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Movement Velocity during High- and Low-Velocity Resistance Exercise Protocols in Older Adults

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Abstract

The primary aim of the present study was to determine the actual movement velocity of highvelocity, low-load (HVLL) and low-velocity, high-load (LVHL) resistance exercise in a group of older adults. The secondary aim was to examine the differences in velocities produced between male and females. In a crossover study design, four males (age: 67±3 years) and five females (age: 68±2 years) completed three sets of leg press, calf raise, leg curl, leg extension, chest press, seated row, bicep curl and tricep extension on six separate occasions (three HVLL and three LVHL sessions). The command "as fast as possible" was given for the concentric phase of HVLL, and two seconds using a 60-bpm metronome controlled the concentric phase during LVHL. Participants had three days of recovery between each session, and a 7-day period before crossing over to the other protocol. Movement velocity was measured during the concentric and eccentric phases of resistance exercise using two-dimensional video analysis. The concentric phases for all exercises were significantly faster ($P<0.001$) during HVLL compared to LVHL. Furthermore, males produced significantly greater velocities than females during the concentric phase of the chest press, seated row, bicep curl, and tricep extension for both HVLL and LVHL ($P<0.05$). These protocols provide a simple solution for exercise professionals to ensure that older adults are training at desired velocities when carrying out resistance exercise, without the need for equipment that measures velocity.

Keywords: Ageing; Physical activity; Health education; Older adults

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Introduction

Sarcopenia is a common manifestation of aging, and is defined as a loss of skeletal muscle mass and function (McLean and Kiel 2015). Furthermore, losses in muscle strength can be approximately 60% greater than predictions from the loss of muscle cross sectional area in older adults (Hughes et al. 2001). This loss of muscle strength is known as dynapenia, and predisposes older adults to severe clinical consequences which include: reduced functional performance, disability, and mortality (Clark and Manini 2012). However, there is strong evidence that resistance exercise is effective in counteracting sarcopenia (Yu 2015), and attenuating age related declines in muscle strength (Liu and Latham 2009). Many studies have attempted to identify optimal resistance exercise prescription for older adults through manipulation of movement velocity, load, and number of repetitions etc. (Tschopp et al. 2011). Thus far, it appears that high-velocity, low-load (HVLL) and low-velocity, high-load (LVHL) resistance exercise (commonly termed power and strength training respectively) may elicit similar increases in muscle strength (Henwood and Taaffe 2006), muscle cross sectional area (Claflin et al. 2011) and improvements in functional performance (Tschopp et al. 2011). Although, more recently, a systematic review by Byrne et al. (2016) revealed that 10 out of 13 studies reported that HVLL was superior at delivering improvements in muscle power and/or functional performance compared with LVHL.

Movement velocity is a key variable of resistance exercise programming (Kraemer and Ratamess 2004), and is largely influenced by the loading used. However, it has been suggested that the actual movement velocity of resistance exercise may not be the most important factor. Behm and Sale (1993) concluded that the intention to move as fast as possible is more important for high velocity specific adaptations of the neuromuscular system, than the actual movement velocity of training. However, McBride et al. (2002) observed performing squat jumps with the intention of maximal movement velocity at 30% 1-RM improved peak velocity, peak power and jump height, where training at 80% 1-RM did not. These findings suggest that the actual movement velocity that is achieved during resistance exercise could play a significant role in velocity specific adaptations (Kawamori and Newton 2006).

Attaining velocity specific adaptations using low external loads may be particularly appealing to sedentary older adults, who may be at greater risk of injury when training at highmovement velocity with heavy loads. Furthermore, training with high-movement velocity against a low external resistance has been shown to shift the development of peak power to a lower external resistance (Sayers and Gibson 2014). This shift in peak power may be of more benefit to activities of daily living (ADL) for older adults, than possessing high levels of maximum strength e.g. being able to move a lower limb quickly to re-stabilise and prevent a fall (Sayers and Gibson 2014). Furthermore, training at a high-movement velocity with 40% of 1-RM for 12-14 repetitions has been shown to elicit similar improvements in strength and power, as training at a low movement velocity for 8-10 repetitions with 80% 1-RM (Sayers and Gibson 2014). Additionally, Richardson et al. (2017) observed that ratings of perceived exertion were significantly greater in a group of older adults when training at 80% 1-RM at a low-movement velocity compared to 40% 1-RM at a high-movement velocity, even when total volume-load was matched. Therefore, if HVLL elicits comparable improvements in strength and functional performance to LVHL, while being perceived as less exerting, HVLL may be a preferential form of resistance exercise for the older population. However, although high-movement velocity exercise is emerging as potentially more beneficial for an older population, it is important to acknowledge that sufficient quantities of maximal strength underpins the development of power (Baker 2001), and is useful for some ADL's such as carrying heavy shopping bags, meaning that LVHL is an important consideration when prescribing resistance exercise to older adults.

The instruction "as fast as possible" has commonly been used to control the movement velocity of the concentric phase of HVLL in older adults (Beltran Valls et al. 2014; Glenn et al. 2015; Sayers and Gibson 2010), whereas performing the concentric phase over two seconds has frequently been used during LVHL (Sayers and Gibson 2010; 2014; Van Roie et al. 2013). Sayers et al. (2016) observed that self-selected maximal lower limb velocity varied considerably between individuals, with those training at the highest movement velocities maximising improvements in functional performance. This highlights the importance of understanding the exact velocity that exercise occurs at. However, many studies have failed to measure and report the velocity that is produced using these commands, which could result in large inter-individual differences, depending on the ability and engagement of the participants (Rajan and Porter 2015). Therefore, it would be useful to measure the velocities that common protocols are producing.

There are several techniques used to measure exercise velocity such as: isokinetic dynamometers (Signorile et al. 2002), linear position transducers (Conceicao et al. 2016), and two-dimensional video analysis (Moss et al. 2003). Isokinetic dynamometers have been shown to be both valid and reliable at controlling velocity of exercise (Drouin et al. 2004). However, isokinetic dynamometers only permit constant motion of the exercising limb at a pre-set velocity (Barnes 1980), not allowing self-selected movement velocity. Linear position transducers are most commonly used during vertical plane movements such as: squats, and deadlifts. They are cost effective and portable, but their reliability and validity vary depending on the exercises, exercise equipment and the loading used (Harris et al. 2010). Two-dimensional video analysis is a common tool used to evaluate the kinematics of dynamic movements (Maykut et al. 2015), and has been used by others as the established method to validate other velocity measuring equipment (Moss et al. 2003). Furthermore, the reliability and validity of two-dimensional video analysis for measuring velocity has been shown to be high when tested against an isokinetic dynamometer (Selfe 1998), and a linear position transducer (Sanudo et al. 2016).

Given that the velocity resistance exercise is performed at is an important variable of resistance exercise, the aim of the present study was to measure the velocity that a group of older adults produce during eight different exercises, when following two commonly used methods of manipulating the movement velocity of resistance exercise. Furthermore, as there are morphological (Miller et al. 1993) and neuromuscular (Quatman et al. 2006) differences between males and females, a secondary aim of this study was to examine any sex differences in movement velocities produced during HVLL and LVHL.

Methods

Design

The present study used a randomised, crossover design. The two protocols (Table 3) were designed to be simple and pragmatic, to provide a direct comparison of the velocities produced during volume-load matched HVLL and LVHL. Each participant was required to attend a familiarisation session, where one repetition maximum (1-RM) for each exercise was obtained. Participants were then randomised to complete volume-load matched HVLL and LVHL (identical total load lifted). Three days of rest were given between each of the three sessions, for each velocity, and a 7-day period was given before crossing over to the other protocol. All sessions were performed as close to the same time of day to minimise fluctuations in strength due to circadian variation.

Participants

Following institutional ethics approval, nine older adults (four males and five females; Table 1) were recruited by word of mouth for participation. All participants were made aware of the exercise protocols and associated risks, before providing written informed consent. All procedures were undertaken in accordance with the Declaration of Helsinki. Each participant was required to meet strict inclusion criteria, namely the absence of: cognitive impairment (Mini-Mental State Examination score<23) (Folstein et al. 1975), acute or terminal illness, myocardial infarction, upper or lower extremity fracture in the previous six months, symptomatic coronary artery disease, congestive heart failure, uncontrolled hypertension (>150/90 mmHg), neuromuscular disease and not undergoing hormone replacement therapy (Reid et al. 2015). Finally, participants were excluded if they had participated in any purposeful strength or power training in the previous six months (de Vos et al. 2005). Fifteen participants applied to take part, three were excluded because they were already involved in resistance training programmes, and a further two were excluded with high blood pressure. Therefore, ten participants completed all testing, although all data for one participant was excluded, as some video files were corrupt and unable to be analysed.

Table 1. Participant characteristics

	Males (*n* = 4)	Females (*n* = 5)
Age (years)	67 ± 3	68 ± 2
Age Range (years)	63 - 71	67 – 71
Height (cm)	175.6 ± 5.6	162.6 ± 5.8
Body Mass (kg)	91.5 ± 14.8	70.9 ± 10.7
BMI ($kg \cdot m^{-2}$)	30 ± 4	27 ± 3
Medications taken	1 ± 1	1 ± 1
Mini mental state examination (0-30)	29 ± 1	29 ± 1

Values are means ± SD; *n* = number of participants

24 *Procedures*

Prior to familiarisation and all sessions, participants were asked to refrain from all other fatiguing exercise for 24 hours. Firstly, height (cm) and mass (kg) were recorded (Seca Instruments, Hamburg, Germany). Participants then completed a warm-up protocol which consisted of five minutes self-selected paced cycling (Marsh et al. 2009) followed by four dynamic stretches (arm circles, arm hugs, partial squats with arm swings, and heel-to-toe walk). This warm-up targeted the main muscles used in the sessions, and was repeated before all subsequent sessions. Following the warm-up, the preferred individual anthropometric setup for each of the eight exercises (chest press, leg press, calf raise, leg extension, leg curl, seated row, bicep curl and tricep extension), performed on Cybex exercise equipment (Cybex, Medway, MA, USA) was obtained and recorded for future sessions. The correct technique for all exercises, as described by Cybex, were demonstrated to participants and practiced.

Finally, participants were taken through a protocol to predict 1-RM for all exercises. For each exercise, participants performed repetitions with a load they felt was challenging but manageable. The resistance was progressively increased, with regular two-minute rest intervals, until momentary failure occurred within 10 repetitions where possible. Ten repetitions was selected, as the prediction equation used (Brzycki 1993) becomes less accurate when more than ten repetitions are performed. It must be noted (Table 2), that some participants reached 12 repetitions on some exercises, likely resulting in slightly overestimated 1-RM's. Load lifted and number of repetitions completed were used to provide an estimation of 1-RM for each exercise (Table 2), using the prediction equation: load lifted ÷ (1.0278- (0.0278 × number of repetitions performed) (Brzycki 1993). Following a minimum three days of recovery after the familiarisation session, participants attended the sports centre for their first session.

Table 2. Predicted 1-RM data with the median and range of repetitions used to predict 1-RM (Brzycki 1993)

	Leg Press	Seated Row	Chest Press	Leg Extension	Leg Curl	Calf Raise	Tricep Extension	Bicep Curl
Male 1-RM (kg)	122 ± 26	64 ± 8	57 ± 3	62 ± 17	55 ± 6	121 ± 30	38 ± 6	32 ± 8
Median	10	10	10	10	9	10	10	7
Range	10-12	10-11	8-10	10-11	7-10	10-10	8-10	2-10

Female 1-RM (kg)	79 ± 13	34 ± 5	21 ± 3	29 ± 7	26 ± 4	89 ± 20	16 ± 7	13 ± 6
Median	10	10	8	10	10	10	10	10
Range	8-12	9-12	4-10	7-12	5-10	9-10	6-11	6-12

Values are means ± SD; 1-RM = One repetition maximum

Exercise Protocols

The exercise protocols used in the present study (Table 3) were based on others that have previously demonstrated a positive impact on functional performance in older adults (Kalapotharakos et al. 2005; Reid et al. 2015), with the number of sets and repetitions being similar to others that have attempted to match volume-loads (Hortobagyi et al. 2001; Sayers and Gibson 2014). The concentric phase in the HVLL sessions were performed "as fast as possible" without causing dangerous unloading of the weight stack, and the eccentric phase was performed over three seconds (Henwood et al. 2008). During the LVHL sessions the concentric phase was performed over two seconds, and the eccentric phase over three seconds (Van Roie et al. 2013). A 60-bpm metronome (iOS app, Pro metronome, EUMlab, Hangzhou, China) provided the cadence for exercise. Different sounds were used to denote each second of both the concentric and eccentric phases, except during the concentric phase of the HVLL protocol. During the sessions, feedback was provided to participants, emphasising the need to produce the fastest velocities they could during the concentric phase of HVLL, and to follow the metronome closely during LVHL. Figure 1 displays a schematic diagram of the study.

Table 3. Exercise protocols

HVLL	**LVHL**
40% 1-RM	80% 1-RM
3 sets	3 sets
14 repetitions	7 repetitions
Concentric phase: "as fast as possible"	Concentric phase: 2 seconds
Eccentric phase: 3 seconds	Eccentric phase: 3 seconds
2 minutes recovery between sets	2 minutes recovery between sets
3 minutes between exercises	3 minutes between exercises

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23 HVLL = High-Velocity, Low-Load; LVHL = Low-Velocity, High-Load; 1-RM = One 24 repetition maximum

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Measurement of movement velocity

A high definition camera (Sony HDR-HC9E, Sony Corporation, Tokyo, Japan) was used to record every set of each exercise at 50 fps. The camera was mounted on a stable tripod, and a 3,4,5 triangle used to ensure that the camera was placed perpendicular to the plane of motion for each exercise. Flat disk reflective markers were attached to the moving parts of each piece of exercise equipment on a black background, these markers remained attached for the duration of the study to ensure identical placement for each session. An external, direct light source was placed directly above and behind the camera to illuminate the markers for filming. A 50 cm x 50 cm calibration board was placed directly in the plane of motion for each video as a known distance reference point for two-dimensional digitisation in Quintic software (9.03 version 17, Quintic Consultancy Ltd, Coventry, UK). All videos were calibrated for automatic digitisation by the same experimenter. Following digitisation, the data was smoothed using the optimal Butterworth filter values recommended by Quintic software to smooth any data anomalies that may have occurred during the digitisation process. Using the data outputs, each repetition was manually analysed by the same experimenter to calculate velocity in meters per second ($m \cdot s^{-1}$) for both the concentric, and eccentric phases of each exercise. The total number of repetitions analysed was the sum of sets, repetitions, exercises, number of sessions and participants. HVLL (3 sets x 14 repetitions x 8 exercises x 3 sessions =1,008 repetitions) for each of the 9 participants (*n* = 9,072 total repetitions; male *n* = 4,032; female *n* = 5,040), and for LVHL (3 sets x 7 repetitions x 8 exercises x 3 sessions = 504 repetitions) for each of the 9 participants (*n* = 4,536 total repetitions; male *n* = 2,016; female *n* = 2,520).

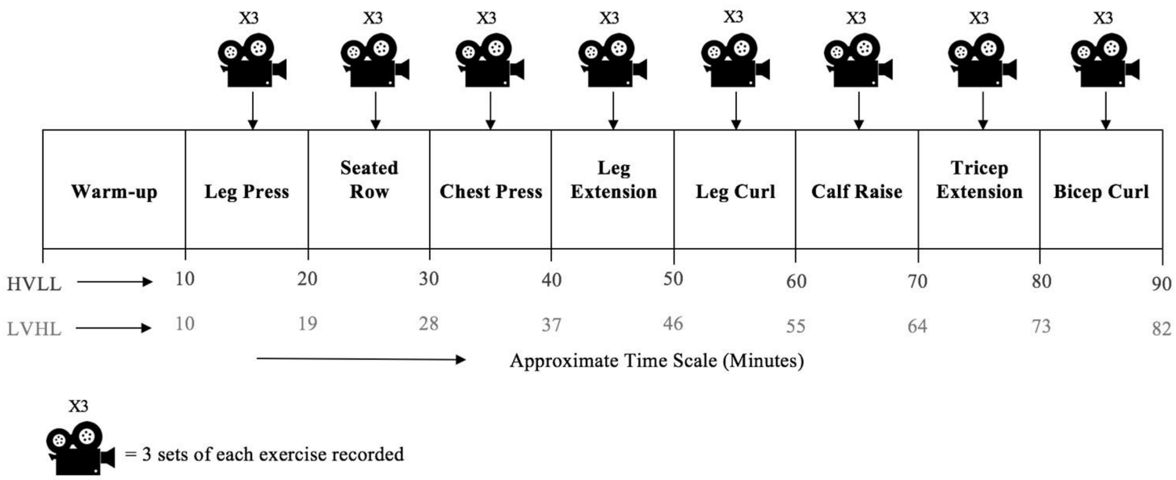


Figure 1. A schematic diagram of the experimental protocols

Statistical Analysis

All data was analysed using IBM SPSS Statistics for Windows, Version 22.0 (Armonk, NY: IBM Corp), descriptive statistics are presented as mean ± SD and 95% confidence intervals (95% CI). Factorial analysis of variance (ANOVA) with repeated measures were used to compare the dependent variable, exercise velocity with the independent variables; exercise protocol and sex. When Mauchley's test of sphericity was significant and the GreenhouseGeisser level of violation was >0.75, degrees of freedom were corrected using Huynh-Feldt adjustment. When violation was <0.75, Greenhouse-Geisser correction was used. Where any statistical differences were found, pairwise comparisons with Bonferroni correction were used to show exactly where they lay. Significance was determined by a *P* value of <0.05 and reported as exact values unless below *P*=0.001. Effect size was used to quantify the meaningfulness of any differences found between conditions, and was calculated using □$_P^2$ and defined as: trivial (<0.1), small (0.1-0.29), moderate (0.3-0.49) or large (0.5>) (Hopkins et al. 2009). An *a priori* power calculation using G*Power software (version 3.1.9.2, Franz Faul, Universitat Kiel, Dusseldorf, Germany) for repeated measures ANOVA revealed, detection of a moderate effect size (0.4) with α as 0.05 and a 1–β error probability of 0.8, required a sample size of eight.

Results

Bicep Curl

The concentric phase was 42% faster ($F_{(1,7)}$=174.480; *P*<0.001; 95%CI: 0.52,0.74; □$_P^2$ =0.96; Figure 2) and the eccentric phase, 17% faster ($F_{(1,7)}$=36.674; *P*=0.001; 95%CI: 0.08,0.17; □$_P^2$ =0.84; Figure 4) during HVLL compared to LVHL. There was a large significant interaction between sex and velocity for the concentric phase ($F_{(1,7)}$=19.830; *P*=0.003; □$_P^2$ =0.73;Figure 3), with males producing greater velocities than females during both HVLL and LVHL. Lastly, there were no significant differences in velocity during the eccentric phase between males and females (*P*=0.456; 95%CI: -0.13,0.25; Figure 5).

Calf Raise

The concentric phase was 68% faster ($F_{(1,7)}$=49.163; P<0.001; 95%CI: 0.16,0.33; η_{p}^{2} =0.88; Figure 2) and the eccentric phase, 31% faster ($F_{(1,7)}$=24.032; P=0.002; 95%CI: 0.02,0.05; η_{p}^{2} =0.77; Figure 4) during HVLL compared to LVHL. There were no significant differences in velocities produced in the concentric phase (P=0.973; 95%CI: -0.12,0.12; Figure 3) or eccentric phase (P=0.551; 95%CI: -0.02,0.04; Figure 5) between males and females.

Chest Press

The concentric phase was 48% faster ($F_{(1,7)}$=91.291; P<0.001; 95%CI: 0.33,0.54; η_{p}^{2} =0.93; Figure 2) and the eccentric phase, 12% faster ($F_{(1,7)}$=31.128; P=0.001; 95%CI: 0.02,0.05; η_{p}^{2} =0.82; Figure 4) during HVLL compared to LVHL. There was a large significant interaction between sex and velocity for the concentric phase ($F_{(1,7)}$=11.670; P=0.011; η_{p}^{2} =0.63; Figure 3). The interaction plot revealed that males produced greater velocities than females during the concentric phase during both HVLL and LVHL. However, there were no significant differences in velocity of the eccentric phase between males and females (P=0.215; 95%CI: -0.03,0.10; Figure 5).

Leg curl

The concentric phase was 48% faster ($F_{(1,7)}$=89.084; P<0.001; 95%CI: 0.39,0.65; η_{p}^{2} =0.93; Figure 2) and the eccentric phase, 30% faster ($F_{(1,7)}$=59.878; P<0.001; 95%CI: 0.11,0.21; η_{p}^{2} =0.90; Figure 4) during HVLL compared to LVHL. There were no significant differences in velocities produced in the concentric phase (P=0.100; 95%CI: -0.04,0.38; Figure 3) or eccentric phase (P=0.784; 95%CI: -0.14,0.11; Figure 5) between males and females.

Leg extension

The concentric phase was 54% faster ($F_{(1,7)}$=105.224; P<0.001; 95%CI: 0.53,0.85; η_{p}^{2} =0.94; Figure 2) and the eccentric phase, 22% faster ($F_{(1,7)}$=95.342; P<0.001; 95%CI: 0.06,0.10; η_{p}^{2}

=0.93; Figure 4) during HVLL compared to LVHL. There were no significant differences in velocities produced in the concentric phase (P=0.157; 95%CI: -0.07,0.35; Figure 3) or the eccentric phase P=0.312; 95%CI: -0.03,0.07; Figure 5) between males and females.

Leg press

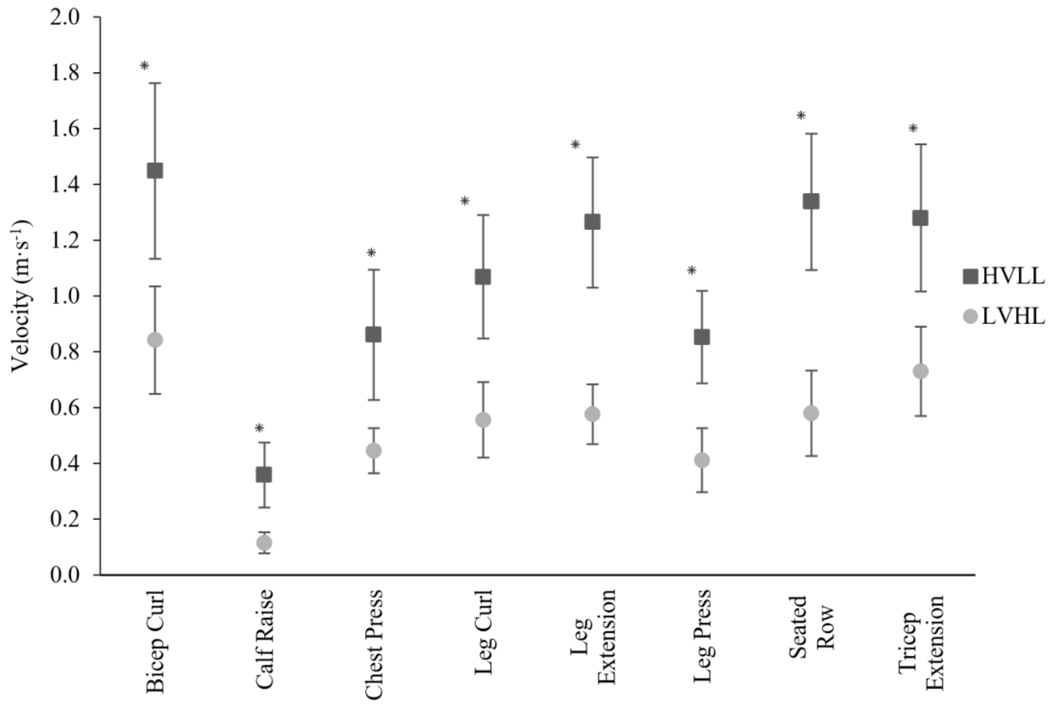
The concentric phase was 52% faster ($F_{(1,7)}$=81.002; P<0.001; 95%CI: 0.33,0.56; η_P^2 =0.92; Figure 2) and the eccentric phase, 36% faster ($F_{(1,7)}$=151.013; P<0.001; 95%CI: 0.09,0.14; η_P^2 =0.96; Figure 4) during HVLL compared to LVHL. There were no significant differences in velocities produced in the concentric phase (P=0.497; 95%CI: -0.14,0.26; Figure 3) or the eccentric phase (P=0.632; 95%CI: -0.06,0.09; Figure 5) between males and females.

Seated Row

The concentric phase was 57% faster ($F_{(1,7)}$=103.407; P<0.001; 95%CI: 0.58,0.94; η_P^2 =0.94; Figure 2) and the eccentric phase 28% faster ($F_{(1,7)}$=211.889; P<0.001; 95%CI: 0.11,0.15; η_P^2 =0.97) during HVLL compared to LVHL. Males produced significantly faster concentric velocities compared with females for both HVLL and LVHL (P=0.014; 95%CI: 0.06,0.40; Figure 3), but there were no sex differences for the eccentric phase (P=0.162; 95%CI: -0.03,0.15; Figure 5).

Tricep Extension

The concentric phase was 43% faster ($F_{(1,7)}$=123.192; P<0.001; 95%CI: 0.45,0.69; η_P^2 =0.95; Figure 2) and the eccentric phase, 16% faster ($F_{(1,7)}$=28.883; P=0.001; 95%CI: 0.05,0.13; η_P^2 =0.81) during HVLL compared to LVHL. There was a large significant interaction between sex and velocity for the concentric phase ($F_{(1,7)}$=8.043; P=0.025; η_P^2 =0.54; Figure 3), where males produced greater velocities than females during the concentric phase of the tricep extension, during both HVLL and LVHL. However, there were no significant sex differences during the eccentric phase (P=0.393; 95%CI: -0.09,0.19; Figure 5).



Values are means ± SD; HVLL = High-Velocity, Low-Load; LVHL = Low-Velocity, High-

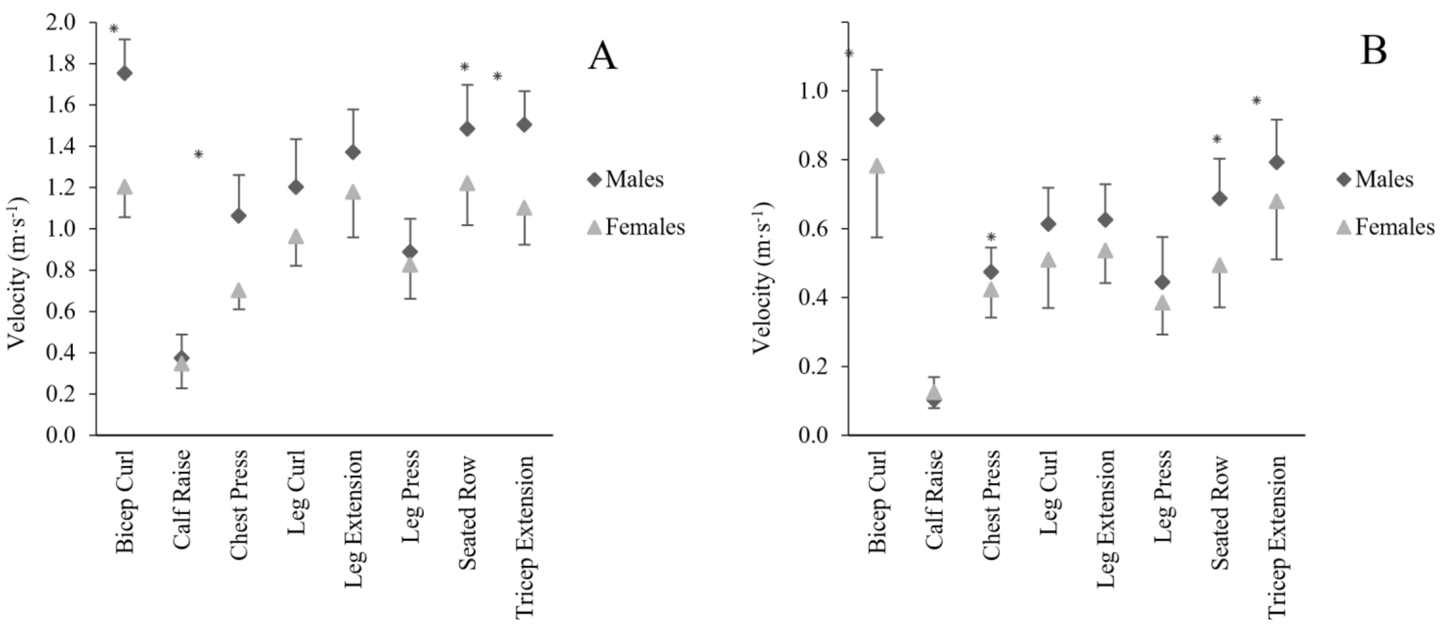


Figure 2. Movement velocity of the concentric phase for all exercises

Load

*= HVLL significantly faster than LVHL

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Figure 3. Movement velocity during the concentric phase for males and females during (A) HVLL and (B) LVHL

Values are means ± SD; HVLL = High-Velocity, Low-Load; LVHL = Low-Velocity, HighLoad

*= Males produced significantly greater velocity than females

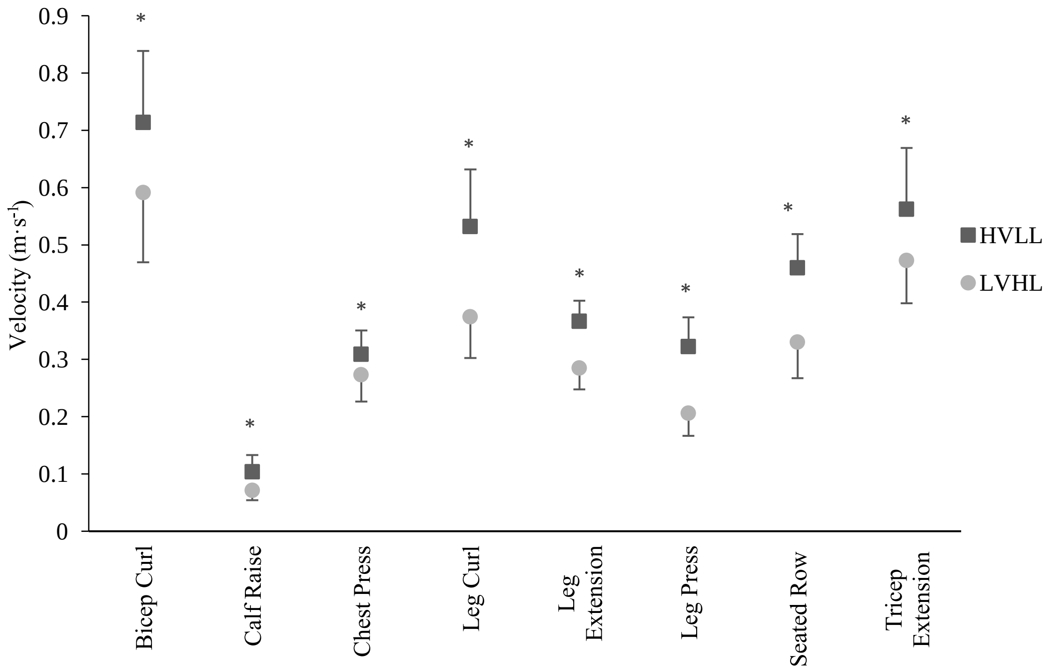

Figure 4. Movement velocity for the eccentric phase for all exercises
Values are means ± SD; HVLL = High-Velocity, Low-Load; LVHL = Low-Velocity, High-Load
*= HVLL significantly faster than LVHL

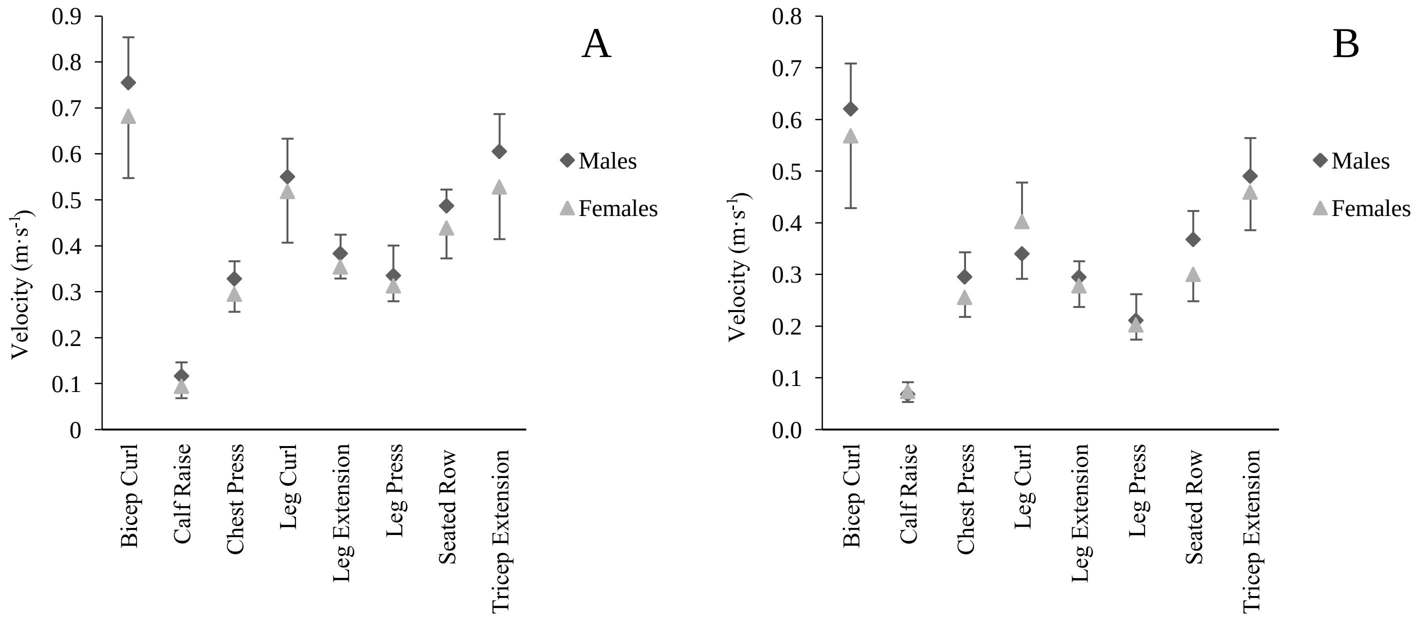

Figure 5. Movement velocity during the eccentric phase for males and females during (A) HVLL and (B) LVHL
Values are means ± SD; HVLL = High-Velocity, Low-Load; LVHL = Low-Velocity, High Load

Discussion

The primary aim of the present study, was to measure the differences in movement velocity produced during eight different exercises, in a sample of older adults, when performing two commonly used protocols to manipulate the movement velocity of resistance exercise. The current study assessed movement velocity when the concentric phase was performed “as fast as possible” or over two seconds, and the eccentric phases for both protocols were performed over three seconds. A secondary aim of this study was to examine the differences in velocities produced between males and females. The findings suggest that these two simple protocols can be used by exercise professionals as a simple way to manipulate exercise velocity, to produce high- or low-velocity resistance exercise. Additionally, these findings may help to dispel some criticism of research that has used similar metronome based protocols and not reported movement velocity.

It is important to note that the present study only established whether older adults can execute resistance exercises using different movement velocities, with no assessment of force or power output. Literature is supportive of the notion that high-velocity training, resulting in higher peak power output, is beneficial for functional performance and ADL’s in older adults (Sayers and Gibson 2014). Prior research has reported that high-velocity resistance exercise shifts the resistance at which peak power is produced, to a lower percentage of 1-RM (Sayers and Gibson 2014). However, many studies have made no attempt to ascertain if movement velocity differed when participants were asked to execute resistance exercises at different velocities (Rajan and Porter 2015). Instead, such studies appear to assume, that when requested to move at different velocities, the execution of these movements are possible, consistent, and that HVLL and LVHL are demonstrably different in older adults. With advancing age, there is a loss in the adaptability of movement (Vaillancourt and Newell 2003), meaning optimal movement variability may not be possible. With this loss in adaptability of movement, movement tasks, such as the resistance exercises performed in the current study become more rigid, homogenous and less variable in nature (Harbourne and Stergiou 2009). The present study addresses this issue and as such provides original information which can be used to better understand the movement velocity produced during commonly used methods of manipulating resistance exercise velocity.

In the present study, movement during the eccentric phase was also significantly faster for HVLL compared to LVHL for all exercises. Both protocols used a three second eccentric phase and so, it is surprising that velocities produced were significantly different. One simple explanation is that the maximal velocity produced in concentric phase of HVLL, meant participants exceeded the minimum range of motion for each exercise, meaning that greater movement velocity was required over the eccentric phase, to return to the start position. As placing range of motion constraints on resistive exercise equipment may inhibit the ability to produce maximal movement velocity (Brown et al. 1995), and placing movement restrictions on the exercise equipment in this study, could have presented an injury risk when reaching the end range, we elected not to control range of motion. The fact that range of motion differed between protocols, and eccentric velocity was faster during HVLL was not considered to be a key variable, as the protocols demonstrated a difference in concentric movement velocity while being safe to use for older adults.

It has been established that males are generally stronger than females because of morphological differences such as: larger body size, greater muscle mass (Heyward et al. 1986), greater muscle fiber size (Miller et al. 1993), and a higher ratio of type two to type one muscle fibres (Schiaffino and Reggiani 2011). Males have also been shown to have greater neuromuscular performance than females, from the age of puberty (Quatman et al. 2006). In the present study, males produced significantly greater velocities on the four upper body exercises compared to females, despite lifting heavier loads. Such a finding agrees with research reported by Frontera et al. (1991), who observed that 70-year-old females had 60% and 59% the strength of 70-year-old males in the lower extremities, when examined at low- and high-velocities respectively. Whereas, in the upper extremities females had 50% and 46% the strength of males, which demonstrates sex differences in upper and lower extremity strength. A further explanation to the findings of this study, and Frontera et al. (1991) may be that females have a smaller proportion of lean tissue distributed in the upper body (Miller et al. 1993).

The present study is not without limitations, as the two exercise protocols were designed to be pragmatic and reduce participant burden, all estimations of 1-RM made on the same day, meaning some exercises may have been affected by fatigue. Furthermore, some participants reached 12 repetitions before momentary failure on the predicted 1-RM test which likely resulted in slightly overestimated 1-RM's. Finally, both protocols differed in intended movement velocity, the loads used, and potentially participant effort, meaning it is unclear how these variables may have impacted movement velocity. As participants in the present study were of similar age, and muscle mass (McLean and Kiel 2015) and muscle strength (Hughes et al. 2001) decline with advancing age, future research should examine the velocities produced when participants are segregated based on decade of life to observe how age impacts the ability to perform these exercises at maximal velocity.

Conclusion

The protocols used for both HVLL and LVHL, produce an appreciable difference in movement velocity. During the HVLL protocol, participants performed the concentric phase significantly faster for all exercises compared with LVHL: bicep curl (42% faster), calf raise (68% faster), chest press (48% faster), leg curl (48% faster), leg extension (54% faster), leg press (52% faster), seated row (57% faster) and tricep extension (43% faster). The eccentric phases for all exercises were also significantly faster for all exercises during HVLL compared to LVHL, likely due to range of motion not being controlled. Furthermore, males produced significantly faster velocities for all four of the upper body exercises compared to females. Therefore, these protocols provide a simple way for exercise professionals to ensure that older adults are training at desired velocities, without the need for specialist equipment to measure velocity. Future research would be useful, separating participants into groups based on decade of life to examine how velocities produced varies with age group.

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