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Effects of aging on maximal and rapid velocity capacities of the leg extensors☆

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ABSTRACT

Declines in muscle strength and power are commonly reported as a consequence of aging; however, few studies have investigated the influence of aging on maximal and rapid velocity characteristics. The objective of this study was to examine the effects of aging on maximal and rapid velocity characteristics of the leg extensor muscles. Twenty-three young (age = 25 ± 3 yrs) and twenty-one old (72 ± 4 yrs) men performed three leg extension maximal voluntary contractions (MVCs) at $240° \cdot s^{-1}$ and at maximum unloaded velocity (Vmax). Vmax was calculated as the highest velocity attained during the unloaded MVC and RVD was the linear slope of the velocity–time curve for the 240 $deg \cdot s^{-1}$ (RVD240) and maximum unloaded velocity (RVD–Vmax) contractions. The old men exhibited lower ($P < 0.01$) Vmax (10.1%), RVD240 (37.2%), and RVD–Vmax (26.7%) compared to the young men. These lower velocity characteristics for the old men may contribute to the increased functional limitations often observed in older adults. Interestingly, the greater age-related declines observed for RVD240 and RVD–Vmax compared to Vmax perhaps suggest an enhanced age-related impairment in the ability of the older adults' muscle to generate velocity rapidly versus the ability to generate maximal velocity. Such findings highlight the importance of time-dependent velocity measures when assessing the effects of aging on rapid velocity capacities.
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1. Introduction

Age-related declines in function and mobility are a major public health concern. By the year 2030, approximately 30% of the population in the United States will be 65 yrs or older, with the majority likely to experience at least one or more functional limitations (Hunter et al., 2004), leading to a reduction in independency and a deterioration in health and quality of life (Van Roie et al., 2011). As life expectancy continues to increase, the ability of elderly individuals to remain healthy, vigorous, and free of disability into the final years of life may be even more important than the absolute number of years achieved (Curb et al., 2006). Thus, the prospect of identifying performance-based measures that can successfully discriminate between a wide-range of functional abilities, including those of younger healthy individuals may be critical in the assessment of "healthy" aging in the elderly as well as improving our understanding of the involved mechanisms linked to such age-related declines in functional performance. Given the importance of this prospect, recent research has been heavily focused on identifying highly sensitive performance characteristics to reflect the physiological and functional effects of aging and disabilities among young and older adults using traditional laboratory-based measurements (Lanza et al., 2003; Yamauchi et al., 2009).

The majority of previous research investigating muscle function capacities between young and older individuals have used muscle strength- and/or power-related measures to identify age-related declines in performance (Harries and Bassey, 1990; Lanza et al., 2003). Interestingly however, few studies have examined the functional impact of aging on *in vivo* velocity characteristics. Because velocity is a principal component of muscle power (i.e., power = torque · velocity) (Dalton et al., 2012), velocity-based performance measurements, such as maximum velocity and rapid velocity development, may also be useful for identifying age-related declines in functional performance ability. For example, Van Roie et al. (2011) reported that maximum unloaded velocity (Vmax) of the leg extensor muscles was the single best predictor of functional performance capacity in elderly individuals. However, previous authors have shown mixed findings regarding age-related declines in Vmax. For example, Yamauchi et al. (2009) reported that Vmax of the lower body musculature was unchanged with aging, while Dean et al. (2004) revealed moderate age-related declines of 16% for the hip extensors and flexors. Moreover, Larsson et al. (1979) showed small declines in Vmax for the leg extensors between young and old men. This lack of consensus among studies is likely due to inconsistencies in terms of differences in muscles, age-ranges, sex, and techniques used for examining Vmax. In addition, it is possible that the measurement of maximum unloaded velocity is not highly sensitive to functional

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changes, particularly in healthy adults. Alternatively, other velocity measures may be used to exhibit higher sensitivity of such muscle function changes. This concept is supported by previous authors (Murray et al., 2007; Nguyen et al., 2009) who have suggested that using rapid velocity measurements, which include rate of velocity development (RVD), may provide for a more sensitive measure than maximal velocity to identify functional performance abilities. However, although studies have examined and reported the utility of RVD as a functional measurement in younger individuals (Murray et al., 2007; Nguyen et al., 2009), no studies to date have examined the effects of aging on RVD changes. Because the time required (i.e., ~100–200 ms) to achieve maximal velocity during a maximal voluntary contraction (MVC) is greater for old compared to younger individuals (Lanza et al., 2003), the time-dependent RVD characteristics may be more functionally relevant than Vmax in the elderly. The application of these characteristics may be reflective of the short response times that are normally available (i.e., less than ~100–200 ms) to accelerate the limbs during many functional loco-motor tasks (i.e., balance recovery, running, etc.). Thus, given the potential time-sensitive functional relevance between RVD and loco-motor movements, and the limited amount of research investigating the effectiveness of rapid velocity parameters to identify age-related changes in muscle function, further research is warranted to examine the effects of aging on these variables. Identification of the most sensitive and relevant muscle function measures may provide important insight regarding implications for the relationships between aging and functional performance capacities, as well as shed light on mechanisms involved in these age-related deteriorating processes. Therefore, the purpose of the present study was to examine the effects of aging on maximal and rapid velocity characteristics of the leg extensors in healthy young and older men.

2. Methods

2.1. Participants

Twenty-three young (mean $\pm$ SD: age = 25 $\pm$ 3 yrs; body mass = 88.09 $\pm$ 21.47 kg; height = 178.84 $\pm$ 7.74 cm) and twenty-one old (age = 72 $\pm$ 4 yrs; body mass = 88.40 $\pm$ 13.32 kg; height = 177.55 $\pm$ 6.39 cm) healthy men volunteered to participate in this study. The study was approved by the Institutional Review Board and all participants signed and completed an informed consent document and health history questionnaire. All participants were free of any current or ongoing neuromuscular diseases or musculoskeletal injuries of the knee or hip on the testing side (right side) within one year prior to testing.

2.2. Procedures

Participants visited the laboratory on two separate occasions. The first visit was a familiarization trial where all participants practiced the MVCs of the leg extensors. Within 2–4 days following familiarization, participants reported back to the laboratory for the experimental trial. Participants were instructed to refrain from any vigorous physical activity or exercise within 48 h and caffeine consumption within 12 h of testing.

2.3. Maximal voluntary contractions

All MVCs were performed with the right leg using a calibrated Biodex System 4 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY). For all isokinetic assessments, participants were seated with restraining straps placed over the trunk, pelvis, and thigh and the input axis of the dynamometer was aligned with the axis of rotation of the knee. Prior to the testing, participants performed a 5 min warm-up on a cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity workload, followed by three submaximal isokinetic leg extension and flexion muscle actions at $60° \cdot s^{-1}$ at approximately 75% of their perceived maximal effort. Following the warm-up, participants performed three MVCs each at $240° \cdot s^{-1}$ and at Vmax. Vmax was used to assess the maximal shortening velocity of the muscle-limb unit where there was no resistance (with the exception of the lever arm) provided throughout the duration of the contraction (i.e. velocity of the dynamometer was set above all subjects' maximum velocity capacities), in accordance with the procedures of Van Roie et al. (2011). The order of velocity testing was randomized and 1 min of recovery was provided between each contraction. For all MVCs, participants were instructed to "kick up" as "hard and fast as possible." The range of motion was set to move from 90 to 10 deg of leg extension (0° = horizontal plane).

2.4. Data analyses

The velocity ($deg \cdot s^{-1}$) signal was sampled at 2 kHz with a Biopac data acquisition system (MP 150WSW, Biopac Systems Inc.; Santa Barbara, CA) stored on a personal computer (Dell Inspiron, Dell Inc., Round Rock, TX) and processed offline with custom written software (Labview 8.5, National Instruments, Austin, TX). The scaled velocity signal was filtered using a fourth-order, zero-phase shift, low pass Butterworth filter with a 10-Hz cutoff frequency. Vmax ($deg \cdot s^{-1}$) was calculated as the highest velocity attained during the unloaded MVC. RVD ($deg \cdot s^{-2}$) was determined as the linear slope of the velocity–time curve (Δvelocity/Δtime) for the 240 $deg \cdot s^{-1}$ (RVD240) and maximal unloaded velocity (RVD–Vmax) contractions. RVD was calculated from the onset of velocity to the point where the signal reached 2 $deg \cdot s^{-1}$ below the target velocity level, which was at 238 $deg \cdot s^{-1}$ and at 2 $deg \cdot s^{-1}$ below Vmax for RVD240 and RVD–Vmax, respectively (Fig. 1). These procedures were used to obtain the linear portion of the rate of rise in velocity, while excluding the deceleration or "rounding off" of the signal observed at the edge of the velocity plateau. The onset of velocity was determined as the point when the velocity signal reached a threshold of 2 $deg \cdot s^{-1}$ above baseline (Fig. 1). The MVC with the highest RVD or Vmax was used for all analyses. In addition, the range of motion (ROM, deg) for both the acceleration and deceleration phases of the maximal velocity contraction were calculated (Brown et al., 1995). Reliability for the velocity variables was performed on a subset of the young and old participants on 2 non-consecutive days. The intraclass correlation coefficients (ICCs) and standard error of measurement (SEM) expressed as a percentage of

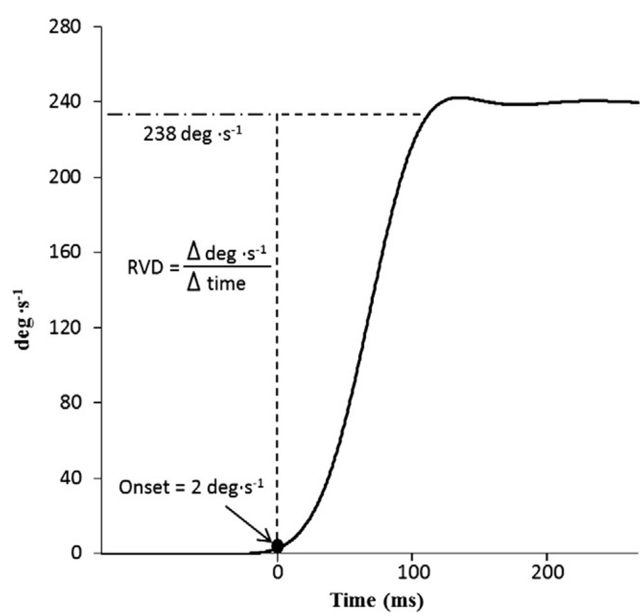

Fig. 1. A representative velocity–time tracing for a maximal concentric isokinetic leg extension at 240 $deg \cdot s^{-1}$ depicting the calculation of rate of velocity development (RVD) as the linear slope of the line between onset and 238 $deg \cdot s^{-1}$.

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