

## Original Article

# Bone health, muscle properties and stretch-shortening cycle function of young and elderly males

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## Abstract

The aim of this study was to examine bone, muscle, strength and stretch-shortening cycle (SSC) performance in young and elderly individuals with an ankle model to elucidate potential effects of ageing that have been suggested to influence fall risk. Moderately active young (n=10; age=22.3±1.3 yrs) and elderly (n=8; age=67.5±3.3 yrs) males completed a peripheral quantitative computed tomography scan on the dominant lower leg, maximal voluntary isometric plantarflexions (MVIP) and SSC tasks: a countermovement hop and drop hops from three different heights. Bone stress-strain index at 14% of the lower leg and muscle density, muscle cross-sectional area and muscle+bone cross-sectional area at 66% of the lower leg were all significantly greater (p≤0.05) in younger males than elderly males. Younger males also had significantly greater rate of force development and peak force during the MVIP when compared to the elderly. Younger males achieved significantly higher forces, velocities and hop heights during all SSC tasks than elderly males. Such information provides support for greater specificity in exercise interventions that prevent lower leg morphological and functional decrements in the ageing population.

**Keywords:** Power, Hopping, Ankle, Ageing

## Introduction

The effect of ageing has been researched extensively to ascertain how this natural phenomenon might manifest in bone health, muscle quality and dynamic movement degradation<sup>1-4</sup>. Although less than post-menopausal females, males still experience a loss of ~1% bone mass per year after the age of 50<sup>5</sup>. Furthermore, cellular mechanisms to increase and maintain muscle mass begin to decay even in the active, ageing population, ultimately decreasing longevity<sup>6,7</sup>. The downstream effect of this reduction in muscle mass is the lessened capacity of the contractile elements as a whole to

generate force<sup>4</sup>. With age-associated strength decrements, quality of movement can also be affected, which has been shown in different types of stretch-shortening cycle (SSC) tasks compared between younger and older populations<sup>8</sup>, however, little information exists on how characteristics of the lower leg, in particular, differ between groups. Such knowledge is valuable, since proprioceptive feedback and reflex-loops concerning ankle position adjustment have been suggested to suffer in an elderly, high fall risk population<sup>9</sup>. The purpose of the current investigation was to compare young and elderly individuals by examining bone, muscle, strength and SSC performance in a single joint model to elucidate potential effects of ageing.

Osteoporosis and bone fracture risk is of serious concern in geriatric individuals<sup>5</sup>. However, efforts to determine and combat underpinning reasons for this issue are more prominent in females than males<sup>10</sup>; the overarching decline in bone health exists in both sexes due to ageing<sup>3</sup>. Mechanical loads imposed on the skeletal system during exercise are beneficial for prevention of age-related bone mineral density decrements<sup>11</sup>. For example, it was recently demonstrated that dancers possess higher tibial stress-strain indexes and

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ultimate fracture loads than their untrained counterparts as evaluated by peripheral quantitative computed tomography (pQCT)<sup>12</sup>. Levels of physical activity during developmental stages of life have in fact shown significant effects on bone health measures in older males<sup>13</sup>, indicating that prolonging bone demineralization begins early on. The aforementioned study found that elderly males who participated in high levels of physical activity during their youth possessed greater tibial cross-sectional area (CSA), bone failure load and bone stiffness than males with lower levels of physical activity<sup>13</sup>. Maintaining a healthy and active lifestyle is imperative for the elderly to preserve functionality and attenuate fracture risk, especially due to falls<sup>14</sup>. Thus, physical activity is promoted not only to improve bone health, but to also augment levels of muscle mass and muscle force output<sup>7</sup>.

About 10-15% of strength is lost every decade starting at the age of 30, however, these losses are not functionally noticeable until approximately 60 years of age<sup>4</sup>. Significant disparities in maximal strength levels have been observed in both isometric knee flexion<sup>15</sup> and isometric plantarflexion<sup>16</sup> between young and old males. Reasons for this have been attributed to the lower muscle CSA and the smaller size of type II muscle fibers in elderly individuals as well<sup>17</sup>. D'Antona and colleagues found contradicting results that only type I muscle fiber size was significantly lower in elderly males compared to younger males<sup>18</sup>. It was further reported that specific force, or tension, ( $P_o/CSA$ ) of type I, I-IIA and IIA muscle fibers were significantly less in elderly males than younger males<sup>18</sup>. Evidence suggests that several factors decline force generation capabilities of the aged sarcomere. One of the more prominent explanations is due to significantly lower fractions of myosin heads in strong-binding structural states during maximal isometric contraction, experimentally identified by site-specific electron paramagnetic resonance in old mice compared to young mice<sup>19</sup>. Other speculation that ATPase activity is inhibited by increased oxidative modifications to cysteine residues of myosin is reflected in the loss of  $P_o/CSA$  as well<sup>20</sup>. Thus, the apparent decline of strength in older individuals from in vivo and in vitro muscle might be attributed to impaired cross-bridge cycling<sup>20</sup>, rather than neural degeneration<sup>16</sup>. Similarly, maximal rate of torque development was drastically slower in older males than younger although motor unit firing rates were not significantly different between the groups<sup>16</sup>. While CSA at the muscle fiber and whole muscle level have shown differences between young and elderly males, no known data exists on comparison of muscle density levels in these populations.

Another area of interest in regards to ageing is the degeneration of movement efficacy, like running or jumping. When comparing young and elderly trained athletes, there is a prominent gap between these groups' SSC capabilities. Even in trained master long-distance runners, unmistakable disparity exists that jumping performance is lessened<sup>8</sup>. Some evidence suggests that there is an age-related inability to utilize elastic energy stored in the tendinous tissues during drop jumps<sup>21</sup>. The ensuing effect of this was observed in longer times to take-off and relative peak force. Recent

findings have indicated that isolated ankle-joint hopping performance (i.e. center of mass displacement and peak force) is also significantly lower in elderly males compared to young males<sup>22</sup>. While contact time has previously been measured in some of the aforementioned studies, impulse has never been compared between these groups performing a countermovement hop and drop hops. It may be that the force-velocity profiles of these groups are age-related and thus, hopping height may be dictated by such parameters for maximal SSC capabilities that could interrelate with fall risk prevention.

It is the authors' contention that measuring bone and muscle morphology, maximal strength and SSC performance in a single joint model might provide greater insight to the attenuated function of the ankle-joint in elderly individuals. This comparison is expected to clarify what some of the confounding variables for strength and dynamic performance might be between young and elderly groups. Furthermore, the findings of this study may present greater insight as to why fall risk might in part rely on ankle-joint function. It is hypothesized that bone and muscle measures, maximal strength levels and hopping performance will be significantly lower in elderly males than young males.

## Materials and methods

Moderately active young ( $n=10$ ; age=  $22.3\pm 1.3$  yrs; height=  $181\pm 7$  cm; body mass=  $90.3\pm 14.2$  kg) and moderately active elderly ( $n=8$ ; age=  $67.5\pm 3.3$  yrs; height=  $175\pm 8$  cm; body mass=  $84.5\pm 11.0$  kg) males volunteered to participate in the present investigation, which was approved by the Institutional Review Board. All subjects signed an informed consent form before participating in the investigation. All subjects were required to participate in at least one hour of weight bearing exercise three times per week and be healthy with no neuromuscular disease or lower limb musculoskeletal injury within the past 6 months. All young males performed some type of strength- and power-training (i.e. Olympic lifting, plyometrics, resistance training), whereas elderly males were generally participating in a combination of resistance and cardiovascular exercise. The authors were most interested in observing subjects whom participate regularly in weight bearing exercise to demonstrate the potential effects such type of training might have on the variables investigated. Subjects were asked to refrain from exercise 24 hours prior to testing, be well nourished and hydrated prior to testing, avoid alcohol within 12 hours of testing and avoid caffeine and tobacco within 3 hours of testing.

Subjects visited the Neuromuscular & Biomechanics Laboratory on one occasion for approximately 90 minutes. Subject's height, body mass and lower leg anthropometrics were measured followed by a pQCT scan of the functionally dominant lower leg. Subjects were then tested for maximal voluntary isometric plantarflexion force (MVIP) at the ankle joint while on a custom-made sled at an inclination of 20 degrees with a force plate as previously described by Rice, et

**Table 1.** Hopping performance variables for the countermovement hop (CMH) and drop hops at 20 cm (DH20), 30 cm (DH30) and 40 cm (DH40): peak force eccentric (PF<sub>ECC</sub>), peak force concentric (PF<sub>CON</sub>), peak power eccentric (PPECC), peak power concentric (PPCON), peak velocity (PV), hopping height (HH) and impulse (IMP).

| Hop Type                | CMH            |                 | DH20           |                 | DH30           |                 | DH40           |                 | P-value   |       |
|-------------------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|-----------|-------|
|                         | Young (n = 10) | Elderly (n = 8) | Young (n = 10) | Elderly (n = 8) | Young (n = 10) | Elderly (n = 8) | Young (n = 10) | Elderly (n = 8) | Condition | Group |
| PF <sub>ECC</sub> (N)   | 1,632±552*     | 1,084±278       | 2,668±543      | 2,363±276       | 3,431±832*     | 2,600±557       | 4,179±1311*    | 3,102±53        | 0.02      | 0.04  |
| PF <sub>CON</sub> (N)   | 1,763±461*     | 1,209±212       | 2,502±378      | 2,341±287       | 3,149±561*     | 2,440±531       | 3,400±564      | 2,929±442       | 0.03      | 0.03  |
| PP <sub>ECC</sub> (W)   | -477±300       | -251±195        | -1,754±537     | -1,628±255      | -2,720±803     | -2,069±469      | -4,194±2138    | -2,860±463      | 0.07      | 0.08  |
| PP <sub>CON</sub> (W)   | 1,262±459*     | 627±205         | 1,849±462*     | 1,241±392       | 2,256±594*     | 1,239±431       | 2,538±668*     | 1,460±378       | 0.06      | <0.00 |
| PV (m·s <sup>-1</sup> ) | 1.05±0.21*     | 0.72±0.15       | 1.31±0.17*     | 1.07±0.21       | 1.42±0.17*     | 1.05±0.21       | 1.53±0.15*     | 1.12±0.17       | 0.26      | <0.00 |
| HH (m)                  | 0.11±0.04*     | 0.07±0.02       | 0.16±0.04*     | 0.11±0.04       | 0.18±0.05*     | 0.11±0.05       | 0.19±0.03*     | 0.12±0.04       | 0.26      | <0.00 |
| IMP (N·s)               | 206 v 26       | 183±22          | 238±25*        | 209±32          | 241±30*        | 204±29          | 255±28*        | 204±29          | 0.15      | <0.00 |

\* Indicates statistically significant difference between young and elderly ( $p \leq 0.05$ ).

al.<sup>12</sup>. Subjects then performed a series of countermovement hops and drop hops on the same custom-made sled<sup>12</sup>.

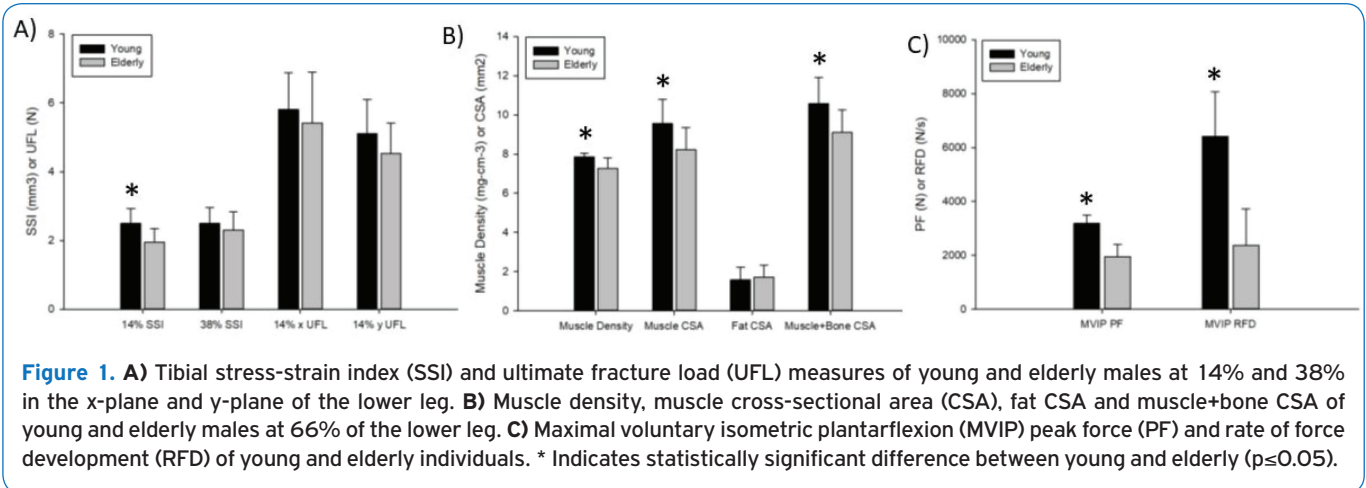
Lower leg length was measured from the lateral malleolus of the fibula to the lateral head of the fibula. This measurement was utilized for determination of percentage locations during pQCT (Stratec Medizintechnik, Pforzheim, Germany) scanning. The subject placed their dominant lower leg into the device and sat motionless while an 8- to 12-minute scan was performed (voxel size of 0.50 mm and measuring speed of 20 mm/sec). 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. Ultimate fracture load (UFL) was calculated in the x- and y-plane at the 14% location. Stress-strain index (SSI) was measured at the 14% and 38%. Lower leg muscle, fat and muscle + bone CSA were obtained at the 66% location. All morphological scans were analyzed by one trained technician according to the described manufacturer's protocol.

MVIP force was measured utilizing a custom-made sled at an inclination of 20° with dual force plates (Berotec, Columbus, OH, USA)<sup>12</sup>. Force plate analog signals were converted to a digital signal (NI PCI-6014, National Instruments, Austin, TX) with a BNC-2010 interface box at a 1,000 Hz sampling rate. 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. Two-minute rest periods were provided between trials, with three trials completed. The trial of each subject with the highest peak force was used for analysis. Data were collected and analyzed in a custom-designed LabVIEW program (National Instruments, Version 8.2, Austin, TX).

Subjects performed a series of hops, remaining in the same experimental set-up on the custom-sled as in the MVIP at a 20° incline<sup>12</sup>. The knees of the subjects remained tethered to a fixed position on the sled so that the knee joint could not contribute to the hopping performance.

Subjects were familiarized with the hopping protocols and three to five practice hops were performed prior to actual data collection. For completion of a countermovement hop (CMH), subjects were instructed to rise onto the toes and hold for three seconds before dorsiflexing the ankles rapidly and then generate force into a plantarflexed position to hop to a maximal height. Subjects then performed drop hops at 20 cm (DH20), 30 cm (DH30) and 40 cm (DH40) respectively for each individual's height. 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 to rapidly generate force when their feet came into contact with the force plates into a plantarflexed position, attempting to hop back upwards to a maximal height. Two-minute rest periods were provided between trials, with three trials completed for each type of hop. Subjects' highest hop height was used for further analysis. A potentiometer (Celesco, Chatsworth, CA, USA) attached to the custom-made sled was used to calculate displacement and provided hopping height (HH) measurements. Our laboratory has previously established intra-class correlation coefficients (ICC) above the minimum acceptable criterion (CMH=0.94; DH20=0.79; DH30=0.91; DH40=0.85)<sup>12</sup>. The concentric phase of each hop was described as the upward slope of the displacement-time curve from maximal depth until the force-time curve returned to zero. The eccentric phase of each hop was described as the downward slope of the displacement-time curve from the time at which the force-time curve exceeded zero to the change in direction of the displacement-time curve. Impulse (IMP) was defined as the integration of force and time from the concentric phase. Peak force (PF) was determined as the maximal force during the concentric phase. Forward dynamics was used to obtain a velocity-time curve from force plate data, which allowed for determination of peak velocity (PV) and peak power (PP) from the product of force and velocity.

Individual force- and velocity-time curves were re-sampled from original signals to 500 samples by changing time delta<sup>23</sup>



between samples for CMH, DH20, DH30 and DH40 trials with previously published methodology<sup>24</sup> 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. A very strong intra-subject test-retest reliability for average force- and velocity-time curves has been formerly established in our laboratory (ICC=0.96)<sup>24</sup>.

All statistical analysis was performed using SPSS version 24.0 (SPSS, Inc. Chicago, IL, USA) and an *a priori* level of significance was set at 0.05. Age, height, body mass, MVIP, and pQCT measures were compared using independent samples t-tests. Effect sizes were computed as Cohen's *d* and interpreted as small (0.20), medium (0.50) and large (0.80). A series of two-way factorial analyses of variance were used to compare hopping variables across condition (CMH, DH20, DH30, DH40) and groups (young, elderly). Partial eta squared effect sizes for each analysis were computed as small (0.01), medium (0.06), and large (0.14). Statistical Parametric Mapping was also implemented using a general linear model univariate analysis of variance for each set of data in the respective average force- and velocity-time curves to determine areas of significant difference between groups during each hopping condition<sup>11,24</sup>.

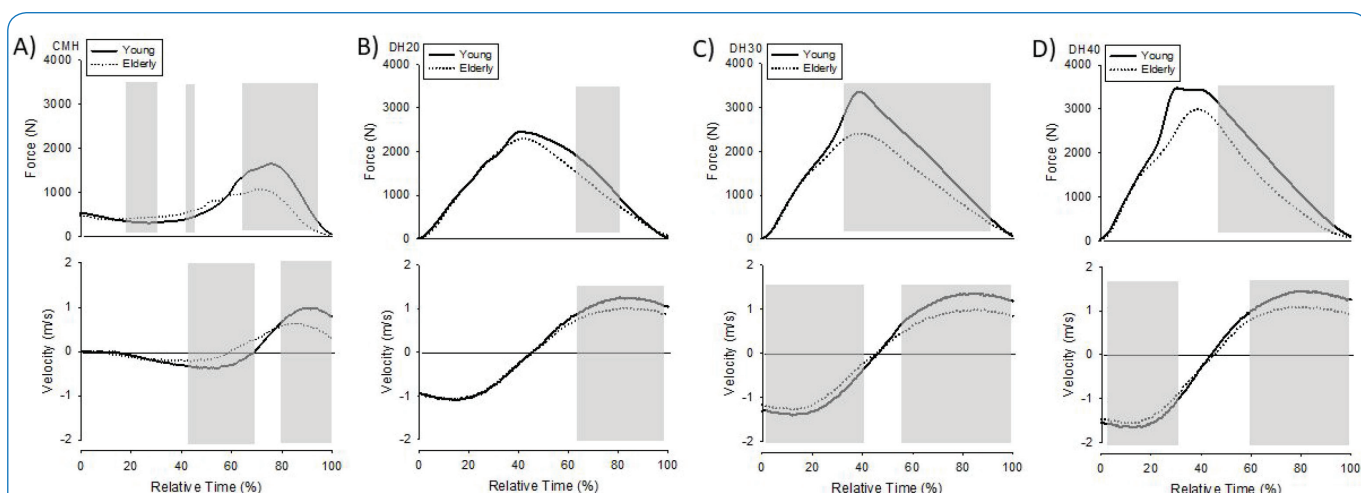
## Results

There was a significant difference in age between the groups (young= 22.3±1.3 yrs, elderly= 67.5±3.3 yrs,  $p=0.00$ ,  $d=19.70$ ). 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 SSI at 14% was significantly higher ( $p=0.02$ ,  $d=1.28$ ) in young subjects (Figure 1A). Muscle density ( $p=0.01$ ,  $d=1.59$ ), muscle CSA ( $p=0.03$ ,  $d=1.13$ ) and muscle + bone CSA ( $p=0.03$ ,  $d=1.17$ ) were significantly higher in young

compared to elderly subjects (Figure 1B). MVIP PF ( $p=0.00$ ,  $d=3.24$ ) and MVIP RFD ( $p=0.00$ ,  $d=2.70$ ) were significantly higher in young versus elderly subjects (Figure 1C).

For peak force in the eccentric phase (PF<sub>ECC</sub>), significant group-by-condition interaction effects were observed ( $F_{3,48}=3.53$ ,  $p=0.02$ ,  $\eta^2=0.18$ ), as was a significant main effect of group ( $F_{1,16}=5.32$ ,  $p=0.04$ ,  $\eta^2=0.25$ ). Post-hoc comparisons revealed significant differences between groups for the CMH ( $p=0.02$ ), DH30 ( $p=0.03$ ), and DH40 ( $p=0.05$ ). For peak force in the concentric phase (PF<sub>CON</sub>), significant group-by-condition interaction effects were observed ( $F_{3,48}=3.30$ ,  $p=0.03$ ,  $\eta^2=0.17$ ), as was a significant main effect of group ( $F_{1,16}=6.59$ ,  $p=0.02$ ,  $\eta^2=0.29$ ). Post-hoc comparisons revealed significant differences between groups for the CMH ( $p=0.01$ ) and DH30 ( $p=0.02$ ). For peak power in the eccentric phase (PPECC), no significant group-by-condition interaction effects were observed ( $F_{3,48}=2.49$ ,  $p=0.07$ ,  $\eta^2=0.14$ ), nor was a significant main effect of group observed ( $F_{1,16}=3.43$ ,  $p=0.08$ ,  $\eta^2=0.18$ ). For peak power in the concentric phase (PPCON), no significant group-by-condition interaction effects were observed ( $F_{3,48}=2.61$ ,  $p=0.06$ ,  $\eta^2=0.14$ ). However, a significant main effect of group was observed where young had greater PPCON than the elderly ( $F_{1,16}=20.47$ ,  $p<0.00$ ,  $\eta^2=0.56$ ) for the CMH ( $p=0.01$ ), DH20 ( $p=0.01$ ), DH30 ( $p=0.00$ ) and DH40 ( $p=0.00$ ). For PV, no significant group-by-condition interaction effects were observed ( $F_{3,48}=1.38$ ,  $p=0.26$ ,  $\eta^2=0.08$ ). A significant main effect of group was observed where young had greater PV than the elderly ( $F_{1,16}=24.71$ ,  $p<0.00$ ,  $\eta^2=0.61$ ) during the CMH ( $p=0.00$ ), DH20 ( $p=0.01$ ), DH30 ( $p=0.01$ ) and DH40 ( $p=0.00$ ). For HH, no significant group-by-condition interaction effects were observed ( $F_{3,48}=1.38$ ,  $p=0.26$ ,  $\eta^2=0.08$ ). A significant main effect of group was observed where young hopped higher than the elderly ( $F_{1,16}=24.71$ ,  $p<0.00$ ,  $\eta^2=0.61$ ) during the CMH ( $p=0.01$ ), DH20 ( $p=0.03$ ), DH30 ( $p=0.01$ ) and DH40 ( $p=0.00$ ). For IMP, no significant group-by-condition interaction effects were observed ( $F_{3,48}=1.87$ ,



**Figure 2.** A) Average force- and velocity-time curve comparison during a countermovement hop (CMH) between young and elderly males. B) Average force- and velocity-time curve comparison during a 20-cm drop hop (DH20) between young and elderly males. C) Average force- and velocity-time curve comparison during a 30-cm drop hop (DH30) between young and elderly males. D) Average force- and velocity-time curve comparison during a 40-cm drop hop (DH40) between young and elderly males. \*Shaded gray areas indicate statistically significant difference between young and elderly ( $p \leq 0.05$ ).

$p=0.15$ ,  $\eta^2=0.11$ ), but a significant main effect of group was observed where young had greater IMP than the elderly ( $F_{1,16}=10.92$ ,  $p=0.00$ ,  $\eta^2=0.41$ ). Post-hoc comparisons revealed significant differences between groups for the DH20 ( $p=0.05$ ), DH30 ( $p=0.02$ ) and DH40 ( $p=0.00$ ). The statistically significant differences in the average force- and velocity-time curves between young and elderly subjects for the CMH (Figure 2A) and DH20 (Figure 2B), DH30 (Figure 2C) and DH40 (Figure 2D) are highlighted by the shaded grey areas.

## Discussion

The primary finding of the current investigation is that elderly males generate significantly lower forces and velocities during isolated-joint stretch-shortening cycle actions than young males. The obtained results during countermovement and drop hopping are additionally supported by the lower bone, muscle and maximal strength parameters measured in the lower leg of elderly males for the present study. Such information might provide support for more specific exercise interventions for prevention of the observed decrements to maintain the capability to complete activities of daily living and quality of life in the ageing population. 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<sup>25</sup>. In a study by Stenroth, et al., they showed that plantarflexion strength is a strong predictor of mobility, emphasizing the importance of identifying underpinning mechanisms of ageing<sup>26</sup>. Thus, our results further support past findings that have classified different variables, which indicate health status in the elderly.

Age has been formerly established as the most influential factor on bone microstructure of men ranging from 50-84 years of age<sup>23</sup>. More specifically, the previous study found that tibial cortical porosity and cortical bone mineral density were strongly associated with age. However, both cortical and trabecular bone elements experience cellular and structural changes due to age, which thin and perforate the cortical and trabecular networks<sup>27</sup>. It is suggested that this is attributed to decaying osteoblastic bone remodeling abilities in the geriatric population, and thus, bone health attenuates whole body function<sup>27</sup>. 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. The present findings suggest that, overall, younger males possess greater stress-strain index and ultimate fracture load levels of the tibia. Evidence has also shown that higher trabecular and cortical BMD levels are related to greater muscle density of the lower leg<sup>28</sup>.

Muscle density has been reported to be independently associated with fall status<sup>29</sup>. 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 CSA, muscle + bone CSA and MVIP PF and RFD were significantly higher in young males than elderly males. It is the authors' contention that lower leg morphology and functional characteristics are interrelated and vary due

to age. In particular, a drastic gap existed in RFD capabilities between groups. One could speculate that the accumulation of reactive oxygen and nitrogen species in the ageing muscle that induce sarcopenia might also defect shortening velocity of the myofibril<sup>20</sup>. As mentioned, impaired cross-bridge cycling has been observed in geriatric human muscle, which in turn, would inhibit the muscle's ability to quickly develop force and realize movement<sup>20</sup>. With altered mechanical function of the muscle, dynamic performance is concurrently observed to suffer in older individuals.

The present study found that operative forces and velocities differed between young and elderly males during several SSC tasks. In utilizing a hopping model, the ankle-joint is isolated and allows for specific examination of dynamic movement patterns. The younger males hopped significantly higher in the countermovement and all drop hop tasks in addition to what appears to be predominantly larger concentric force and velocity measures. Force-velocity loops have previously been generated to identify differences in SSC ability between jumpers and non-jumpers during a countermovement jump<sup>30</sup>. Similar findings unveiled that the greater area beneath the curves coincided with superior CMJ performance<sup>30</sup>. Peak velocity, impulse and concentric phase peak power were also greater across all hopping tasks in young males than elderly males. These parameters have each been reported to predict and contribute to center of mass displacement during SSC actions in different populations<sup>12,31</sup>. It may be that muscle-tendon characteristics and interaction, which dictate movement proficiency, may significantly decline with age. Tendon stiffness during hopping between young and elderly individuals has been compared by Hoffrén and colleagues, who found that the elderly group had significantly lower values from 75% to maximal hopping intensities<sup>2</sup>. Peak Achilles tendon force was also significantly lower in the elderly group during maximal hopping. It has further been reported that triceps surae complex characteristics (i.e. soleus pennation angle, Achilles tendon stiffness) are associated with mobility levels, which are commonly measured to determine fall risk<sup>26</sup>. The links between biomechanical measures and SSC performance have shown in the present investigation to be influenced by age as well.

In conclusion, it appears that geriatric males experience losses of lower leg bone, muscle and movement proficiency. The aim of the current study was to more precisely observe ankle-joint function of young and elderly males, as the ankle and the surrounding muscle-tendon properties contributes to fall risk in the older populations. Preservation of bone health, muscle quality and stretch-shortening cycle capabilities is of utmost importance as individuals age to prevent such increases in risk of falling. Although this study was limited with a small sample size, it is the first to ever holistically compare morphological and mechanical properties between young and elderly males with a single-joint model. With this information, exercise scientists and clinicians should seek to implement exercise interventions that induce muscle hypertrophy, are osteogenic in nature and preserve dynamic movement in the elderly.

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