD RECORD

Subject Code: __________________________ Date: ____________________ □ Weekday or □ Weekend

Please list all food/beverages/water/medications/supplements. Estimate all food/drink amounts accurately.

<table>
<thead>
<tr>
<th>TIME</th>
<th>AMOUNT</th>
<th>DESCRIPTION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Was this a typical day? If not, why? ____________________________________________________________

Did you take all of your usual medications and supplements as prescribed? □ Yes □ No
Appendix F: Study Adverse Event Form

Study Adverse Event Form

EFFECTS OF LOW-LOAD, HIGH-VOLUME RESISTANCE TRAINING WITH DIFFERENT WORKOUT FREQUENCY ON MUSCLE MASS AND MUSCLE PERFORMANCE IN AGING FEMALES

SUBJECT ID #: ________  SUBJECt INITIALS: _______

Describe the adverse event:

________________________________________________________________________
________________________________________________________________________

Is this event a new event? ______

Is this event a change/resolution of an ongoing event? ______

Onset of Adverse Event (date/time): ________________________________

Resolution of Adverse Event (date/time): ______________________________

Is this event Serious? ______

Yes ☐ No ☐

(Results in death, is life threatening, requires hospitalization, results in persistent or significant disability.)

Is this event intermittent? ______

Yes ☐ No ☐

1. Rate Intensity (severity):

   Mild   Moderate   Severe   Life threatening

Different levels of intensity are defined as follows:
- Mild: Awareness of sign or symptom, but easily tolerated
- Moderate: Discomfort enough to cause interference with normal daily activities
- Severe: Inability to perform normal daily activities
- Life Threatening: Immediate risk of death from the reaction as it occurred

2. Is the adverse event is still present: ______

Yes ☐ No ☐
3. Frequency: ________________________________

4. Relationship to experimental procedure (food, exercise or other procedure): Please circle one:
   Not related  Unlikely  Possible  Probable  Definite

Relationship to the supplement, exercise training, or other procedure:
- Not related: An adverse event which is not related to the study
- Unlikely: An adverse event for which an alternative explanation is more likely
- Possible: An adverse event which might be due to the study. An alternative explanation is inconclusive. The relationship in time is reasonable; therefore, the causal relationship cannot be excluded.
- Probable: An adverse event which might be due to the study. The relationship in time is suggestive (i.e. confirmed by dechallenge of the treatment). An alternate explanation is less likely.
- Definite: An adverse event which cannot be reasonably explained by alternative explanation. The relationship in time is very suggestive (e.g. it is confirmed by dechallenge and rechallenge).

Was treatment administered?    Yes ☐ No ☐

Details:

________________________________________

* This is a SERIOUS ADVERSE EVENT - will be reported to the Research Ethics Board and your family physician (if permission is granted)

Signature: ___________________________    Date: ___________________________

Signature of PI: ______________________    Date: ___________________________