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Original articles

ASSOCIATION OF CT-ESTIMATED LUMBAR BONE MINERAL DENSITY AND FATTY INFILTRATION OF PSOAS MUSCLE IN A YOUNG AND MIDDLE AGE POPULATION

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Aims: Age-related changes of bones and skeletal muscles were investigated in previous studies. The aim of our study was to determine the possible association of CT-estimated lumbar spine bone density and psoas major muscle changes in a young and middle-aged population, in whom the age-related changes are not considerably advanced. We also investigated to which extent the iodine contrast affected bone and muscle attenuation.

Methods: Baseline and CT imaging data of patients aged 18 to 49 years, who underwent a multiphasic abdominopelvic CT exam at the University Hospital Split from July to December 2021, were retrospectively retrieved. CT attenuation values, Hounsfield Units (HU), of lumbar spine and psoas major muscle were measured at the level of L4 on native (precontrast), arterial and venous postcontrast scans.

Results: The mean age of 113 included patients was 40.61 years, 51.33% were men. CT attenuation values of lumbar spine and psoas major muscle correlated. The highest correlation was found between age and L4, while the correlation between age and psoas muscle was somewhat weaker. No significant differences were observed between the sexes, except higher L4 HU in women. The application of iodine contrast significantly increased HU, with a mean increase of nearly 12% at lumbar spine and 18-26% at psoas muscle.

Conclusion: CT attenuation values of lumbar spine and psoas major muscle correlate in young and middle-aged population. Age-related changes were somewhat stronger in bones than in muscles. Iodine contrastysignificantly increases the HU of both bone and muscle.

Keywords: CT, BONE MINERAL DENSITY, CONTRAST MEDIA, PSOAS MAJOR MUSCLE

INTRODUCTION

Osteoporosis is a disease of reduced bone density and increased bone fragility. Fractures due to osteoporosis cause global health problem, especially in the elderly population (1). Dual-energy x-ray absorptiometry (DXA) is the most preferred method for measuring bone mineral density (BMD) due to the simplicity of the technique and low doses of radiation exposure (2). However, DXA can be inaccurate in cases of severe degeneration of the spine, scoliosis or after spine surgery, which is not the case with computerized tomography (CT) measurements, because itocan measure the trabecular part of the bone (3). In recent decades, the idea of opportunistic CT estimation of BMD has been broadly introduced, showing an excellent correlation with DXA (4, 5). Each CT scan, performed for other indication, contains unused valuable information which could greatly aid in the detection of reduced bone density. The information can be obtained without any additional procedures, medicalscosts, or additional radiation exposure. Also, CT is an excellent method for the assessment of changes in skeletal muscles due to precise differentiation and measurement of muscle attenuation values expressed in Hounsfield Units (HU), which are an indicator of muscle fat infiltration (6). Skeletal muscles and bones share common embryological origin, and mass and strength of both tissues decline with age, which is manifested by an accumulation of adipose tissue in both cases (7). The main feature of muscle and bone aging process and fatty infiltration on CT is a decrease in HU. The psoas major muscle is one of the most important muscles that covers the spine. So far, it has been confirmed that the psoas muscle size was associated with acute and chronic low back pain, and with many other conditions, such as sarcopenia and loss of global muscle mass (8, 9). In addition to the fact that fatty infiltration results in reduced muscle strength and function, it is also associated with an increased risk of bone fractures (8-10).

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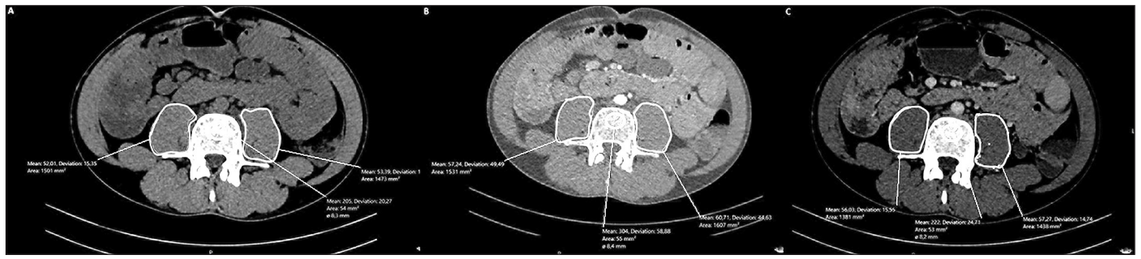

Figure 1.
Method of measuring the trabecular bone attenuation of the L4 vertebra and the psoas muscle at the same level on axial CT slice during native-precontrast (A), arterial (B) and venous (C) phase.

Thus far, the association of fatty paravertebral muscle infiltration and reduced bone mineral density was investigated through several modalities, including CT,IMRI, and ultrasound (11-15). However, the issue remained under-investigated in younger population, in whom the age-related and degenerative changes are not considerably advanced. The aim of this study was to determine the possible association of HU of the lumbar spine and the psoas major muscle on abdominal CT scans in young and middle-aged population. We additionally investigated to which extent the use of iodine contrast changes bone and muscle CT attenuation values, because more and more CTs are performed without native (precontrast) scanning phase to reduce radiation dose.

MATERIALS AND METHODS

Population sample

A retrospective analysis of baseline and imaging data from the Hospital Information System (HIS) and Picture Archiving and Communication System (PACS) of all patients aged 18-49 years, who underwent an abdominopelvic multi slice CT (MSCT) exam done in three phases (native, arterial and venous) from July 1st to December 31st, 2021, at the Clinical Department of Diagnostic and Interventional Radiology at University Hospital Split, was done. The initial search yielded 145 patients. However, 14 patients were excluded due to the lack of a native imaging phase, imaging artifacts, non-standard imaging position, some pathological conditions, primarily of spine,twhich could influence the results. Finally, 131 patients were included in the study.

Data acquisition

MSCT of the abdomen and pelvis was performed on two devices, a 128-layer Siemens Somatom Definition CT and 128-layer Philips Ingenuity Elite with automatic exposure control. The abdominopelvic region was scanned from the xiphoid process of the sternum to the pubic symphysis. A tube voltage of 120-140 kV was used, while the mAs were automatically adjusted depending on the individual patient characteristics. Slice thickness was 0,7 mm. The iodine contrast agent iohexol under the factory name "Omnipaque 350 mgI/mL" was used, and it was applied with an automatic syringe to an amount depending on the weight of the individual patient. CT scanning was performed in3three phases: native (precontrast), arterial and venous postcontrast phases. Scanning in the arterial phase started in an average timespan of 25 seconds and in the venous phase after 60 seconds after the application of the contrast agent.

Lumbar spine and psoas muscle CT attenuation values were measured in all three CT phases at the level of the L4 vertebral body on axial CT slices. The level of the L4 vertebra was determined manually on the sagittal sections, oriented on the anatomy of the L5 vertebra and the sacrum. HU values were measured by placing a circular ROI on the trabecular part of the anterior part of the L4 vertebral body, while the cortical part was left outoto avoid irrelevant increase in HU values, similarly to the posterior part of the vertebral body due to the anatomical position of the spinal vessel canal (Figure 1). The contours of both psoas muscles were carefully manually drawn at the same level (L4) using the so-called "freehand ROI" and the mean value of left and right muscle attenuation was used in the analysis (Figure 1).

Statistical analysis

The normality of the distribution was checked with the Kolmogorov-Smirnov test. To analyse differences between groups, T-test for independent samples, chi-square, and ANOVA were used, depending on the sample type. P<0.05 was considered to be a statistically significant.

RESULTS

The mean age of 113 patients included was 40.61±8.33 years, with a mean women age of 39.96±8.83 years and men age 41.2±7.85 years (P=0.215). There were slightly more men than women included; 58 (51.33%) men and 55 (48.67%) women (P=0.790), (Table 1). The mean attenuation of L4 in a total population sample was 179.65±43.73 HU, and the density of the psoas major muscle was 38.15±12.08 HU. The L4 attenuation values were significantly higher in women, 190.13 HU vs. 169.71 HU in men, P=0.010, in comparison to no sex differencefin the psoas muscle attenuation values (38.04 vs. 38.19 HU, P=0.947) (Table 1).

L4 attenuation weak-to-moderately decreased with age in our population sample (R=-0.44, P<0.00001). Although weaker association, a significant decrease was also found between psoas muscle density and age (R=-0.21, P=0.026). Also, the intercorrelation of L4 and the psoas major muscle was weak (R=0.34, P=0.0002).

Table 1.
Baseline characteristics.

Basic characteristics (M±SD)	Total	Men	Women	
Total, n (%)	113 (100%)	58 (51.33%)	55 (48.67%)	P=0.790
Age (years)	40.6 ±8.33	41.2±7.85	39.96±8.83	P=0.215
Lumbar spine at L4 (HU)	179.65±43.73	169.71±42.47	190.13±42.94	P=0.010
Psoas major muscle at L4 level (HU)	38.15±12.08	38.19±13.47	38.04±10.55	P=0.947

HU - Hounsfield Unit, M - Mean, SD - Standard deviation

Intravenous application of iodine contrast increased the mean HU of the lumbar spine in both arterial and venous postcontrast scans by nearly 20 HU (12%) compared to the precontrast scan, which represented a significant difference observed in a total population sample, and in both sexes separately (P<0.00001), (Table 2). We noticed the arterial phase was more heterogenous, compared to the venous phase, in which the increase stabilized. However, no significant difference in bone and muscle attenuation between the two postcontrast phases was found.

Similarly, intravenous application of iodine contrast increased the mean HU of the psoas major muscle in both arterial and venous postcontrast phases from native 38.15 HU to 44.30 HU in arterial and to 46.81 HU in venous phase in a total population sample (P<0.00001). The increase ranged from 18% to 26%, depending on the sex and the postcontrast imaging phase. This effect was non-significantly more expressed in women. No significant difference between the two postcontrast phases was found (Table 3).

Table 2.
Bone densities (HU) of the L4 vertebral body during multiphasic CT protocol.

L4 HU (M±SD)	L4 native	L4 arterial	L4 venous
Total	179.65±43.73	199.04±43.93	201.89±44.71
Men	169.71±42.47	188.27±43.26	190.27±41.88
Women	190.13±42.94	210.40±42.08	214.14±44.68

P<0.00001 (ANOVA for repeated measurements)

Table 3.
Psoas major muscle densities (HU) during precontrast and two postcontrast CT phases.

Psoas HU (M±SD)	Psoas major muscle native	Psoas major muscle arterial	Psoas major muscle venous
Total	38.15±12.08	44.30±11.94	46.81±12.40
Men	38.19±13.47	42.76±12.82	44.98±12.52
Women	38.04±10.55	45.93±10.81	48.73±12.09

P<0.00001 (ANOVA for repeated measurements)

DISCUSSION

The key results of our study showed that lumbar bone attenuation values were associated with the psoas muscle attenuation in young and middle-age population. The association of both measured parameters with age was weak-to-moderate. Lumbar HU were significantly higher in women compared to men. Application of iodine contrast increased bone and muscle HU in both postcontrast scans.

The bone density of the lumbar spine decreases significantly with age, as does the density of the psoas major muscle, although the latter was slightly less pronounced in our population sample. Theskey features of fatty infiltration muscles on CT are reduced HU values, and due to the high ability to distinguish tissues of similar attenuations, CT established itself as a valuable method in the diagnosis of muscle changes (11). The mean density of the psoas major muscle in our study of younger patients was 38.15 HU, without pronounced individual differences between patients, which does not indicate fatty infiltration in the examined group, and perhaps explains the weaker association obtained with age. The nega-

tive correlation of bone mineral densities and lower HU with the increasing age is completely in accordance with previous studies, which found a decrease in trabecular bone density of the lumbar spine and paraspinal muscles with aging (12-15). Ekin et al. confirmed the correlation of reduced bone density and muscle atrophy in geriatric patients (14). They found decreased bone density in 76% of geriatric patients, more often in women than men, as well as muscle atrophy in somewhat lower percent (63%) of patients. In patients with reduced bone density, muscle atrophy was 5.7 times more common than in patients with normal bone density.

Wetdid not generally observe any sex differences in our population sample. The only significant difference in our study was higher native HU of L4 bone density in women, around 20 HU, compared to men. This can be explained by the positive effects of estrogens on bone density in the reproductive period of women who were included in the research. It is well documented that upon entering menopause, bone mineral density drops sharply in women and the mean women's age in our population sample was 39 years, thus confirming non-menopausal women's age (16). Although there was no significant difference between the sexes on postcontrast CT scans, we noticed slightly higher bone and muscle densities in women in both post-contrast imaging phases, which could also be explained by an estrogen effect on circulation in premenopausal women.

An increase in HU of the trabecular part of L4 between the native and both post-contrast phases was nearly 12%. Thus, we confirmed our hypothesis that the application of iodine contrast falsely increases HU of lumbar spine, as it was found infmost investigations conducted on lumbar spine, presenting a similar percent of BMD increase (17). The arterial phase was more heterogeneous, compared to the venous phase, in which we noticed the stabilization of the increase. Increase in HU of psoas muscle between native and postcontrast scans was also observed. However, the increase was somewhat higher than the lumbar spine (18-25% of psoas vs. 12% of lumbar spine). The post-contrast attenuation of muscles was rarely investigated. We found two studies that confirmed significant increase in muscle attenuation on postcontrast scans (12, 18).

Limitations of our study are the relatively small number of very young participants, especially those in their twenties, probably because they do not often have an indication for abdominal CT. Since more detailed anamnestic data, such as patient's diseases, body weight, and potentially other parameters that might influence the researched associations, were not available for all participants, their effect was not included in the statistical analysis. We selected a group of participants who underwent CT imaging regardless of indication, with the assumption that they would represent a heterogeneous group of the population.

CONCLUSION

We confirmed that the decrease in vertebral bone density has a positive correlation with fatty infiltration of the psoas muscle. This result was obtained by subsequent analysis of CT scans of younger and middle-aged patients, in whom we believe the degenerative changes of bones and muscles are not yet considerably advanced. The application of intravenous iodine contrast led to higher attenuation values of both the lumbar spine and the psoas major muscle in the arterial and venous phase, which should be considered in cases where native CT scans are not available.

All data in this paper are part of the results of the undergraduate thesis "Correlation between bone density of the lumbar spine and fatty infiltration of psoas muscle in abdominalnCT" written at the University Department of Health Studies, University of Split (19).

Abbreviations:

HU - Hounsfield Units
DXA - Dual-energy x-ray absorptiometry
BMD - Bone mineral density
CT - Computerized,Tomography
HIS - Hospital Information System
PACS - Picture Archiving and Communication System

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Sažetak

POVEZANOST CT-OM PROCIJENJENE MINERALNE GUSTOĆE LUMBALNE KRALJEŽNICE I MASNE INFILTRACIJE MIŠIĆA PSOASA U PACIJENATA MLAĐE I SREDNJE ŽIVOTNE DOBI

Matea Bolčić, Danijela Budimir Mršić, Ivan Ordulj

Cilj: Promjene kostiju i skeletnih mišića povezane sa starenjem istraživane su u prethodnim studijama. Cilj našeg istraživanja bio je utvrditi moguću povezanost gustoće kosti lumbalne kralježnice i promjene velikog slabinskog mišića procijenjenih CT-om u mlađoj i srednjoj populaciji, u koje dobne promjene nisu značajno uznapredovale. Također, istražili smo u kojoj mjeri jodni kontrast utječe na atenuaciju kostiju i mišića.

Metode: Retrospektivno su prikupljeni osnovni i CT slikovni podatci pacijenata u dobi od 18 do 49 godina, koji su podvrgnuti multifaznom CT-u abdomena i zdjelice u KBC-u Split od srpnja do prosinca 2021. godine. Vrijednosti CT atenuacije, izražene u Hounsfieldovim jedinicama (HJ), lumbalne kralježnice i velikog slabinskog mišića mjerene su na razini L4 na nativnim (prekontrastnim), arterijskim i venskim postkontrastnim snimkama.

Rezultati: Prosječna dob 113 uključenih bolesnika bila je 40,61 godina, a 51,33% bili su muškarci. Vrijednosti CT atenuacije lumbalne kralježnice i velikog slabinskog mišića su korelirale. Najveća povezanost utvrđena je između dobi i atenuacije trupa L4, dok je povezanost između dobi i mišića psoasa bila nešto slabija. Nisu primijećene značajne razlike između spolova, osim viših atenuacijskih vrijednosti L4 u žena. Primjena jodnog kontrasta značajno je povećala atenuacijske vrijednosti, s prosječnim povećanjem od gotovo 12% u lumbalnoj kralježnici i 18-26% u mišiću psoasu.

Zaključak: Vrijednosti CT atenuacije lumbalne kralježnice i velikog slabinskog mišića su korelirale u pacijenata mlađe i srednje životne dobi. Promjene vezane uz dob bile su nešto veće u kostima nego u mišićima. Jodni kontrast značajno je povećao atenuacijske vrijednosti kosti i mišića.

Ključne riječi: CT, KONTRASTNO SREDSTVO, MINERALNA KOŠTANA GUSTOĆA, VELIKI SLABINSKI MIŠIĆ

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