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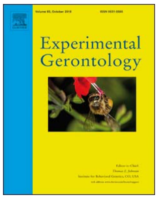

Age-related reductions in muscle quality influence the relative differences in strength and power☆

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ABSTRACT

Age-related changes in the relative differences in isokinetic strength and power may reflect fast twitch fiber function. We aimed to examine the influence of muscle quality on the relative differences in strength and power in younger and older men. Twenty younger (20.1 ± 1.5 yrs) and 20 older (69.5 ± 3.1 yrs) healthy, recreationally active men performed two plantarflexion maximal voluntary isometric contractions (MVCs) and three maximal concentric isokinetic contractions at a slow ($0.52\ \text{rad}\cdot\text{s}^{-1}$) and fast ($2.09\ \text{rad}\cdot\text{s}^{-1}$) velocity. Absolute and normalized (%MVC) isokinetic peak torque (PT), mean power (MP), peak power (PP), the relative differences in PT (%decrease), MP and PP (%increase) from 0.52 to $2.09\ \text{rad}\cdot\text{s}^{-1}$, and electromyographic (EMG) amplitude were examined. Ultrasonography was used to determine subcutaneous fat corrected echo intensity (EI) to represent muscle quality. The younger men exhibited greater absolute isometric PT, isokinetic PT, MP, and PP at 0.52 and $2.09\ \text{rad}\cdot\text{s}^{-1}$ ($P = 0.001$–0.003); but these differences were no longer present following normalization ($P = 0.079$–0.954). The older men exhibited similar EMG amplitude values but higher EI values ($P < 0.001$), a greater %decrease in PT (43.6% vs. 38.9%; $P = 0.006$), and a lower %increase in MP (167.5% vs. 186.3%; $P = 0.049$) and PP (125.5% vs. 144.5%; $P = 0.006$). Echo intensity was related to the %decrease in PT ($r = 0.605$; $P < 0.001$), %increase in MP ($r = -0.419$; $P = 0.009$), and %increase in PP ($r = -0.605$; $P < 0.001$) from 0.52 to $2.09\ \text{rad}\cdot\text{s}^{-1}$. The absolute age-related reductions in isokinetic strength and power were no longer present following normalization to isometric strength. However, age-related differences in strength and power remained intact when examining the relative differences from slow to fast velocities, which appear to be influenced by the qualitative changes in skeletal muscle.

1. Introduction

In 2014, adults ages 65 and older accounted for 15% of the population, which is anticipated to grow to 21% by 2030 (Federal Interagency Forum on Aging-Related Statistics, 2016). Furthermore, 44% of these adults report having one or more limitations performing daily tasks (e.g., walking or climbing steps) (Federal Interagency Forum on Aging-Related Statistics, 2016) which may lead to a high incidence of injury and a subsequently significant economic burden (Janssen et al., 2004). For example, up to 30% of older adults experience a fall each year (Gillespie et al., 2012), potentially resulting in a deterioration of health and the inability to live independently (Ayoung-Chee et al., 2014). The age-related loss of strength and power, coined *dynapenia*, has been noted as a major contributor to physical disability (Manini and Clark, 2012).

The age-related reduction in maximal absolute isometric and isokinetic strength has been well documented (Alway et al., 1996; Candow and Chilibeck, 2005; Jenkins et al., 2015; Lanza et al., 2003; Ochala et al., 2004; Thelen et al., 1996; Thom et al., 2007). To account for differences in absolute strength, previous authors have assessed normalized strength and power to provide a comparison of the relative rate of loss of strength/power across angular velocities (Harries and Bassey, 1990). Studies examining normalized isokinetic peak torque (% of maximal isometric strength) have shown mixed results (Harries and Bassey, 1990; Jenkins et al., 2015; Lanza et al., 2003; Thelen et al., 1996) and it is unclear whether age-related differences remain with normalization. A recent study conducted by Jenkins et al. (2015) found that the age-related differences in absolute isokinetic strength and

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power were no longer present following normalization. However, due to the greater age-related differences in strength and power at faster contraction velocities (Candow and Chilibeck, 2005; Jenkins et al., 2015), differences still existed between younger and older men when examining the relative differences in isokinetic strength and power (i.e., %decrease in peak torque [PT], %increase in mean power [MP]) from slow to fast isokinetic velocities. Furthermore, these relative differences were suggested to be noninvasive indicators of dynapenia that may reflect age-related changes in motor unit remodeling including changes in type II muscle fiber number, size, and/or function (Jenkins et al., 2015), in addition to the simultaneous increase in non-contractile (fat and fibrous) tissue (Goodpaster et al., 2006; Lexell, 1995, 1997; Visser et al., 2005). Recently, echo intensity (EI), a quantitative gray-scale analysis of ultrasound images, has become an attractive method to examine muscle tissue quality in older adults (Choi et al., 2016; Pillen et al., 2009; Ryan et al., 2015). Echo intensity has been shown to be a reliable method to determine qualitative alterations in muscle composition (i.e. infiltration of fat and/or fibrous tissue) (Rosenberg et al., 2014). It is possible that EI values may reflect the extent of these age-related alterations in type II muscle fibers and the simultaneous infiltration of non-contractile tissues (Choi et al., 2016; Ryan et al., 2015; Young et al., 2015), an aforementioned contributing factor to dynapenia.

In an effort to follow-up the Jenkins et al. (2015) study, we sought to simultaneously examine isokinetic strength and power, and ultrasound EI in the plantarflexors, a muscle group critical to maintaining normal gait with aging (van der Krogt et al., 2012). Thus, the purpose of this study was to examine the influence of muscle quality on the relative differences in strength and power in younger and older men. Given the findings of Jenkins et al. (2015), we hypothesized that: (1) the age-related differences in absolute values for PT, MP, and peak power (PP) during isokinetic muscle actions would be eliminated with normalization to isometric PT; (2) the %decrease in PT and %increase in MP and PP would be greater and lower in older men, respectively, when compared to the younger men; and (3) poorer muscle quality (higher ultrasound EI values) would be related to a greater %decrease in PT and a lower %increase in MP and PP.

2. Methods

2.1. Participants

Twenty younger and 20 older men volunteered to participate in this study (demographics listed in Table 1). All participants were considered recreationally active due to their self-reported weekly exercise habits (younger = 6.2 ± 4.6 h/week; older = 5.5 ± 2.2 h/week). None of the participants reported any metabolic or neuromuscular diseases, or musculoskeletal injuries sustained within the past three months specific to the low back, hip, knee, or ankle. All participants completed and signed an approved consent form, and a health history and exercise status questionnaire. This study was approved by the University Institutional Review Board.

Table 1
Mean ± standard deviation (SD) values for demographics, plantarflexor muscle characteristics, and isometric peak torque in the younger and older men.

	Younger men	Older men
Age (years)	20.10 ± 1.52*	69.45 ± 3.07
Mass (kg)	71.66 ± 9.68*	80.77 ± 8.18
Stature (cm)	173.71 ± 7.47	177.70 ± 6.23
Uncorrected EI (AU)	78.00 ± 5.60*	92.37 ± 8.94
SCF thickness (cm)	0.36 ± 0.11*	0.28 ± 0.10
Corrected EI (AU)	92.50 ± 6.96*	103.59 ± 10.18
Isometric PT (Nm)	139.37 ± 27.24*	109.37 ± 17.09

SCF subcutaneous fat; *EI* echo intensity (average of the medial and lateral gastrocnemius); *PT* peak torque.

* $P < 0.05$, significant difference between the younger and older men.

2.2. Experimental design

Each participant visited the laboratory on three separate occasions separated by 2–7 days at the same time of day (± 2 h). The first visit was a familiarization trial where all participants practiced the isometric and isokinetic strength assessments. To determine test-retest reliability, participants performed the same plantarflexion strength assessments on the second and third visit. Participants performed 2–3 isometric maximal voluntary contractions (MVCs) followed by three maximal isokinetic strength assessments at both slow (0.52 rad·s^{-1}) and fast (2.09 rad·s^{-1}) velocities specific to the plantarflexors (Fugl-Meyer et al., 1980), in random order. Isometric and isokinetic data from the third visit was used for all analyses. During the second visit, all of the ultrasound (US) assessments preceded the strength assessments. All participants refrained from any vigorous physical activity 24 h prior to testing.

2.3. Isometric and isokinetic strength assessments

All of the plantarflexion strength assessments were conducted on a calibrated HUMAC Norm dynamometer (Computer Sports Medicine Inc., Stoughton, MA, USA) using a custom-designed steel foot plate (length = 36 cm; width = 17 cm; thickness = 0.9 cm). Participants were seated at a 135° angle between the torso and thigh, with restraining straps placed over the chest, pelvis, and thigh, and they were required to keep their arms crossed in front of their chest during testing. The participants' right leg was fully extended and the foot was secured in a thick rubber heel cup with straps placed over the toes and metatarsals, aligning the lateral malleolus of the fibula with the axis of rotation of the dynamometer.

Prior to strength testing, participants performed a warm-up comprised of two submaximal isometric voluntary contractions at 50 and 75% of their perceived maximal effort for 3–4 s at a neutral joint angle (0° of dorsiflexion). Each participant then performed 2–3 isometric maximal voluntary contractions (MVCs) for 3–4 s with 2 min of recovery between trials. Following the MVCs, participants completed three maximal voluntary isokinetic muscle actions of the plantarflexors at 0.52 rad·s^{-1} and at 2.09 rad·s^{-1} (in random order) with 2 min of rest between each testing velocity. The isokinetic muscle actions began with the investigator passively pushing the footplate into dorsiflexion at a velocity of 0.35 rad·s^{-1} until the participant indicated a slight stretch by verbal cue. The investigator immediately released the footplate allowing the participant to maximally plantarflex to 20° of plantarflexion. Over the duration of each muscle action, participants received strong verbal encouragement in which they were instructed to plantarflex “as hard and fast as possible”.

2.4. Electromyography

Pre-amplified, bipolar surface electrodes (TSD150B Biopac Systems, Santa Barbara, CA, USA; gain = 350 and interelectrode distance of 20 mm) were placed parallel to the muscle fiber orientation on the medial gastrocnemius (MG) and soleus (SOL) muscles. According to the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) guidelines (Hermens et al., 2000), electrode placement on the MG occurred at most prominent bulge, whereas placement on the SOL occurred at two-thirds of the distance between the femoral medial condyle and the medial malleolus. A pre-gelled, disposable reference electrode was placed over the tibial tuberosity on the right leg (Ag-Ag Cl Quinton Quick Prep; Quinton Instruments Co, Bothell, WA, USA). Preceding the electrode placement, the skin was shaved, lightly abraded, and cleaned with isopropyl alcohol to reduce interelectrode impedance and increase the signal-to-noise ratio.