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Assessment of muscle mass depletion in chronic liver disease: Dual-energy x-ray absorptiometry compared with computed tomography

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ABSTRACT

Objectives: The aim of this study was to perform intermethod comparisons between the following three measures of muscle mass depletion in patients eligible for liver transplantation: 1) fat-free mass index (FFMI) measured by dual-energy x-ray absorptiometry (DXA), 2) appendicular skeletal muscle mass index (ASMI) measured by DXA, and 3) skeletal muscle index (SMI) measured at the third lumbar level by computed tomography (CT).
Methods: The medical records of patients who received liver transplants between 2009 and 2012 at Karolinska University Hospital were retrospectively reviewed. Adult patients with a chronic liver disease who had both DXA and CT scans performed within a 30-d period during their pretransplant workup were included.
Results: Appendicular skeletal muscle mass index measured by DXA ($ASMI_{DXA}$) and skeletal mass index measured by computed tomography (SMI_{CT}) provide similar results when assessing the presence of muscle mass depletion in patients with chronic liver diseases and $FFMI_{DXA}$ can be falsely high in patients with ascites. Both $ASMI_{DXA}$ and SMI_{CT} thus appear to be useful methods in the pretransplant evaluation of muscle mass depletion both for patients with and without ascites.
Conclusions: ASMI measured with DXA is a useful alternative method to SMI measured with CT when a CT scan is not clinically indicated or available.

Introduction

Malnutrition and depletion of muscle mass are common in patients with chronic liver disease but there is no generally preferred method for diagnosing malnutrition. Sarcopenia is defined by the European Society for Clinical Nutrition and Metabolism as "a syndrome of its own characterized by the progressive and generalised loss of skeletal muscle mass, strength and function (performance) with a consequent risk of adverse out-comes" [1]. Sarcopenia is associated with mortality on the waiting list for liver transplantation [2] and has an effect on duration of hospitalization [3] and post-transplant infection risk [4]. Sarcopenia also is associated with mortality in patients with liver cirrhosis [5–7] and after liver transplantation [8,9].

Both the amount and the functional quality of muscles are important in chronic liver disease. Computed tomography (CT) can evaluate both skeletal muscle depletion and muscle attenuation, which indirectly measures fat infiltration in the muscle [10]. The muscle attenuation is a measure of muscle quality and is expressed in Hounsfield units (HU) [11,12]. Low muscle attenuation reflects mainly myosteatosis, which is a process of fat infiltration in both the intermuscular and the intramuscular compartments [11]. Myosteatosis is associated with poor physical performance [13,14] and it is associated with longer hospital stays and increased mortality in patients with malignancies [15,16]. In cirrhosis, muscle wasting is characterized by both a reduction in muscle size and by myosteatosis. Muscle wasting is also associated with a higher mortality risk in patients with cirrhosis [10].

Assessment of muscle mass with CT in patients with liver cirrhosis has attracted much interest in recent years. CT and magnetic

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resonance imaging are precise ways of estimating lumbar-level muscle mass and are considered the gold standards for diagnosing sarcopenia in the elderly [17]. CT, however, a costly procedure, which is not always done as part of the pretransplant investigation. Alternative techniques are therefore needed. Dual-energy x-ray absorptiometry (DXA) is routinely performed as part of the pretransplant assessment for evaluation of bone mineral density. The DXA enables a high precision determination of muscle mass [18], but the presence of ascites (e.g., accumulation of fluid in the abdomen) may cause an overestimation of muscle mass [19]. To avoid this problem, the lean soft tissue of the arms and legs, excluding the abdomen where the majority of the excess fluid is present, can be evaluated separately to obtain the appendicular lean soft tissue (ALST). The muscles of the arms and legs constitute a large proportion of the body's total skeletal muscle mass and therefore can be used as a surrogate measure for the whole body skeletal muscle mass [20].

Belarmino et al. evaluated the influence of ascites on DXA results in men and found that appendicular skeletal muscle mass index (ASMI, which is ALST related to body height) was not influenced by the presence of ascites [21].

The primary aim of the present study was to perform intermethod comparisons between the following three measures of muscle mass depletion in patients eligible for liver transplantation:

1 Total body fat-free mass index (FFMI) measured by DXA.
2 ASMI measured by DXA.
3 Skeletal mass index (SMI) measured at the third lumbar level (L3) by CT.

Materials and methods

The medical records of patients who received liver transplants between 2009 and 2012 at Karolinska University Hospital were retrospectively reviewed. Adult patients with a chronic liver disease who had both DXA and CT scans performed within a 30-d period during their pretransplant workup were included. Exclusion criteria were multiorgan transplantation, acute liver failure, previous liver transplantation, or liver transplantation in non-cirrhotic patients.

Clinical and laboratory assessments

The following data were retrieved from patient medical records and from the local transplant registry: age, sex, weight, height, body mass index (BMI), type of liver disease, presence of ascites, Child-Pugh score, and Model for End-Stage Liver Disease (MELD) score at the time of transplantation workup.

DXA measurements

A fan-beam DXA (GE Lunar iDXA) was used. This model has a high reported precision with a coefficient of variation (CV) of 0.5% for lean tissue and 0.8% for total fat mass [22]. Bone mineral content, total fat mass, and lean soft tissue were measured. Fat-free mass (FFM) was calculated as the sum of bone mineral content and lean soft tissue. FFM was adjusted for height, which provided an additional measure: $FFMI_{DXA}$ (FFM_{DXA} in kg/m^2). Another measurement was added to minimize the influence of ascites on the FFM: the appendicular lean soft tissue ($ALST_{DXA}$) from upper and lower limbs. $ALST_{DXA}$ was adjusted for height, which provided $ASMI_{DXA}$ ($ALST_{DXA}$ in kg/m^2).

The two different measures from the DXA scans that were used for the analyses in this study were $FFMI_{DXA}$ and $ASMI_{DXA}$.

CT measurements

CT scans performed as part of the pretransplant workup were analyzed retrospectively. When several CT scans were done, the CT scan closest in time to the DXA scan was used. All CT scans were done within 1 mo of the DXA scans. The tube voltage for CT was 100 to120 kV. A transverse single 5-mm-thick image from the middle of the L3 vertebra was extracted from each scan. Image J 1.50c software from the National Institutes of Health [23] was used for segmentation according to a previously described method [24]. In each image, the following muscles were segmented: the psoas and paraspinal muscles (erector spinae, quadratus lumborum), and the abdominal wall muscles (transversus abdominis, external and internal obliques, rectus abdominus). Visceral and subcutaneous adipose tissues at the L3 level were also segmented. The segmented tissues were quantified by applying HU thresholds; −150 to −30 was used for fat [25] and −29 to +150 for muscle [26]. The areas with HU −29 to +30 were segmented separately [11] and recorded together with average attenuation for quantification of muscle fat.

The cross-sectional areas for skeletal mass (SMA) and total adipose tissue were normalized for height to calculate the SMI (expressed as cm^2/m^2) [27]. ASMI and whole body FFM were estimated from CT as previously described [27] to enable comparisons between the CT and DXA measures:

$$ASMI_{CT} = 0.11 \times (\text{skeletal muscle at L3/height}^2\,(\text{cm}^2/\text{m}^2)) + 1.17$$
$$FFM_{CT} = 0.30 \times (\text{skeletal muscle at L3}(\text{cm}^2)) + 6.06.$$

FFM_{CT} was normalized for height to $FFMI_{CT}$.

Definitions for sarcopenia or muscle mass depletion

Guidelines by the European Society for Clinical Nutrition and Metabolism recommend including not only loss of muscle mass, but also loss of muscle strength or loss of muscle performance when considering a diagnosis of sarcopenia [1]. The term *sarcopenia* should only be used when having data on muscle strength or muscle performance. Therefore the term *muscle mass depletion* was used to describe patients with a muscle mass below established cutoffs. FFM depletion was defined as FFMI indices <10th percentile, according to standard tables from an Italian reference population [28] because there is no data available on a Swedish population. ASMI cutoffs for muscle depletion were 7.59 kg/m^2 for men and 5.47 kg/m^2 for women [29]. SMI cutoffs for muscle depletion were <43 cm^2/m^2 for men with BMI <25 kg/m^2 and <53 cm^2/m^2 for BMI >25 kg/m^2 and <41 cm^2/m^2 for women in all BMI ranges [30]. Over the past few years, new cutoffs were published on a cirrhotic population. These are 50 cm^2/m^2 for men and 39 cm^2/m^2 for women [31]. These new cutoffs were also applied to our population for comparison. Previously described cutoffs were used to define myosteatosis: <41 HU in patients with BMI <24.9 kg/m^2, and <33 cm^2/m^2 HU in patients with BMI ≥25 kg/m^2 [30].

Statistical analyses

Intra-class correlation (ICC) scores were calculated to examine reliability of the segmentation method. ICC scores between two independent raters were calculated for 20 of the patients. Data were tested for normal distribution with the Shapiro-Wilks test. Data were presented as median value and interquartile range (IQR). For categorical variables, the χ^2 test or the Fisher test was used for group comparisons. To detect any differences between patients with and without muscle mass depletion, one-way analysis of variance was used for variables of symmetric distribution and the Mann–Whitney test for variables of asymmetric distribution. Correlations between continuous variables were assessed using Pearson correlation coefficients. $P < 0.05$ was considered significant in two-sided test. The software used for the analysis were SPSS version 19 (IBM, Armonk, NY, USA) and SAS (SAS Institute, Cary, NC, USA) for Windows.

Ethical considerations

The study was approved by the regional ethics committee in Stockholm1). The study follows the Declaration of Helsinki.

Results

There were 228 adult liver transplantations performed in our center between 2009 and 2012. Fifty-three adult patients with chronic liver diseases had both a DXA and a CT scan done within a 30-d period during workup for liver transplantation and were included in the study. The patients were predominantly men (70%) and the median age was 57 y (Table 1). Half the population was Child-Pugh A, with a median Child-Pugh score of 6 (IQR, 3) and median MELD (without extra exception points) of 11. Most of the patients had viral diseases with and without alcohol (51%) or autoimmune diseases (30%). Around half of the patients (53%) had coincident hepatocellular carcinoma (HCC), in all cases within the University of California, San Francisco (UCSF) transplant criteria [32].

Body composition and muscle mass depletion

The median BMI among the men was 24.9 (IQR, 4.4) and among the women, 26.2 (IQR, 7.9). Body composition characteristics are presented in Table 2. Obesity (BMI >30 kg/m^2) was found in 15% of the patients. A higher proportion of the patients had muscle depletion according to SMI_{CT} (40%) compared with $ASMI_{DXA}$ (39%) and

Table 1
Patient clinical characteristics

Parameter	All (n= 53)	Muscle depleted according to SMI_{CT} (n = 21)	Not muscle depleted according to SMI_{CT} (n = 32)	*P*-value
Age, y	57 (16: 47, 62)	57 (15: 47, 61)	57 (19: 44, 63)	0.53
Male/female, n (%)	37 (70)/16 (30)	10 (27)/11(69)	27 (73)/8(31)	0.004
MELD	11 (8: 7.6, 15.5)	10 (9: 7, 16)	11 (7: 8, 15)	0.68
Child-Pugh score, n (%)				0.87
A	27 (51)	11 (52)	16 (50)	
B	14 (26)	6 (29)	8 (25)	
C	12 (23)	4 (19)	8 (25)	
Ascites, n (%)	19 (36)	7 (33)	12 (38)	0.76
Hepatocellular carcinoma, n (%)	28 (53)	10 (48)	18 (56)	0.54
Time on waiting list, d	66 (93: 29, 122)	81 (144: 44, 187)	47 (77: 26, 102)	0.12
Mortality, n (%)	5 (9)	1 (4)	4 (14)	0.64
Cause of liver disease, n (%)				0.97
Viral with/without alcohol	27 (51)	10 (48)	17 (53)	
Autoimmune	16 (30)	7 (33)	9 (28)	
Alcohol	4 (8)	2 (10)	2 (6)	
Other	6 (11)	2 (10)	4 (13)	

CT, computed tomography; MELD, Model for End-Stage Liver Disease; SMI, skeletal mass index
Mann–Whitney was used for data with non-symmetrical distribution. χ^2 test or the Fisher test was used for group comparisons. Data is presented as median and IQR: 25th percentile; 75th percentile unless otherwise stated

Table 2
Body composition characteristics of the population

Parameter	All	Men	Women
Weight (kg)	75.2 (20.5)	77.5 (17.3)	66.8 (29.3)
Height (cm)	171 (12.8)	177.5 (12.5	164 (9.7)
BMI ($kg/m^{2)}$	25.1 (5.3)	24.9 (4.4)	26.2 (7.9)
$ASMI_{DXA}$* (kg/m^2)	7.5 (1.9)	8 (1.4)	6.1 (2.1)
Estimated $ASMI_{CT,}$ (kg/m^2)	6.7 (1.8)	7.1 (1.1)	5.4 (1)
$FFMI_{DXA,}$ (kg/m^2)	18 (2.7)	18.1 (2.4)	17.1 (4)
FFM_{DXA} (kg)	52 (13.9)	54.7 (10)	42.1 (8)
Estimated $FFMI_{CT,}$ (kg/m^2)	15.7 (4.1)	16.1 (2.3)	12.8 (2.5)
Estimated FFM_{CT} (kg)	54.7 (15.2)	57.3 (8.7)	42.2 (8)
Skeletal muscle area L3 (cm^2)	162.2 (50.5)	170.8 (28.9)	120.3 (26.8)
SMI_{CT} (cm^2/m^2)	50.5 (16.4)	54.3 (9.9)	38.7 (9.1)
Skeletal muscle density (HU)	45.1 (12.1)	46.3 (13.6)	42.7 (12.9)

ASMI, appendicular skeletal muscle mass index; BMI, body mass index; CT, computed tomography; DXA, dual energy x-ray absorptiometry; FFM, fat free mass; FFMI, fat free mass index; FM, fat mass; FMI, fat mass index; SMI, skeletal mass index
Data are presented as median and IQR
*Missing data two patients.

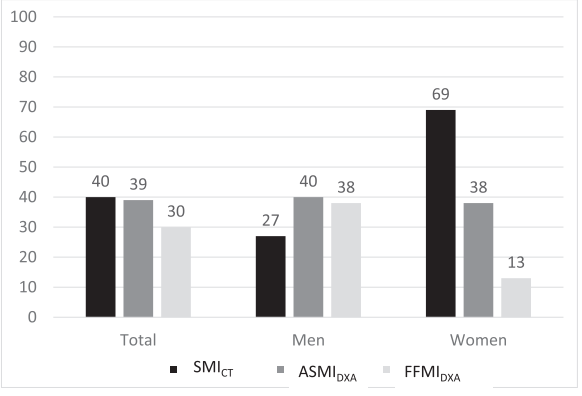

Fig. 1. Prevalence of muscle mass depletion in patients during workup for liver transplantation (%). ASMI, appendicular skeletal muscle mass index; CT, computed tomography; DXA, dual-energy x-ray absorptiometry; FFMI, fat-free mass index.

$FFMI_{DXA}$ (30%; Fig. 1). The prevalence of muscle depletion according to SMI_{CT} decreased to 32% when applying the most recent cutoffs for patients with cirrhosis [31]. There was a large sex-dependent difference between the three methods in detecting muscle depletion. $FFMI_{DXA}$, $ASMI_{DXA}$, and SMI_{CT} were relatively consistent among men ($FFMI_{DXA}$ 38%, $ASMI_{DXA}$ 40%, and SMI_{CT} 27%), but among women there were large discrepancies between methods ($FFMI_{DXA}$ 13%, $ASMI_{DXA}$ 38%, and SMI_{CT} 69%; Figure 1). Muscle depletion according to SMI_{CT} was not significantly associated with liver function (Child-Pugh: $P = 0.366$, MELD: $P = 0.497$), etiology of liver disease ($P = 0.57$) or with the presence of HCC ($P = 0.70$; Table 1).

Comparison of measurements from DXA vs CT

The median time between DXA and CT scans was 5 d (IQR, 14). $ASMI_{DXA}$ and SMI_{CT} showed the strongest correlation ($r = 0.66$; $P < 0.001$), whereas the correlations between $FFMI_{DXA}$ and SMI_{CT} ($r = 0.29$; $P = 0.035$) and $FFMI_{DXA}$ and $ASMI_{DXA}$ ($r = 0.39$; $P = 0.005$) were weaker (Fig. 2, Table 3).

ASMI and FFM estimated from CT data were correlated with those based on DXA data (ASMI: $r = 0.62$; $P = 0.002$ and FFM: $r = 0.71$; $P = 0.0001$).

For the assessment of skeletal mass, the mean ICC score for between-rater analyses was 0.971 and the mean ICC score for within-rater analyses was 0.999.

Muscle quality

The median skeletal muscle density was 45.1 ± 12.1 HU. Myosteatosis was present in 10 patients (19%) with a mean density of 33.6 ± 6.3 HU. Patients with myosteatosis had a mean Child-Pugh score of C10 and patients without myosteatosis had a mean Child-Pugh score of A6 ($P = 0.07$). The median reduced muscle attenuation area was 38.5 ± 23.2 cm^2.

Ascites

Ascites was present in 36% of the study patients, with the majority classified as mild (26%). $FFMI_{DXA}$ correlated with SMI_{CT} in patients without ascites ($r = 0.394$; $P = 0.021$), but not in patients with ascites ($r = 0.129$; $P = 0.597$). $FFMI_{DXA}$ correlated with $ASMI_{DXA}$ in patients

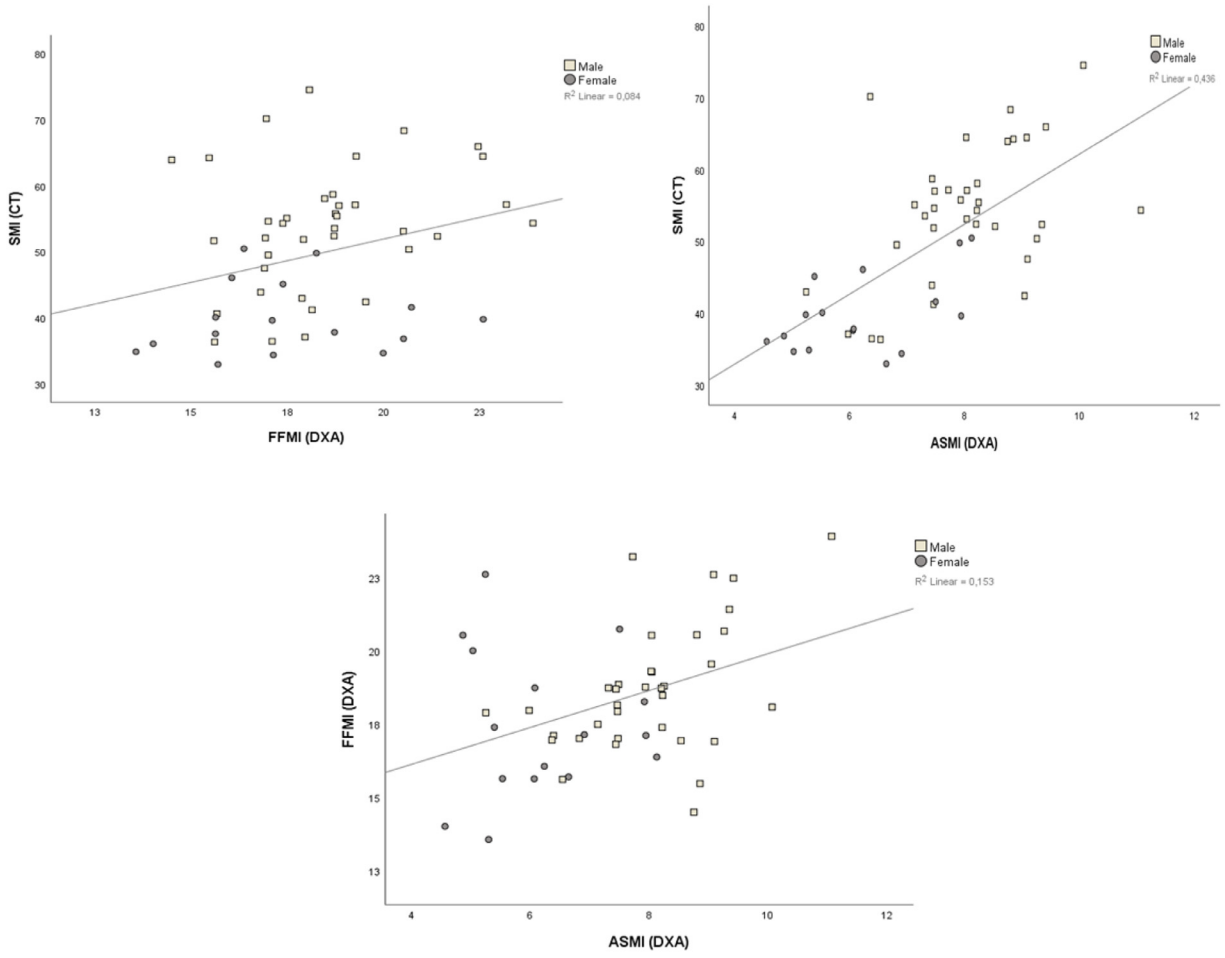

Fig. 2. Scatter plot of the relationship and variation among SMI_{CT}, $FFMI_{DXA}$, and $ASMI_{DXA}$. ASMI, appendicular skeletal muscle mass index; CT, computed tomography; DXA, dual-energy x-ray absorptiometry; FFMI, fat-free mass index; SMI, skeletal muscle mass index.

Table 3
Correlation between DXA measurements and CT measurement according to sex

	All patients		Males		Females	
	r	*P*-value	*r*	*P*-value	*r*	*P*-value
$FFMI_{DXA}$ vs $ASMI_{DXA}$	0.391	0.005	0.473	0.004	0.009	0.973
SMI_{CT} vs $FFMI_{DXA}$	0.290	0.035	0.257	0.125	0.087	0.750
SMI_{CT} vs $ASMI_{DXA}$	0.660	<0.001	0.465	0.005	0.518	0.040

ASMI, appendicular skeletal muscle mass index; CT, computed tomography; DXA, dual energy x-ray absorptiometry; FFMI, fat-free mass index; SMI, skeletal muscle mass index
Pearson correlation

without ascites ($r = 0.503$; $P = 0.003$), but not in patients with ascites ($r = 0.249$; $P = 0.304$). However, $ASMI_{DXA}$ correlated with SMI_{CT} in patients with ascites ($r = 0.716$; $P = 0.001$) and without ascites ($r = 0.616$; $P < 0.001$; Table 4). The presence of ascites did not influence the prevalence of muscle depletion according to $ASMI_{DXA}$ ($P = 0.214$), $FFMI_{DXA}$ ($P = 0.94$), or SMI_{CT} ($P = 0.159$). However, the average skeletal muscle density measured by CT was lower in patients with ascites than in patients without ascites (40 vs 48 HU; $P = 0.001$).

Mortality

Owing to the small number of events (five deaths during the first posttransplant year), it was not possible to test whether muscle mass depletion was associated with mortality.

Discussion

Knowledge about body composition in patients with cirrhosis, especially the presence of sarcopenia, is of great clinical value for prognostication and planning of pre- and posttransplant care. Therefore, it is important to know if different methods provide comparable results when assessing patients and when comparing the outcomes in different studies. In the present study, measurements from CT were compared with those from DXA. A strong intermethod correlation between SMI_{CT} and $ASMI_{DXA}$ was observed. The results thus suggested that DXA is a good alternative to CT when assessing the presence of sarcopenia in liver cirrhosis.

In agreement with a previous study by Giusto et al. [33], the observed occurrence of sarcopenia in the present study varied both

Table 4
Correlation between DXA measurements and CT measurement according to presence of ascites

	All patients		No ascites		Ascites	
	r	*P*-value	*r*	*P*-value	*r*	*P*-value
$FFMI_{DXA}$ vs $ASMI_{DXA}$	0.391	0.005	0.503	0.003	0.294	0.304
SMI_{CT} vs $FFMI_{DXA}$	0.290	0.035	0.394	0.021	0.129	0.597
SMI_{CT} vs $ASMI_{DXA}$	0.660	<0.001	0.616	<0.001	0.716	0.001

ASMI, appendicular skeletal muscle mass index; CT, computed tomography; DXA, dual energy x-ray absorptiometry; FFMI, fat-free mass index; SMI, skeletal mass index
Pearson correlation

with the choice of method and the measure of assessment. The highest occurrence of muscle depletion was observed with SMI_{CT} and the lowest when based on $FFMI_{DXA}$. The prevalence according to $ASMI_{DXA}$ was similar to that of SMI_{CT} and $ASMI_{CT}$.

Methods such as bioelectrical impedance analysis (BIA) and anthropometry, but also $FFMI_{DXA}$, are influenced by fluid retention. Calculating only arm and leg muscle mass from DXA ($ASMI_{DXA}$) mitigates overestimation in patients with ascites [21]. The influence of ascites on $FFMI_{DXA}$ resulted in a poor correlation with SMI_{CT} and $ASMI_{DXA}$, whereas SMI and $ASMI_{DXA}$ were better correlated (Fig. 1).

The clinical course of muscle wasting varies between individuals but also between men and women [34–36]. Many reports identify disproportionately more cirrhotic men than cirrhotic women as malnourished. This has prompted concerns for the risk for malnourished women to go undiagnosed [37]. We noted a marked sex-dependent variation: Muscle depletion was present among 13% to 50% of the women and among 38% to 43% of the men. Abdominal fat edema, which is more common among women, can be misclassified when evaluating $FFMI_{DXA}$ but this is avoided by using SMI_{CT} or $ASMI_{DXA}$.

A possible explanation for the variation in sarcopenia could be the lack of cutoffs for a Swedish population. Of note, published cutoffs are based on different types of populations: those with end-stage liver disease [31] and those with cancer [30]. There are no ideal or comprehensive cutoffs for diagnosing muscle mass depletion in patients with chronic liver diseases. When we used cutoffs for SMI_{CT} that were based on 1473 patients with cancer [30,38], SMI_{CT} identified the highest percentage of muscle-depleted patients (SMI_{CT} 42%). When we applied the new proposed cutoffs for SMI_{CT}, which were based on almost 400 patients with cirrhosis [31], $ASMI_{DXA}$ identified the highest percentage of patients ($ASMI_{DXA}$ 39% vs SMI_{CT} 32%). The new proposed cutoffs for SMI for patients with cirrhosis have a different cutoff for men (50 cm^2/m^2) than for patients with cancer (<43 cm^2/m^2 for men with BMI <25 kg/m^2 and <53 cm^2/m^2 for BMI >25 kg/m^2) and decreases the cutoff for women (39 cm^2/m^2 vs 41 cm^2/m^2), which explains the large difference in muscle-depleted patients. Cutoffs should be method-, population-, and disease-specific. It should also be noted that normal body composition also varies between different nationalities. Thus, a possible explanation for the observed variation in sarcopenia above could be due to the country from which data were collected.

The new cutoffs for SMI did not affect the number of men defined as depleted (27% vs 30% according to cutoffs for cirrhosis and cancer) but lowered the number of women defined as depleted (50% cirrhosis vs 69% cancer cutoffs). Several studies have used the cutoffs developed from patients with cancer and found a correlation between mortality and sarcopenia [2,5,6]. More studies are needed to confirm the clinical value of the new proposed cutoffs in cirrhosis. The large sex differences may in part be explained by the low number of women in the present study. The results on women should be interpreted with caution.

Muscle mass naturally diminishes with age and this influences body composition [35]. The age distribution in study cohorts may thus influence the observed prevalence of muscle mass depletion. There are age-specific cutoffs for $FFMI_{DXA}$, and those were applied in the present study, but to our knowledge there are no such cutoffs for $ASMI_{DXA}$ and SMI_{CT}.

Muscle radiodensity (attenuation on CT) tends to be lower in patients with cirrhosis than in healthy controls [39]. We observed a non-significant ($P = 0.07$) association between worse liver status and myosteatosis: Myosteatotic patients had a mean Child-Pugh score of C10 compared with A6 among non-myosteatotic patients. Low muscle attenuation suggests a reduced muscle function [40] and may be the result of fluid retention, myosteatosis, or a combination of both. Water has a higher density (0 HU) than fat (−150 to −30 HU), but a lower density relative to muscle (−29 to 150 HU). Water skews the average voxel density toward 0 HU, which is illustrated by the significantly lower muscle density observed among patients with ascites than those without ascites (40 vs 48 HU; $P = 0.001$). The average attenuation in skeletal muscle in all our patients (45 HU) was higher than previous reports on patients with liver cirrhosis [3,10] and on those with cancer [15,24]. A plausible explanation is the lower number of patients with ascites in our study compared with other published studies [3,6]. A limitation in the present study was that the CT scans were performed for clinical purposes, where the majority of the scans were obtained after contrast media. It has been shown that contrast media in CT can affect the attenuation [41].

We demonstrated that $ASMI_{DXA}$ and SMI_{CT} provide similar results when assessing the presence of muscle mass depletion in patients with chronic liver diseases and that $FFMI_{DXA}$ can be falsely high in patients with ascites. Both $ASMI_{DXA}$ and SMI_{CT} thus appear to be useful methods in the pretransplant evaluation of muscle mass depletion both for patients with and without ascites. The present results cannot establish which method is better at assessing muscle mass depletion in liver cirrhosis. DXA involves less cost and less radiation and can provide information on body composition in patients who do not need a CT scan for other reasons. SMI_{CT} appears to be more sensitive for identifying women with muscle mass depletion and also can provide information on muscle attenuation. DXA and CT have both advantages and disadvantages, and both are to some extent influenced by ascites.

Conclusion

Based on the present results, ASMI measured with DXA appears to be a useful alternative method to SMI measured with CT when a CT scan is not clinically indicated or available.

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