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The Acute Physiological Effects of High and Low Velocity Resistance Exercise in Older Adults

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Abstract

The aim of the present study was to determine if workload matched, high velocity (HVE) and low velocity (LVE) resistance exercise protocols, elicit differing acute physiological responses in older adults. 10 older adults completed three sets of eight exercises on six separate occasions (three HVE and three LVE sessions). Systolic blood pressure, diastolic blood pressure and blood lactate were measured pre- and post-exercise, heart rate was measured before exercise and following each set of each exercise. Finally, rating of perceived exertion was measured following each set of each exercise. There were no significant differences in blood lactate ($F_{(1,9)}$=0.028; P=0.872; $\eta_p^2 = 0.003$), heart rate ($F_{(1,9)}$= 0.045; P=0.837; $\eta_p^2 = 0.005$), systolic blood pressure ($F_{(1,9)}$= 0.023; P=0.884; $\eta_p^2 = 0.003$) or diastolic blood pressure ($F_{(1,9)}$= 1.516; P=0.249; $\eta_p^2 = 0.144$) between HVE and LVE. However, LVE elicited significantly greater ratings of perceived exertion compared to HVE ($F_{(1,9)}$=13.059; P=0.006; $\eta_p^2 = 0.592$). The present workload matched HVE and LVE protocols produced comparable physiological responses, although greater exertion was perceived during LVE.

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

Introduction

Ageing is associated with the loss of skeletal muscle mass known as sarcopenia and the loss of muscle strength known as dynapenia (Clark and Manini 2008), both of which contribute to disability, frailty, comorbidities, hospital admissions and death in older adults (Yu 2015). In addition to ageing, a lack of physical activity has been identified as playing a significant role in the loss of muscle size and strength (Cruz-Jentoft and Landi 2014), contributing to functional decline and loss of independence in older adults (Clark and Manini 2008). To effectively address such issues requires a multidisciplinary approach, comprising aspects of both exercise prescription and nutritional strategies (Cruz-Jentoft and Landi 2014). Within exercise prescription, one approach that has been explored is resistance exercise. Resistance exercise has been shown to be effective in attenuating age related declines in muscle strength (Liu and Latham 2009), whilst having beneficial effects on functional status, health and quality of life in older adults (Hunter et al. 2004).

The fact that resistance exercise has been shown to have these positive effects, has led to major health organisations such as the American College of Sports Medicine (ACSM), developing resistance exercise guidelines for older adults. These ACSM guidelines state that 10-15 repetitions of 8-10 exercises that target the major muscle groups should be performed on two or more nonconsecutive days per week, partnered with other activities that improve flexibility and balance (Nelson et al. 2007). These are similar to the physical activity guidelines in the United kingdom (UK) (Bull et al. 2010). However, as these guidelines are so brief, it is unsurprising that few older adults in the UK are meeting them (Jefferis et al. 2014). Therefore, there is a need for these physical activity guidelines to be expanded upon to provide more guidance to older adults.

An important step in providing more guidance, is to understand the most pertinent mode of resistance exercise for producing positive effects on functional status, strength and muscle mass in older adults. Early investigation into resistance exercise identified the importance of muscle strength for functional performance in older adults (Aniansson et al. 1980). More recently, it has been highlighted that muscle power may be more relevant to functional performance, as being able to move a limb fast against a low external resistance (e.g. moving a limb quickly to stabilise to avoid a fall) is more useful than being able to move a limb slowly against a high external resistance (Sayers and Gibson 2014). This has led to investigation into the influence of high velocity (HVE) and/or low velocity (LVE) resistance exercise (also referred to as power and strength training respectively) on functional performance (Ramirez-Campillo et al. 2014), muscle mass (Van Roie et al. 2013) and strength gains (Marsh et al. 2009). Yet, despite numerous investigations, the most effective mode of resistance exercise remains unclear (Tschopp et al. 2011).

Surprisingly, it appears there has been little consideration of the acute physiological changes that resistance exercise may facilitate in older adults, with the few studies that have, focusing on hormonal changes (Hakkinen and Pakarinen 1995; Marcell et al. 1999). It is well reported that the physiological mechanisms that are stimulated during resistance exercise are dependent on the nature of that exercise (e.g. sets, repetitions, velocity, mode etc.) with repeated exposure to a certain exercise stimulus, facilitating specific adaptations of those physiological mechanisms (Kraemer et al. 1988). It has been shown that the assessment of acute physiological responses to resistance exercise protocols can aid in understanding how they differ (Kraemer et al. 1996) and may be useful in explaining the mechanisms of potential adaptations (Ramirez-Campillo et al. 2014). Such investigation is important to better understand the utility and safety of each type of resistance exercise for exercise prescription in older adults.

As ageing negatively influences the structure and function of the cardiovascular system, arteries, peripheral circulation and the autonomic nervous system (Queiroz et al. 2010), the effect resistance exercise can have on blood pressure is a significant concern for older adults. At the time of performing resistance exercise, there can be very large increases in blood pressure (MacDougall et al. 1985) but following cessation, blood pressure can decrease below that of baseline, also known as post-exercise hypotension (Hurley and Gillin 2015). However, it is unclear if factors such as: frequency, intensity, time, mode and volume have an effect on blood pressure following exercise (Hurley and Gillin 2015), meaning the differences between HVE and LVE in older adults are not well understood. Additionally, other useful measures can be derived from blood pressure data, such as mean arterial pressure which has been shown to be a predictor of cardiovascular disease (Sesso et al. 2000) and combined with heart rate, rate pressure product which can be used as a measure of myocardial oxygen demand and cardiac workload (Hermida et al. 2001).

Differing intensity, load and velocity of resistance exercise has been shown to have a varying influence on blood lactate responses in young men, with greater exercise intensity showing a greater increase in blood lactate than low intensity (Arazi et al. 2014). However, between studies it is hard to compare physiological responses, as protocols have varied in combinations of intensity, number of sets, rest times and velocity of movement (Arazi et al. 2014). Mazzetti et al. (2007) observed that LVE elicited a greater lactate response than HVE whereas, Nitzsche et al. (2017) observed that both blood lactate and heart rate responses were similar following three different resistance exercise protocols that varied in load, repetitions, number of sets and rest times.

As prior research has not fully considered whether velocity of resistance exercise elicits different acute physiological responses in older adults, the optimal prescription of resistance exercise in this population remains to be fully elucidated. Therefore, an important first step is to examine acute physiological markers such as heart rate, blood pressure and blood lactate. Furthermore, perception of exercise intensity is related to physiological demand, and the subsequent feelings of exertion that occur as a consequence of exercise intensity, may influence exercise adherence (Ekkekakis et al. 2005). Hence, monitoring rating of perceived exertion (RPE) would provide guidance on the perceptual response to both HVE and LVE. Such data is key in better refining resistance exercise programming for older adults, and informing health care professionals on how physiological and perceptual responses vary with velocity of resistance exercise. Therefore, the aims of this study were to measure the physiological and perceptual responses of a group of older adults to workload matched HVE and LVE protocols. We hypothesised that both physiological responses and RPE would be greater during LVE compared to HVE.

Materials and Methods

Participants

The present study used a randomised, counterbalanced, crossover study design and following institutional ethics approval by the local ethics committee, 10 recreationally active older adults (five 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 informed consent, and completing a health screen questionnaire prior to each trial. After providing details of any current medications, 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 should not have had participated in any purposeful strength or power training in the previous six months (de Vos et al. 2005) to be eligible to take part.

Table 1. Participant characteristics

Participant Information	Males (*n*=5)	Females (*n*=5)
Age (years)	66±3	68±2
Age Range (years)	63-71	67-71
Height (cm)	174.5 ± 5.4	162.6 ± 5.8
Body Mass (kg)	89.4 ± 13.6	70.9 ± 10.7
Body Mass Index (kg/m^2)	29 ± 4	27 ± 3
Baseline Systolic Blood Pressure (mmHg)	141 ± 9	140 ± 7
Baseline Diastolic Blood Pressure (mmHg)	80 ± 6	81 ± 6
Baseline Mean Arterial Pressure (mmHg)	100 ± 7	101 ± 6
Medications Taken	1 ± 1	1 ± 1
Mini-Mental State Examination score (0-30)	29 ± 1	29 ± 1

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

Familiarisation

Prior to familiarisation and all trials, participants were asked to refrain from caffeine use for a minimum of 12 hours (Syed et al. 2005) and any other fatiguing exercise or physical activity 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 five dynamic stretches which targeted the main muscle groups and joints used in the programme (Miszko et al. 2003). This warm-up was repeated before all subsequent trials. Following the warm-up, the correct, individual anthropometric setup for each exercise was noted on each piece of Cybex exercise equipment (Cybex, Medway, MA, USA). The correct technique for all exercises were then demonstrated to participants and practiced. Finally, participants were taken through a predictive 1-RM (one repetition maximum) testing protocol for each exercise, which provided a prediction of the maximum amount of weight, that could be lifted for just one repetition. Participants performed repetitions on a weight they felt was challenging but manageable. The resistance was progressively increased until no more than 10 repetitions could be performed with correct form. If a participant could complete more than 10 repetitions before failure, three minutes of rest was given, the weight increased by 10-15% and the process repeated. Weight lifted and number of repetitions completed were used to provide an estimation of 1-RM for each exercise (Table 2) using the prediction equation: (weight lifted ÷ (1.0278- (0.0278 × number of repetitions performed) (Brzycki 1993).

Exercise protocol

For clarity, when discussing the exercise protocols, the word trial is used to describe each visit to the sports centre, and set is used to describe the collection of single repetitions (one complete movement of an exercise). Participants were randomised to complete one of the two workload matched protocols (identical total weight lifted) displayed in Table 2. Both protocols consisted of three sets of eight different exercises (chest press, leg press, leg extension, leg curl, calf raise, seated row, bicep curl and tricep extension). Participants had three days of rest between each of the three trials for each velocity of training and a week 'washout period' before crossing over to the other protocol, meaning the trial period lasted approximately five weeks. The exercise protocols used in the present study (described in Table 2) were based on others that have previously demonstrated a positive impact on functional performance in older adults (Beltran Valls et al. 2014; Brochu et al. 2002; Kalapotharakos et al. 2005; Reid et al. 2015) with the number of sets and repetitions being similar to others that have attempted to match workloads (Hortobagyi et al. 2001; Sayers and Gibson 2014).

The concentric phase (lifting of the weight) in the HVE group was performed "as fast as possible" without causing dangerous fly away (unloading) of the weight stack, and the eccentric phase (lowering of the weight) was performed over three seconds (Henwood et al. 2008). The LVE group performed the concentric phase over two seconds and the eccentric phase over three seconds (Van Roie et al. 2013). A metronome was used to provide the cadence for exercise, except during the concentric phase of the HVE protocol. Each participant performed all their trials as near to the same time of day as possible to reduce fluctuations in strength due to circadian variation (Duncan and Oxford 2011).

Table 2. 1-RM data and details of the exercise protocols

Exercises	1-RM Males (kg)	1-RM Females (kg)	HVE Protocol	LVE Protocol
Leg Press	130.2 ± 29.5	78.9 ± 12.5	40% 1-RM	80% 1-RM
Seated Row	62.6 ± 7.5	33.8 ± 4.8	3 sets	3 sets
Chest Press	54.4 ± 5.3	21.4 ± 2.6	14 repetitions	7 repetitions
Leg Extension	58.8 ± 16.1	29.1 ± 7.2	Concentric phase “as fast as possible” with 3 second eccentric	2 second concentric phase and 3 second eccentric phase
Leg Curl	51.6 ± 9.1	25.6 ± 4.0		
Calf Raise	117.7 ± 27.2	89.1 ± 19.9		
Tricep Extension	36.0 ± 6.9	15.5 ± 6.8	2 minutes rest between sets	2 minutes rest between sets
Bicep Curl	30.3 ± 7.6	12.5 ± 6.4	3 minutes between exercises	3 minutes between exercises

Values are means ± SD; HVE = High Velocity Exercise; LVE = Low Velocity Exercise; 1-RM = One repetition maximum

Physiological measurements

Systolic and diastolic blood pressure were measured with an automatic blood pressure monitor (Omron M3 Intellisense HEM-7200-E, Omron Matsusaka Co Ltd, Kyoto, Japan) from the left arm, while seated in an upright position, prior to every trial and immediately following the last exercise of each session. Mean arterial pressure (2 x diastolic blood pressure + systolic blood pressure)/3 and rate pressure product (systolic blood pressure x heart rate) were calculated prior to and post-exercise using the blood pressure data. A fingertip blood sample was collected via a capillary tube, prior to each session and immediately at the end of the session. Samples were then analysed using a blood lactate analyser (Biosen C-line clinic, EKF Diagnostics, Magdeburg, Germany). Finally, heart rate was measured using heart rate telemetry (Polar Electro Oy, Kempele, Finland) before exercise and immediately following each set of each exercise.

Perceptual measure

RPE (Borg 1982) was used to assess the intensity that participants perceived during each of the exercise protocols. The 15-point RPE scale ranges from 6 (no exertion) to 20 (maximal exertion) and was presented to participants following each set of each exercise for both HVE and LVE, so that a value from the scale could be given to represent the exertion they perceived in that moment. Figure 1 displays the approximate timescale of the sessions and when various measures were collected. As the LVE protocol had half the amount of repetitions as the HVE protocol, each LVE trial was approximately eight minutes shorter in duration than the HVE trials.

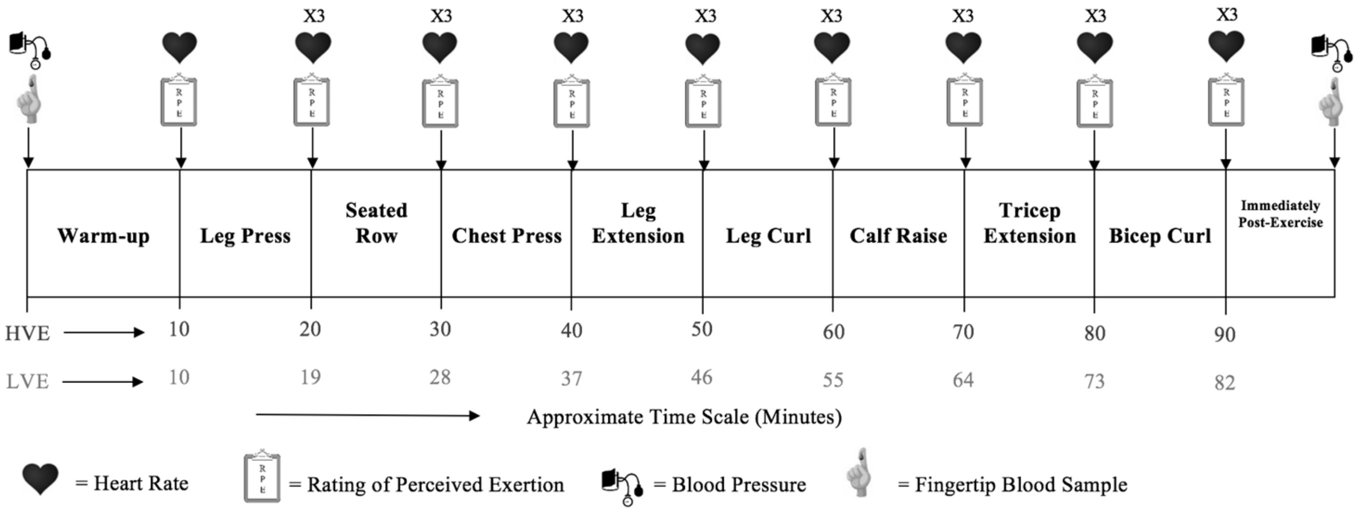

Figure 1. A schematic diagram of the experimental protocol
X3 = Collected following all three sets

Statistical Analysis

All data was analysed using IBM SPSS Statistics for Windows, Version 22.0 (Armonk, NY: IBM Corp) and 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 variables heart rate, blood pressure, blood lactate and RPE with the independent variable, exercise velocity. Within group changes were further investigated using repeated measures ANOVA and T-tests with Bonferroni correction where necessary. When Mauchley's test of sphericity was significant and the Greenhouse-Geisser 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 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, it was calculated using η_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 suggested that a sample size of ten participants would be necessary to detect a statistical difference given an estimated effect size of 0.25, a 1-β error probability of 0.90 and a *P* value significance level less than 0.05.

Results

Blood lactate

There were trivial differences in blood lactate concentrations between HVE and LVE ($F_{(1,9)}$=0.028; *P*=0.872; 95% CI: -0.7, 0.6; η_p^2 =0.003;Table 3) but large increases in blood lactate concentrations from pre- to post-exercise regardless of velocity ($F_{(1,9)}$=13.828; *P*=0.005; 95% CI: 0.9, 3.7; η_p^2 =0.61).

Systolic Blood Pressure

There were trivial differences in systolic blood pressure between HVE and LVE ($F_{(1,9)}$=0.023; *P*=0.884; 95% CI: -5.6, 4.9; η_p^2 =0.003; Table 3) and moderate increases in systolic blood pressure from pre- to post-exercise regardless of velocity ($F_{(1,9)}$=4.068; *P*=0.074; 95% CI: -0.6, 10.3; η_p^2 =0.31).

Diastolic Blood Pressure

There were small differences in diastolic blood pressure during HVE and LVE ($F_{(1,9)}$=1.516; *P*=0.249; 95% CI: -1.1, 3.6; η_p^2 =0.14; Table 3) and small differences between pre- and post-exercise regardless of velocity ($F_{(1,9)}$=2.010; *P*=0.190; 95% CI: -4.8, 1.1; η_p^2 =0.18).

Mean Arterial Pressure

There were trivial differences in mean arterial pressure between HVE and LVE ($F_{(1,9)}$=0.408; *P*=0.539; 95% CI: -2.1, 3.5; η_p^2 =0.04; Table 3) and trivial differences in mean arterial pressure between pre- and post-exercise regardless of velocity ($F_{(1,9)}$=0.074; *P*=0.792; 95% CI: -2.7, 3.4; η_p^2 =0.01).

Rate Pressure Product

There were trivial differences in rate pressure product between HVE and LVE ($F_{(1,9)}$=0.580; *P*=0.466; 95% CI: -1329, 660; η_p^2 =0.06; Table 3) and trivial differences between pre- and post-exercise regardless of velocity ($F_{(1,9)}$=0.867; *P*=0.376; 95% CI: -922, 2213; η_p^2 =0.09).

Table 3. Physiological measures for both HVE and LVE for all trials

	HVE		LVE	
	Pre-Exercise	Post-Exercise	Pre-Exercise	Post-Exercise
Blood Lactate (mmol/l)	2.3 ± 1.2	4.3 ± 2.1	2.0 ± 0.8	4.6 ± 2.8
Systolic Blood Pressure (mmHg)	131.8 ± 14.5	138.7 ± 18.7	133.5 ± 17.4	136.3 ± 18.4
Diastolic Blood Pressure(mmHg)	75.0 ± 7.3	72.5 ± 7.3	75.6 ± 6.6	74.4 ± 8.9
Mean Arterial Pressure(mmHg)	93.9 ± 8.9	94.6 ± 9.6	94.9 ± 9.4	95.0 ± 10.2
Rate Pressure Product (mmHg.bpm)	12383 ± 1846	12720 ± 2853	11740 ± 2425	12694 ± 2392

Values are means ± SD; HVE = High Velocity Exercise; LVE = Low Velocity Exercise

Heart Rate

There was a significant interaction between velocity of exercise and different exercises ($F_{(7,63)}$=8.841; P<0.001; η_P^2 =0.50; Figure 2). Repeated measures ANOVA revealed that there were significant differences in heart rate between exercises for both HVE ($F_{(7,63)}$=10.202; P<0.001; η_P^2 =0.53) and LVE ($F_{(7,63)}$=12.263; P<0.001; η_P^2 =0.58). Further investigation with T-tests revealed heart rate during the leg press (P<0.001; 95% CI: -8.4, -5.4) and seated row (P<0.001; 95% CI: -4.1, -1.2) were significantly higher during LVE compared to HVE. But for both the chest press (P<0.001; 95% CI: 3.4, 7.5) and leg extension (P<0.001; 95% CI: 2.6, 6.6), heart rate was significantly higher during HVE.

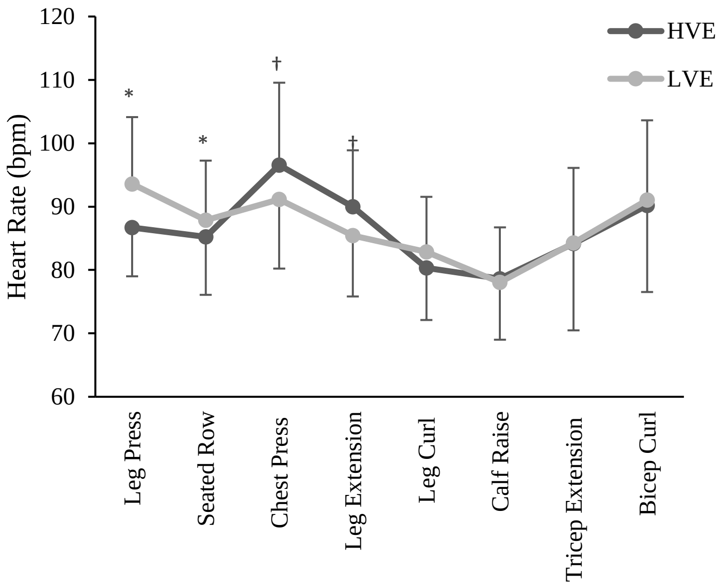

Figure 2. Heart rate (mean ± SD) for all participants during HVE and LVE
*= LVE significantly greater than HVE
†= HVE significantly greater than LVE
HVE = High Velocity Exercise; LVE = Low Velocity Exercise

RPE

There was a significant interaction between velocity and perception of exercises ($F_{(7,63)}$=6.184; *P*<0.001; η_p^2 =0.41; Figure 3). The interaction plot revealed that all exercises were perceived as harder during LVE compared with HVE except for the chest press. T-tests revealed that during LVE, participants rated RPE significantly greater for leg press (*P*<0.001; 95% CI: -3.4, -2.5), seated row (*P*<0.001; 95% CI: -2.0, -1.4), leg curl (*P*<0.001; 95% CI: -2.4, -1.5), and calf raise (*P*<0.001; 95% CI: -2.0, -1.1) than during HVE.

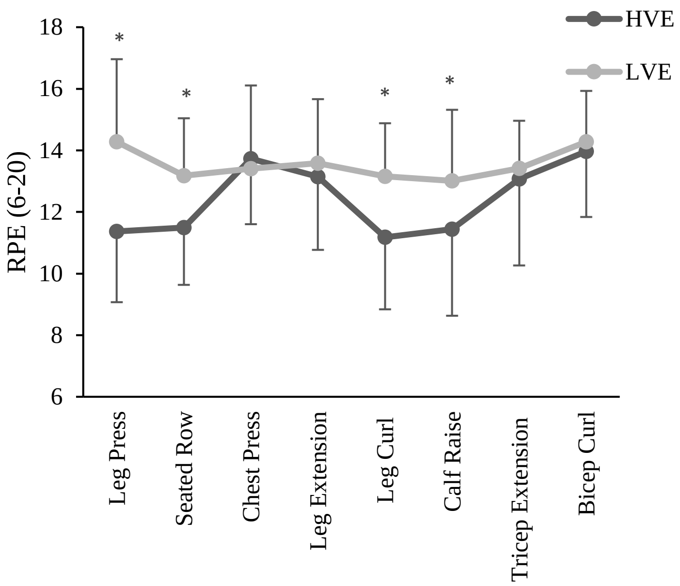

Figure 3. RPE (mean ± SD) for all participants during HVE and LVE
*= LVE significantly greater than HVE
RPE = Rating of Perceived Exertion; HVE = High Velocity Exercise; LVE = Low Velocity Exercise

Discussion

The present study is novel as it reports the physiological and perceptual responses to workload matched HVE and LVE in a sample of older adults. These measures are important in understanding how the ageing biological system responds to these modes of resistance exercise. This information can then feed forward, recognising the effect of exercise is multifaceted and multidisciplinary in nature. We hypothesised that LVE would elicit both a greater physiological response and a greater RPE response than HVE. This hypothesis must be rejected as physiological responses were similar, but the RPE response was significantly greater during LVE. The findings of the present study suggest there are no significant differences between workload matched HVE and LVE in blood lactate, systolic blood pressure, diastolic blood pressure, mean arterial pressure or rate pressure product responses in older adults. As would be expected, heart rate varied between exercises significantly, due to body position (Achten and Jeukendrup 2003) and the varying blood demands of active muscle (Peçanha et al. 2013). The leg press and seated row elicited significantly greater heart rate responses during LVE, while the chest press and leg extension elicited significantly greater heart rate responses during HVE.

Although changes were not significant, HVE produced increases in systolic blood pressure of approximately 10 mmHg in trials one and two from pre- to post-exercise, whereas LVE saw a 10 mmHg increase in trial one and trivial changes in trials two and three. A similar trend was observed by da Silva et al. (2007) who examined acute systolic blood pressure changes following three sets of maximum velocity bench press exercise in untrained older women, the authors reported that blood pressure was significantly lower at baseline than after the first, second, and third sets. This potential increase in systolic blood pressure is something that practitioners should be aware of when designing resistance exercise programmes for older adults, especially in populations at risk.

Previously, it has been reported that resistance exercise can have a post-exercise hypotensive effect (Hardy and Tucker 1998). Although changes were not significant, it is important to note that diastolic blood pressure decreased from pre- to post-exercise following both HVE and LVE in the present study. As the participants were normotensive, and individuals with an elevated blood pressure are those who experience the greatest post-exercise hypotensive effect of resistance exercise (Cardoso et al. 2010), it is unsurprising that only insignificant decreases were observed.

The main differences within the present study lay within the patterns observed for RPE. Despite comparable physiological strain, RPE was significantly greater for four of the eight exercises during LVE compared to HVE. These findings are consistent with Gearhart et al. (2002) who also observed that rating of perceived exertion was significantly greater when workload matched, heavier resistance exercise was performed for fewer repetitions compared with lighter resistance exercise for more repetitions. Therefore, the findings of the present study may have particular implications for exercise adherence, as the American College of Sports Medicine state that when intensity of exercise is higher, exercise adherence is generally lower (Whaley et al. 2006). Furthermore, other affective responses such as enjoyment of exercise, have been shown to predict long-term adherence to exercise programmes (Ekkekakis et al. 2011; Williams et al. 2008) meaning it would be beneficial for future studies to examine the affective responses of HVE and LVE in older adults to establish the likelihood of long-term adherence. Affective responses to exercise are particularly important to consider as it has been suggested that individuals differ in the exercise intensities they can tolerate and prefer (Ekkekakis et al. 2005), meaning that the mode of resistance exercise that should be prescribed may also need to consider individual preference.

Methodological considerations

It may have been useful to measure blood pressure during each exercise to observe if there were differences in blood pressure between LVE and HVE in addition to pre- and post-trial. Furthermore, monitoring blood pressure throughout recovery could have been useful to examine any potential post-exercise hypotensive effects. Lastly, measurement of the velocity of the HVE and LVE protocols would have assured an appreciable difference between protocols and provided some guidance on the range of velocity older adults are able to produce. This is especially important as it has recently been reported that there is a large variation in self-selected maximal limb velocity in such exercise protocols and improvements in functional performance might be optimised in individuals with the highest training velocities (Sayers et al. 2016).

Conclusion

Workload matched HVE and LVE produced comparable physiological responses in a group of older adults. While physiological responses were similar between velocities, LVE was perceived as harder, meaning it is possible that the affective responses to these velocities of exercise were different. Clear recommendations cannot be drawn from the findings of the present study, but HVE might be a more appealing mode of resistance exercise to propose to older adults, as it may produce the same physiological stimulus as LVE while being perceived as less exerting. Exercise practitioners and those working in community settings with older adults might therefore want to employ HVE preferentially given the link between RPE and continuation of exercise in the longer term. However, the investigation of the affective responses to both HVE and LVE would be useful in further clarifying general recommendations for older adults.

Conflict of Interest

None declared

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