LOWER LEG MORPHOLOGY AND STRETCH-SHORTENING CYCLE PERFORMANCE IN YOUNG AND ELDERLY MALES

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Bone and muscle characteristics of the lower leg and stretch-shortening cycle capabilities of the ankle in young (22.3 ±1.3 yrs) and elderly (67.5 ±3.3 yrs) males were examined. Peripheral quantitiative computed tomography assessed bone stress-strain index, bone ultimate fracture load, muscle density, muscle cross-sectional area (CSA), fat CSA and muscle+bone CSA. Maximal voluntary isometric plantarflexion (MVIP) force and force-velocity measurements during a countermovement hop (CMH) and drop hops from 20, 30 and 40 cm were measured. Bone stress-strain index, muscle density, muscle CSA, muscle+bone CSA, MVIP peak force and rate of force development, and force and velocity in both eccentric and concentric phases during the CMH and drop hops, were significantly higher in young males in comparison to elderly males. Aging potentially negatively influences lower leg bone and muscle strength required to perform hopping tasks, indicative of lower stretch-shortening cycle capabilities of the ankle.

KEYWORDS: aging, power, muscle, bone.

INTRODUCTION: Extensive research exists concerning the effect of aging on bone health, muscle quality and potential losses in mobility. Loss of bone and muscle mass after the age of 50 has been documented (Warming, Hassager & Christiansen, 2002). This influences the ability of elderly individuals to generate force and power. Thus, this might be reflected by decreases in isometric strength and dynamic stretch-shortening cycle (SSC) performance. Both aging and changes in the amount of physical activity during life's progression have been implicated as mitigating factors for decreased physical capabilities. No data exists concerning bone stress-strain index and bone ultimate fracture load through peripheral quantitative computed tomography (pQCT) in elderly males. However, dancers have been shown to possess higher bone stress-strain indexes and bone ultimate fracture loads in comparison to untrained individuals indicating the importance of physical activity in sustaining these physiognomies (Rice, van Werkhoven, Merritt, et al., 2018). Muscle strength loss of approximately 10-15% have been observed to occur each decade after the age of 30. Loss of strength has been observed in both isometric knee flexion and plantarflexion in elderly males. General losses in muscle fibre size and significantly lower fractions of myosin heads in strong-binding state during maximal isometric contractions have been indicated as mitigating factors in aging related losses to physical function. Ankle force and power capabilities, in particular, have been indicated as a limitation to overall mobility and dynamic movement capabilities. A recent investigation has shown that hopping performance is lower in elderly males in comparison to young males. Therefore, the purpose of this investigation was to further examine specifically the lower leg, in terms of bone and muscle characteristics and associated strength and SSC capabilities of the ankle in young and elderly males.

METHODS: Moderately active young (n = 10; mean ± SD of age = 22.3 ± 1.3 yrs; 181 ± 7 cm; 90.3 ± 14.2 kg) and moderately active elderly (n = 8; mean ± SD of age = 67.5 ± 3.3 yrs; 175 ± 8 cm; 84.5 ± 11.0 kg) males volunteered to participate in the present investigation, which was approved by the Institutional Review Board. Subjects visited the Neuromuscular & Biomechanics laboratory on one occasion. Subject's height, body mass and lower leg anthropometrics were measured followed by a pQCT scan of the dominant lower leg. Subjects were then tested for maximal voluntary isometric plantar flexion force (MVIP) and then performed three trials of countermovement hops and drop hops from three different heights. Lower leg length was measured from the lateral malleolus of the fibula to the lateral head of the fibula. This measurement was utilized for determination of percentage locations during pQCT (Stratec Medizintechnik, Pforzheim, Germany) scanning. The scan started at the lateral malleolus of the fibula and scanned at 14%, 38% and 66% of the tibia, with 0% representing the lateral malleolus. Stress-strain index was measured at 14% and 38%. Ultimate fracture load (UFL) was calculated in the x- and y-plane at the 14% location. Lower leg muscle, fat and muscle+bone cross-sectional area (CSA) were obtained at the 66% location. MVIP force was measured utilizing a custom-made sled at an inclination of 20˚ with dual force plates (Bertec, Columbus, OH, USA). Subjects laid flat on the sled with a pad behind the knees and a strap just proximal of the patella in order to isolate the movement to only the ankle joint. Subjects were instructed to generate force at the ankle joint over a five-second duration with each foot on a force plate. Subjects performed a series of hops, remaining in the same experimental set-up on the custom-sled as in the MVIP. For completion of the countermovement hop (CMH), subjects were instructed to rise onto the toes and then quickly dorsiflex the ankles rapidly to generate force attempting to hop to a maximal height. Subjects then performed drop hops at 20 cm (DH20), 30 cm (DH30) and 40 cm (DH40). During all drop hops, an investigator would raise the carriage to 20, 30 or 40 cm, count to three and then release the carriage. Subjects were instructed that when their feet came into contact with the force plates to then quickly dorsiflex the ankles rapidly to generate force attempting to hop back upwards to a maximal height. Individual subject force- and velocity-time curves were re-sampled from original signals to 500 samples by changing time delta between samples for CMH, DH20, DH30 and DH40 trials with previously published methodology using a custom-designed LabVIEW program (National Instruments, Version 8.2, Austin, TX). Re-sampling data allowed for better representation and comparison of force- and velocity-time curves with equivalent time intervals expressed from 0-100% of the hop across all subjects. An average force-velocity curve from each hopping condition was then generated for each group. All statistical analysis was performed using SPSS version 12.0 (SPSS Inc., Chicago, IL, USA) and statistical significance was defined at an a priori value of $p \leq 0.05$.

RESULTS: There was a significant difference in age between the groups (young = 22.3 ± 1.3 yrs, elderly = 67.5 ± 3.3 yrs, $p \leq 0.05$, ES = 0.99). Height (young = 181 ± 7 cm, elderly = 175 ± 8 cm) and body mass (young = 90.3 ± 14.2 kg, elderly = 84.5 ± 11.0 kg), however, were not significantly different. The bone stress-strain index at 14% was significantly higher (ES = 0.36) in young subjects (Table 1). Muscle density, muscle CSA and muscle+bone CSA were significantly higher (ES = 0.64) in young compared to elderly subjects (Table 1). Maximal voluntary isometric plantarflexion peak force (MVIP PF) and rate of force development (MVIP RFD) were significantly higher (ES = 0.81) in young versus elderly subjects (Table 1). The statistically significant differences in the average force-velocity curves between young and elderly subjects for the countermovement hop (Figure 1A) and drop hops at 20 cm (Figure 1B), 30 cm (Figure 1C) and 40 cm (Figure 1D) are highlighted by the shaded grey areas. Peak force in the eccentric phase (PFECC), peak force in the concentric phase (PFCON), peak power in the concentric phase (PPCON), peak velocity (PV) and hopping height (HH) were all significantly higher in the young subjects for the countermovement hop (CMH) (ES = 0.59). PPCON, PV, HH and impulse (IMP) were significantly higher in young subjects during the 20 cm drop hop (DH20) (ES = 0.73). PFECC, PFCON, PPCON, PV, HH and IMP were all significantly higher in the young in comparison to the elderly group in the 30 cm drop hop (DH30) (ES = 0.59). PFECC, PPCON, PV, HH and IMP in the 40 cm drop hop (DH40) were significantly higher in the young subjects (ES = 0.81).

Table 1. Stress-strain index (SSI) at 14% of the length of the tibia (14% SSI), muscle density, muscle and muscle+bone cross-sectional area (CSA) from peripheral quantitative computed tomography (pQCT). Peak force (MVIP PF) and rate of force development (MVIP RFD) from maximal voluntary isometric plantarflexion.

Variable	Young (n = 10)	Elderly (n = 8)	p-value
14% SSI (mm^3)	2.49 ± 0.44	1.95 ± 0.39	0.02
Muscle Density ($mg•cm^{-3}$)	78.6 ± 1.9	72.7 ± 5.4	0.01
Muscle CSA (mm^2)	9.56 ± 1.22	8.23 ± 1.12	0.03
Muscle+Bone CSA (mm^2)	10.57 ± 1.34	9.10 ± 1.16	0.03
MVIP PF (N)	3,181 ± 312	1,952 ± 446	0.00
MVIP RFD ($N•s^{-1}$)	6,418 ± 1647	2,376 ± 1350	0.00

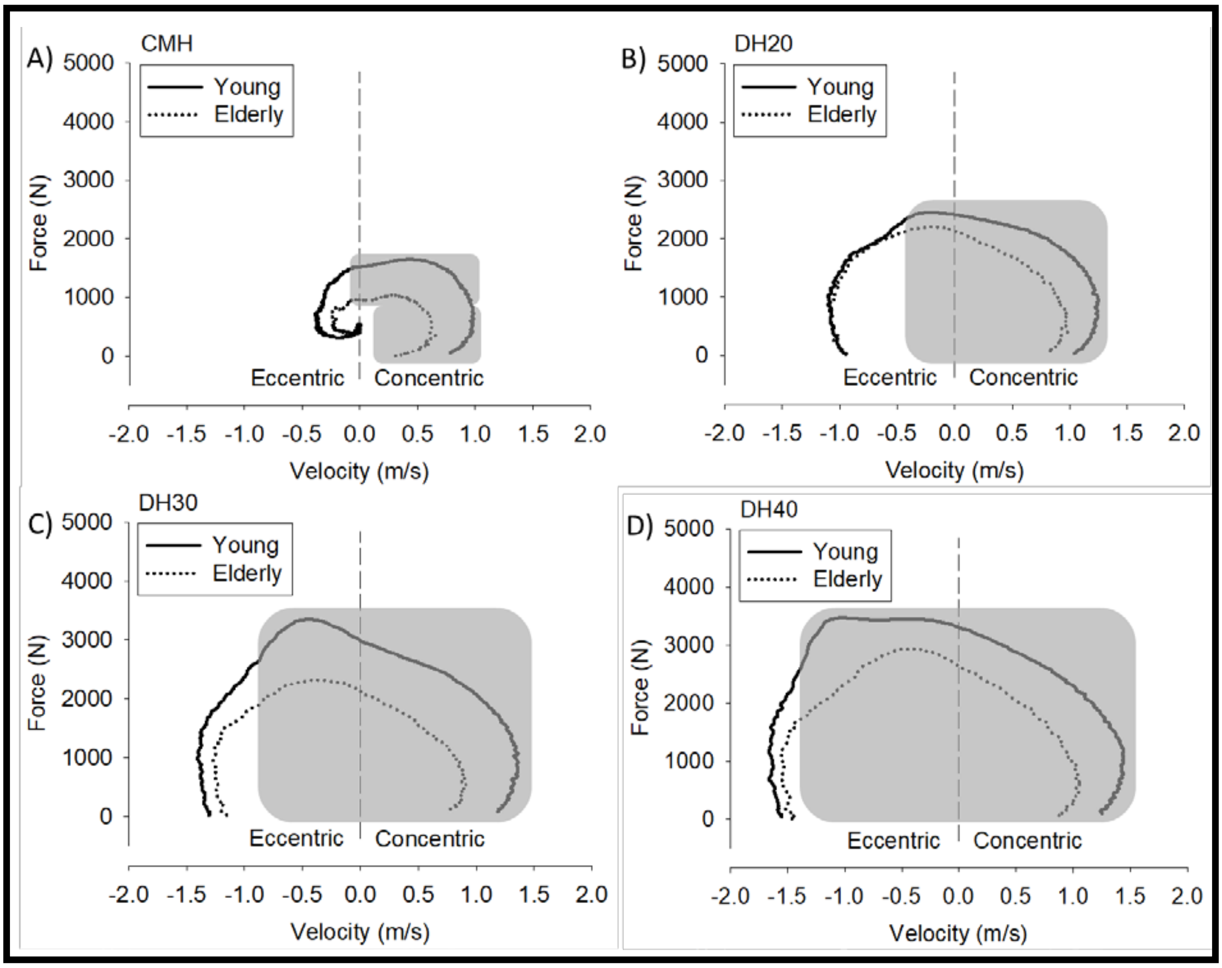

Figure 1: Average force-velocity curves for all subjects combined for A) the countermovement hop (CMH), B) the drop hop from 20 cm (DH20), C) the drop hop from 30 cm (DH30) and D) the drop hop from 40 cm (DH40). Grey boxes indicated areas of significant differences between the young and elderly groups (p ≤ 0.05).

DISCUSSION: The primary finding of the current investigation is that elderly males appear to have lower bone, muscle and maximal strength parameters measured in the lower leg. In addition, elderly males have significantly attenuated force-velocity profiles during isolated-joint (ankle) stretch-shortening cycles (SSC) than young males. The observed characteristics in the lower leg and ankle of elderly males may indicate that the ability to complete activities of daily living and quality of life in the ageing population maybe compromised. A previous study found that tibial cortical porosity and cortical bone mineral density were strongly associated with age. Both cortical and trabecular bone elements experience cellular and structural changes due to age, which thin and perforate the cortical and trabecular networks. This may be attributed to decaying osteoblastic bone remodelling abilities in the geriatric population, and thus, bone health may attenuate whole body function. A previous investigation involving a cohort of almost 6,000 elderly men demonstrated that leg muscle power and physical activity levels were strong contributors to positive bone strength levels (Cousins, Petit, Paudel, et al., 2010). Another investigation indicated that plantarflexion strength is a strong predictor of mobility, emphasizing the importance of identifying underpinning mechanisms of ageing (Stenroth, Sillanpaa, McPhee, et al., 2015). Muscle density has been reported to be independently associated with fall status. Therefore, muscle density might indicate the density of contractile elements within a muscle that assist with force generation in addition to bone strength to prevent injury. A novel finding from the current investigation is that young males have significantly greater muscle density than that of elderly males in the lower leg. Furthermore, muscle cross-sectional area (CSA), muscle+bone CSA and maximal voluntary isometric plantarflexion peak force and rate of force development were significantly higher in young males than elderly males. Force-velocity loops have previously been generated to identify differences in SSC ability between jumpers and non-jumpers during a countermovement jump. This study indicated attenuated force-velocity curves in non-jumpers in comparison to jumpers. In utilizing a hopping model, the ankle-joint is isolated and allows for specific examination of dynamic movement patterns. In the current study, the younger males hopped significantly higher in the countermovement and all drop hop tasks in addition to the larger eccentric and concentric force-velocity measures. Body movement is dependent upon motor cortex initiation to transition into muscle contraction, which transmits force through tendinous tissues, and ultimately, results in skeletal system action. Without appropriate bone strength levels to withstand operative force transmission from the muscles to the bones, risk of injury may increase.

CONCLUSION: The current investigation indicates that aging may possibly be associated with lower bone strength, less muscle mass and decreased muscle force capabilities of the lower leg. In addition, the stretch-shortening cycle capabilities of the ankle in elderly males may be compromised as well. Therefore, resistance and power exercise training protocols should be implemented to attenuate the decreases in these variables associated with aging to maintain physical performance capabilities.

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