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Movement velocity during high- and low-velocity resistance exercise protocols in older adults

Darren L. Richardson[a,*], Michael J. Duncan[a], Alfonso Jimenez[a], Victoria M. Jones[a], Paul M. Juris[b], Neil D. Clarke[a]

[a] Centre for Applied Biological & Exercise Sciences, School of Life Sciences, Coventry University, Coventry, UK
[b] Department of Kinesiology, University of Massachusetts Amherst, 30 Eastman Lane, Amherst, MA, United States

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ABSTRACT

The primary aim of the present study was to determine the actual movement velocity of high-velocity, 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 2 s 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.

1. Introduction

Sarcopenia is a common manifestation of ageing, and is defined as the 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 for achieving desirable adaptations. 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 (one repetition maximum) 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

* Corresponding author at: Life Sciences, Faculty Health and Life Sciences, Coventry University, Priory Street, CV1 5FB, UK.
E-mail address: Richa190@uni.coventry.ac.uk (D.L. Richardson).

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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 high-movement 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 restabilise 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 2 s 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 movement 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 velocity during HVLL and LVHL.

2. Methods

2.1. 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 1-RM was obtained for each exercise. 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.

2.2. 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 mm Hg), 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.

2.3. Procedures

Prior to familiarisation and all sessions, participants were asked to refrain from all other fatiguing exercise for 24 h. 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

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·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.