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Original Article

Lean Soft Tissue Mass Measured Using Dual-Energy X-Ray Absorptiometry Is an Effective Index for Assessing Change in Leg Skeletal Muscle Mass Following Exercise Training

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Abstract

It is difficult to precisely and easily estimate the changes in skeletal muscle mass (SMM) following exercise training. We aimed to assess whether the change in lean soft tissue mass measured using dual-energy X-ray absorptiometry (DXA) reflects the change in SMM measured using magnetic resonance imaging (MRI) following exercise training in both the leg and trunk regions. Anthropometry, DXA, and MRI measurements of the trunk and leg regions were obtained in 10 male college sumo wrestlers before and after exercise training (mean duration between measurements: ~2 yr). Contiguous magnetic resonance images with 1-cm slice thickness and without gap were obtained from the first cervical vertebra to the ankle joints as reference data. Skeletal muscle volume was calculated from the summation of the digitized cross-sectional areas. The volume measurements were converted into mass by using an assumed skeletal muscle density (1.041 g/cm^3). Trunk and leg areas, using DXA regional computer-generated lines, were adjusted to coincide with each discrete region by using MRI. Although the change in the DXA-measured lean soft tissue mass in the trunk region was significantly different from that of the MRI-measured SMM (Cohen's d = −1.3145, concordance correlation coefficient = 0.26, $p < 0.01$), the changes were similar in the leg region (Cohen's d = 0.07, concordance correlation coefficient = 0.87, $p = 0.88$). The exercise training-induced change in lean soft tissue mass significantly correlated with that in SMM, both in the leg ($r = 0.88, p < 0.01$) and trunk ($r = 0.64, p < 0.05$) regions. Bland–Altman analysis did not indicate a bias for the changes in leg lean soft tissue mass and SMM following exercise training. These results suggest that lean soft tissue mass measured using DXA is an effective index for assessing change in leg SMM following exercise training.

Key Words: dual X-ray absorptiometry; magnetic resonance imaging; skeletal muscle mass.

Introduction

It is well-known that skeletal muscle mass (SMM) is approx 40% of fat-free mass (FFM) *(1,2)*. Moreover, it has been repeatedly reported that FFM is strongly associated with SMM *(1,3,4)*. In these previous studies, FFM has been used as the index of the change in SMM following exercise training. However, it is mostly unknown whether the change in FFM following exercise training is related to the change in SMM.

Currently, magnetic resonance imaging (MRI) is considered the most precise, most reliable, and safest method

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for measuring the change in SMM before and after exercise training. However, MRI has the disadvantage of needing a long duration of scan and image analysis (i.e., whole-body scan takes about 30 min and the subsequent image analysis can take up to 5 h). Dual-energy X-ray absorptiometry (DXA) is a potential alternative to MRI for estimating total and regional SMM. Whole-body DXA scans take about 3 min, and analyses can be completed within 3 min.

DXA enables concurrent estimation of total and regional lean soft tissue mass (LSTM), bone mineral content, and fat mass in a single assessment. As the legs consist mostly of SM, bone, and fat, the LSTM of the leg region could be representative of the SMM of this region. Therefore, it is theoretically possible that, for the leg region, LSTM estimated using DXA reflects SMM measured using MRI following exercise training, and investigating this possibility was the first step in this research. On the other hand, as the trunk includes internal organs, the LSTM of the trunk region is not representative of only the SMM. Moreover, it is difficult to accurately estimate the change in SMM especially in the trunk region at the present time. However, the change in LSTM following exercise training might reflect the SMM, which is mainly stimulated by exercise training. Therefore, we explored the possibility of this estimation for the trunk region as a second step in this research. Thus, the present study aimed to assess whether the change in LSTM measured using DXA reflects the change in SMM measured using MRI following exercise training both in the leg and trunk regions.

Materials and Methods

Subjects

Ten male college sumo wrestlers were recruited for the study. These college sumo wrestlers had participated in regular training (“Kei-ko”) for >10 yr. Kei-ko normally consists of wrestling exercises and additional technical drills that include a mix of power, agility, and endurance training *(5)*. Moreover, Kei-ko does not target specific muscles but trains whole-body muscles for proper balance. Anthropometry, DXA, and MRI measurements for the trunk and leg regions were longitudinally obtained before and after exercise training (mean length of time between measurements: about 2 yr). None of the subjects had a history of cardiovascular, endocrine, or orthopedic disorders, nor had they ever tested positive for anabolic steroids or taken any medication during the given measurement time. Because the subjects did not perform any exercise for >48 h before the measurements, the density and hydration of skeletal muscles (SMs) and other organ tissues were stable in each subject. This study followed the guidelines of the Declaration of Helsinki, and the Ethical Committees of Waseda University and National Institute of Health and Nutrition approved all procedures involving human subjects/patients. Written informed consent was obtained from all subjects before testing.

Anthropometric Measurements and LSTM Measured Using DXA

Body mass was measured to the nearest 0.1 kg by using a digital scale, with the subjects wearing only minimal clothing. Height was measured to the nearest 0.1 cm by using a stadiometer. Body mass index was calculated as body weight in kilograms per square of height in meters (kg/m^2) (Table 1).

Regional LSTM was measured using DXA (Delphi A-QDR, version 12.4.3 Auto Whole Body Fan Beam, which provides no correction factor for body thickness; Hologic Inc., Bedford, MA; Table 2). LSTM images were separated into discrete regions using anatomical landmarks that were visible in the scanned images. The trunk region was defined as the area from the first cervical vertebra to the femoral neck, which excluded the arm region from the axillary fossa to the end of the fingers. The leg region was defined as the area from the femoral neck to the malleolus lateralis. By using the customized subregion of interest (ROI) of the DXA scan, each area was adjusted to coincide with the discrete regions of MRI. The estimated

Table 1
Characteristics of Subjects Before and After Exercise Training

	Before	After	Change	Range
Age (yr)	19 ± 1	21 ± 0	2 ± 1	-
Standing height (cm)	171.7 ± 4.9	-	-	-
Body mass (kg)	101.7 ± 13.5	104.7 ± 14.4	2.9 ± 5.4	−6.8 to 9.0
BMI (kg/m^2)	34.5 ± 4.2	35.2 ± 4.3	0.7 ± 1.7	−2.5 to 2.5
Fat (%)	23.7 ± 4.7	25.9 ± 4.7	2.2 ± 3.6	−3.2 to 7.6
Fat mass (kg)	24.6 ± 7.8	27.6 ± 8.8	3.0 ± 4.8	−3.3 to 8.2
Fat-free mass (kg)	77.1 ± 7.8	77.1 ± 7.5	0.0 ± 2.4	−4.3 to 4.8

Note: Data are presented as mean ± standard deviation.
Abbr: BMI, body mass index.