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Knee extension rate of velocity development affects walking performance differently in men and women

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ABSTRACT

Purpose: Acceleration capacity affects physical function, but whether it differentially affects men versus women or weak versus strong individuals is less known. We investigated whether knee extension rate of velocity development (RVD, a measure of acceleration) is associated with walking performance independent of peak torque and whether the relationships differ in men versus women and in weak versus strong individuals.

Methods: Relationships of RVD with walking performance were assessed in 326 women and 365 men aged 26–96 years enrolled in the Baltimore Longitudinal Study of Aging. Tests included knee extension peak torque and RVD assessed during a $180^{\circ}\cdot s^{-1}$ isokinetic strength test and four walking performance measures (usual-paced and fast-paced 6 m walks and 2.5 min usual-paced and 400 m fast-paced walks). Sex-stratified linear regression models were adjusted for age, race, height, appendicular lean mass, fat mass, peak torque, knee pain, and RVD*peak torque interaction.

Results: In men, RVD was not independently associated with any walking performance measure ($p > 0.05$), and, for the 6 m-usual walk only, there was a significant RVD*peak torque interaction ($p < 0.0001$). In women, RVD was independently associated with usual-paced walks ($p < 0.05$) and there were significant RVD * peak torque interactions for all measures. Strength-specific analyses indicated that RVD was most associated with performance among weaker individuals.

Conclusion: RVD is associated with walking performance in women, but less in men, and is most related to performance when strength is low. Strategies to accomplish motor tasks may be sex-specific. Future studies are needed to understand the mechanisms underlying such sex differences.

1. Introduction

Muscle strength is important to walking performance (Bohannon, 1997). The relationship between muscle strength and walking performance is usually explored by studying the independent correlation between maximum muscle strength, often as peak torque or force and some performance measure of walking capacity. Few and relatively small studies have selectively addressed acceleration capacity. The capacity to accelerate the limbs is important for various physical performance tasks (Murray et al., 2007; Wilk et al., 1994). Thus, assessing acceleration capacity may help gain insight into the motor strategies that individuals use to purposefully and efficiently move their limbs.

Rate of velocity development (RVD) is a metric of acceleration capacity during initial muscle contraction that is usually estimated from the time-velocity curve during the unloaded acceleration phase of isokinetic testing (Brown & Whitehurst, 2003; Brown et al., 2005). RVD can be operationally defined as the time required to reach a predetermined angular velocity (Brown & Whitehurst, 2003). The relationships between RVD at various predetermined angular velocities and peak torques are weak ($r = -0.09$ to -0.29), suggesting that RVD captures a different aspect of muscle function than peak torque (Brown et al., 2005). In adults who are physically active, short-term velocity-specific training causes improvement of knee extension RVD, with little or no improvement in knee extension peak torque (Brown & Whitehurst, 2003; Murray et al., 2007). Since RVD reflects some effect of aging on muscle, especially neuromuscular changes (Chen et al., 1994), studying this parameter may help better understanding the effect of aging on mobility performance and provide novel insights into

Abbreviation: ALM, appendicular lean mass; BLSA, the Baltimore Longitudinal Study of Aging; DXA, dual-energy X-ray absorptiometry; RM, repetition maximum; RVD, rate of velocity development; SD, standard deviation

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mechanisms and intervention strategies to prevent or treat mobility decline with aging.

Overall, men are stronger than women of the same size (Brown et al., 1995; Doldo et al., 2006; Musselman & Brouwer, 2005). In contrast, whether acceleration capacity during knee extension differs by sex remains controversial. One study reported that healthy young women compared to men, require on average more time to reach the target velocity, but only at velocities > 240°·s^{-1} (Brown et al., 1995), whereas another study did not find any sex differences in healthy young adults at angular velocities ranging from 30 to 300°·s^{-1} (Chen et al., 1994). Sex differences also exist in walking performance (Tolea et al., 2010), which are only in part explained by differences in anthropometric characteristics (Fragala et al., 2012; Musselman & Brouwer, 2005; Tseng et al., 2014). Further studies are needed to investigate how acceleration capacity contributes to walking performance, independent of peak torque in men and women.

We investigated whether knee extension RVD contributes to walking performance independent of peak torque in women and men aged 20 to 90 years. We further investigated whether, among men and women, the contribution of RVD to mobility performance differs in participants with higher and lower muscle strength. Addressing these questions may help inform mechanisms underlying walking performance and thus provide a rationale for sex and strength-specific exercise programs for the prevention or treatment of mobility disability.

2. Methods

2.1. Participants

This study used cross-sectional data from the Baltimore Longitudinal Study of Aging (BLSA). The BLSA is a prospective observational cohort study aimed at examining mechanisms underlying the decline of physical and cognitive function with aging in humans (Ferrucci, 2008). Between January 2006 and February 2011, 691 BLSA participants (26–96 years old) performed isokinetic, concentric knee extension tests and at least one of four walking performance measures (see legend in Table 1). The present study used data from the most recent visit when these measures were performed in each participant. The BLSA protocol was approved by the Institutional Review Board of record at the time of data collection (National Institute of Environmental Health Sciences, NC) and written informed consent was obtained from all participants.

Table 1
Characteristics of the participants.

	Men		Women		p-Value
	Mean ± SD	n	Mean ± SD	n	
Age (years)	68.74 ± 13.65	365	64.73 ± 12.58	326	< 0.0001
Race (black, %)	21.92	365	38.96	326	< 0.0001
Weight (kg)	83.9 ± 14.7	365	70.6 ± 14.3	326	< 0.0001*
Height (cm)	175.2 ± 7.5	365	162.4 ± 6.0	326	< 0.0001*
ALM (kg)	25.04 ± 3.77	365	17.12 ± 2.61	326	< 0.0001*
Fat mass (kg)	25.38 ± 9.74	365	28.48 ± 10.48	326	0.001*
Knee pain (%)	3.84	365	6.44	326	0.004*
Peak torque (Nm)	108.9 ± 39.1	365	74.2 ± 24.6	326	< 0.0001*
RVD (°·s^{-2})	1556 ± 222	365	1531 ± 207	326	0.015*
400 m walk (m·s^{-1})	1.6 ± 0.3	285	1.5 ± 0.3	245	< 0.0001*
2.5 min walk (m·s^{-1})	1.2 ± 0.2	284	1.2 ± 0.2	238	< 0.0001*
6 m-fast (m·s^{-1})	1.8 ± 0.5	354	1.7 ± 0.3	323	< 0.0001*
6 m-usual (m·s^{-1})	1.1 ± 0.3	357	1.2 ± 0.2	323	0.470*

ALM, appendicular lean mass by DXA; RVD, rate of velocity development. Assessment of 400 m walk started in April 2007. The 2.5 min walk started in July 2007. The 6 m gait tests started in January 2006.

* Age-adjusted *p*-value.

2.2. Knee extension peak torque and RVD assessments

After two practice trials, participants performed three test trials of isokinetic knee extension at 180°·s^{-1} on a Kin-Com isokinetic dynamometer (Kin-Com model 125E, version 3.2, Chattanooga Group, Chattanooga, TN). Range of motion of the knee joint angle was set between 100 and 160° (full extension = 180°). Participants were asked to extend their knee as hard as possible with an instructor's verbal encouragement (Lindle et al., 1997; Lynch et al., 1999). Resting periods between trials were set as 15 s.

All signals were sampled at 100 Hz. After exporting the raw data, we excluded trials where participants could not reach target velocity (n = 9). Participants who performed these trials were older (76.0 ± 10.4 years) compared to those who were able to reach target velocity (66.4 ± 14.2 years). RVD was calculated as the slope of the velocity-time relationship obtained from the time of movement onset and the time when angular velocity first exceeded 178°·s^{-1} (Fig. 1). For peak torque assessment, we considered the maximum torque generated over the period between the time when angular velocity first exceeded 178°·s^{-1} and the time when angular velocity started to decelerate at the end of movement. We selected the trial with the highest peak torque from either leg for both RVD and peak torque.

2.3. Walking performance

The BLSA study began measuring walking performance between January 2006 and July 2007. Gait speed was calculated as distance divided by time of completion expressed to the tenth of a second. For short distance walking performance measures, participants performed the 6 m walk at usual pace (6 m-usual), and then the 6 m walk at fast pace (6 m-fast). For long-distance walking performance measures, participants performed a 2.5 min walk at usual pace (2.5 min, m/s) and then 400 m walk at fast pace (400 m, m/s) (Simonsick et al., 2001; Simonsick et al., 2014). For these two tests, a 20-meter walking course was set with two fluorescent orange traffic cones at each end and tape marking each meter between the cones. The examiner recorded the total time to complete in 400 m walk and the distance covered in a 2.5 min walk, respectively.

2.4. Body composition

We measured whole body fat mass and appendicular lean mass (sum of arm and leg lean mass) (ALM) by using a whole-body dual-energy X-ray absorptiometry (DXA; Prodigy Dual Photon X-ray Absorptiometry unit, General Electric, Milwaukee, WI) with DICOM software ver. 10.51.006 with the array mode (Lindle et al., 1997).

2.5. Subjective knee pain

We asked the participants to report their subjective knee pain over the last 12 months as “in the past 12 months, have you had knee pain lasting at least one month?”

2.6. Statistical analysis

Descriptive data are presented as the mean ± standard deviation (SD) or percentages. Normality of distributions were verified using the Kolmogorov-Smirnov test. A sex difference in age was assessed with an unpaired *t*-test and race difference (black versus non-blacks) was assessed with the chi-square test. Since anthropometric, morphological, and performance characteristics are affected by age, sex differences were assessed by using age-adjusted generalized linear regression models.

Because men and women tend to differ in skeletal muscle mass and performance, and because we hypothesized “a priori” that the role of RVD in walking performance would have been different between men