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Original Article

Muscle and Myotendinous Tissue Properties at the Distal Tibia as Assessed by High-Resolution Peripheral Quantitative Computed Tomography

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Abstract

High-resolution peripheral quantitative computed tomography (HR-pQCT) quantifies bone microstructure and density at the distal tibia where there is also a sizable amount of myotendinous (muscle and tendon) tissue (M_T); however, there is no method for the quantification of M_T. This study aimed (1) to assess the feasibility of using HR-pQCT distal tibia scans to estimate M_T properties using a custom algorithm, and (2) to determine the relationship between M_T properties at the distal tibia and mid-leg muscle density (MD) obtained from pQCT. Postmenopausal women from the Hamilton cohort of the Canadian Multicenter Osteoporosis Study had a single-slice (2.3 ± 0.5 mm) 66% site pQCT scan measuring muscle cross-sectional area (MCSA) and MD. A standard HR-pQCT scan was acquired at the distal tibia. HR-pQCT-derived M_T cross-sectional area (M_TCSA) and M_T density (M_TD) were calculated using a custom algorithm in which thresholds (34.22–194.32 mg HA/cm^3) identified muscle seed volumes and were iteratively expanded. Pearson and Bland-Altman plots were used to assess correlations and systematic differences between pQCT- and HR-pQCT-derived muscle properties. Among 45 women (mean age: 74.6 ± 8.5 years, body mass index: 25.9 ± 4.3 kg/m^2), M_TD was moderately correlated with mid-leg MD across the 2 modalities (r = 0.69–0.70, $p < 0.01$). Bland-Altman analyses revealed no evidence of directional bias for M_TD-MD. HR-pQCT and pQCT measures of M_TCSA and MCSA were moderately correlated (r = 0.44, $p < 0.01$). Bland-Altman plots for M_TCSA revealed that larger MCSAs related to larger discrepancy between the distal and the mid-leg locations. This is the first study to assess the ability of HR-pQCT to measure M_T size, density, and morphometry. HR-pQCT-derived M_TD was moderately correlated with mid-leg MD from pQCT. This relationship suggests that distal M_T may share common properties with muscle throughout the length of the leg. Future studies will assess the value of HR-pQCT-derived M_T properties in the context of falls, mobility, and balance.

Key Words: Cross-sectional area; HR-pQCT; muscle and myotendinous tissue density; pQCT.

Introduction

Skeletal muscle plays a key role in activities of daily living and is essential for maintaining posture, balance, and bone health. Sarcopenia, the age-related decline in muscle mass and function, is associated with increased risk of falls, fractures, hospitalization, and mortality *(1–3)*. Muscle imaging has the potential to play an important role in understanding the etiology of age-related musculoskeletal conditions, such as sarcopenia, in addition to examining the efficacy of interventions aimed at improving or maintaining musculoskeletal health. Recently, efforts have been made

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to quantify muscle using full-body dual-energy X-ray absorptiometry (DXA) and peripheral quantitative computed tomography (pQCT). DXA provides an estimation of total body lean mass or appendicular (upper and lower limb) lean mass *(4)*. With aging and with chronic conditions such as diabetes or chronic obstructive pulmonary disease, not only is there a loss of muscle mass, but also there is increased fat infiltration into muscles, which may decrease muscle function *(5,6)*. A higher amount of fatty infiltration as previously measured using magnetic resonance imaging (MRI) is reflected by a drop in muscle density (MD) of up to 49.3% *(7)*. When inter- or intramuscular fat is reduced, that is, higher MD, muscle strength and physical function can improve *(8)*. MD is therefore an important modifiable characteristic of muscular health. Together, measures of MD and muscle cross-sectional area (MCSA) could be summarized as muscle "quality." Similar to bone, there are emerging concepts regarding muscle quality and aging, with muscle quality being an important aspect of overall muscle health. Although DXA provides a reliable estimation of lean mass, it cannot assess MD or MCSA and, therefore, is unable to directly examine muscle quality.

pQCT is another imaging tool that although most commonly used to determine bone parameters can also quantify muscle densities and morphometry at the radius and tibia *(9–11)*. pQCT had been found to reliably (<5% test-retest error) quantify MD and MCSA *(10)*. Studies of adults have predominantly examined skeletal muscle parameters from scans acquired at the 66% tibia; however, others have examined the 38% or 55% sites *(12–16)*. Smaller MCSA and lower MD have been associated with frailty and mortality in older adults *(17)*. pQCT is limited by its lower resolution (200 μm) compared with high-resolution peripheral quantitative computed tomography (HR-pQCT; 82 μm), and achieves only a single slice per acquisition compared with a stack of 110 slices using HR-pQCT. Furthermore, because of longer duration of scans, pQCT scans are generally more prone to motion artifact, thus limiting the accuracy of MD measurements.

Although DXA and pQCT provide meaningful estimates of muscle properties, no studies to date have examined sites where muscle transitions into tendon. These sites such as at the ankle are potentially important because they are close to the insertion site into the bone and may play a key biomechanical role. It is unknown what myotendinous (muscle and tendon) tissue (M_T) properties are like in older adults and how muscles at proximal locations in the leg are related to the M_T properties at the distal aspect of the muscle. Furthermore, studying a combination of muscle and tendon tissue may enable a better understanding of how they relate to mobility and joint stabilization.

HR-pQCT is a leader in in vivo bone microstructure quantification at the distal tibia and radius. Although second-generation scanners can now examine more proximal locations, most studies to date used the first-generation scanner, which examined only the distal radius and tibia. Based on already collected distal tibia scans, there is potential to measure M_T properties at the same site; however, currently, there is no established segmentation method to assess soft tissue parameters using HR-pQCT. Therefore, the purpose of this investigation was (1) to assess the feasibility of using standard HR-pQCT distal tibia measures to estimate M_T density, area, and volume using a newly designed custom algorithm; and (2) to determine the relationship between M_T properties derived from HR-pQCT at the lower leg and MD and MCSA obtained from pQCT at the mid-leg.

Methods

Participants

Participants were drawn from the Hamilton cohort of the Canadian Multicenter Osteoporosis Study (CaMos). The design and participant recruitment of CaMos have been described in detail elsewhere *(18)*. In brief, CaMos is an ongoing, prospective cohort study of 9423 community-dwelling, randomly selected women (6539) and men (2884), ≥25 years of age at baseline, and living within 50 km of 9 Canadian cities (St. John's, Halifax, Quebec City, Toronto, Hamilton, Kingston, Saskatoon, Calgary, and Vancouver). The present analysis included postmenopausal women older than 50 years who had previously completed both an HR-pQCT (XtremeCT I, Scanco Medical AG, Bruettisellen, Switzerland) and a pQCT (XCT2000, Stratec Medizintechnik, Pforzheim, Germany) scan and resided within 50 km of the Hamilton study center (n = 45), drawn from an initial pool of 340 participants *(10)*.

Anthropometry

Anthropometric measures included height and weight. Height was recorded to the nearest 0.1 cm using a standard physician scale. Weight was measured on a calibrated scale to the nearest 0.5 kg. Body mass index (BMI) was then calculated as weight divided by height squared (kg/m^2).

Physical Performance Measures

Timed up and go (TUG) is a test that measures functional mobility *(19)*. Participants sat on a standard 46-cm-tall chair with their back touching the backrest. Participants were then instructed to stand up, walk to a 3 m mark on the ground, turn and walk back to the chair, and sit down again. They were asked to perform the whole task as quickly as possible, but without running. The time required to complete the task was measured by a stopwatch to the nearest second, which was started once the participants initiated movement and stopped when they were seated again. A longer time to complete the test is related to lower function. This test is commonly used in assessing the general mobility status in older adults and has high test-retest reliability *(20)*.

Muscle and Myotendinous Assessment

A 2.3 ± 0.5 mm thick transaxial slice of the non-dominant tibia was obtained by pQCT (XCT 2000, Stratec