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Optimal lumbar vertebral level for trunk muscle CT assessments in opportunistic sarcopenia screening: a cross-sectional study

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ABSTRACT

Objectives This study aims to identify the optimal lumbar vertebral level for CT-based assessments of trunk muscles in relation to physical function and muscle strength, and to establish a foundation for opportunistic CT screening for sarcopenia.

Design A cross-sectional study was conducted between April 2022 and December 2022. Pearson's correlation coefficients and multiple linear regression analyses were employed to estimate the correlation between CT parameters of trunk muscle with physical function and muscle strength.

Setting and participants The study included community residents aged 50 years and older from Kunming, Yunnan Province, China, who were part of the SOY (Sarcopenia and Osteoporosis Study of Yunnan) cohort. A total of 615 participants were enrolled, comprising 424 men and 191 women. Among these, 31 individuals (20 men and 11 women) were diagnosed with sarcopenia.

Interventions Each participant underwent lumbar CT scanning, the Short Physical Performance Battery (SPPB) and handgrip strength (HGS) assessment.

Primary outcome measures A correlation analysis was conducted for both the general and sarcopenia groups, after adjusting for age and body mass index. Additionally, a gender-stratified analysis was performed.

Results Muscle density and muscle area at all levels exhibited a moderate correlation with grip strength, with the correlation for muscle area being more pronounced (correlation β of muscle density =0.48–0.54, p value <0.001; correlation β of muscle area=0.66–0.68, p value <0.001). However, only muscle density demonstrated a weak correlation in the correlation analysis with SPPB (correlation β of muscle density =0.09–0.12, p value <0.01). When stratified by gender, trunk muscle attenuation at the L1 vertebral level in the male group showed a more pronounced correlation with physical performance (L1-βHGS =0.25, p value <0.001 vs L2–L5-βHGS =0.16–0.19, p value =0.01–0.04; L1-βSPPB =0.31, p value <0.001 vs L2–L5-βSPPB =0.23–0.29, p value <0.01). In the female cohort, both the muscle area and muscle density at all levels showed correlations with grip strength, and the muscle area at L3 vertebrae showed the best performance (L3-βHGS =0.23, p value <0.001). In the sarcopenia group, the L1 level correlates better with HGS and SPPB than other levels. (L1-βHGS =0.54, p value =0.03 and L1-βSPPB =−0.35, p value =0.04).

Conclusions In this study, the area and density of lumbar muscles based on CT showed correlations of varying degrees with grip strength or SPPB. The L1 layer exhibited superior performance in those aged more than 50 years, especially in the male and sarcopenia groups. This study suggests that CT-based muscle assessment at the L1 vertebra may be a feasible option for opportunistic sarcopenia screening.

Trial registration number ChiCTR210005215; Pre-results.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study to employ CT for a comprehensive analysis of the entire lumbar trunk muscle, offering a broader and more objective comparison of data for selection.
⇒ This study provides important data for the potential use of CT as an opportunistic screening tool for sarcopenia.
⇒ The sample size of men and women was not well matched, which may affect the comparison of sex-related research results.

INTRODUCTION

Sarcopenia is a geriatric syndrome, defined by loss of muscle mass, low muscle strength and/or low physical performance.[1 2] It has significant clinical implications and contributes to an increased medical burden, leading to considerable attention in recent years.[3 4] Traditional diagnosis of sarcopenia encompasses three aspects: imaging, muscle strength and physical function assessment. Muscle strength is typically evaluated using handgrip strength (HGS), while physical function is assessed through tests such as the Short Physical Performance Battery (SPPB), six-metre walking speed test and the five-time sit-to-stand test. Among these, SPPB is the most frequently employed diagnostic indicator. Additionally, measuring the maximum calf circumference, combined with the SARC-F

scale (including Strength,Assistance in walking, Rise from a chair, Climb stairs and Falls assessment) serves as an alternative screening tool, providing a rapid and effective means of identifying sarcopenia, particularly in community healthcare settings where more detailed assessments may not be feasible. However, the traditional sarcopenia diagnostic procedure was often cumbersome and difficult to implement in routine outpatient medical practice, leading to low detection rates and delays in early intervention.[1]

Current qualitative assessments of sarcopenia through imaging were expected to be supplemented and potentially replaced by quantitative methods, which could enable more accurate and timely detection.[5] CT is regarded as a more precise imaging method, with high sensitivity to minor changes in muscle tissue.[6] Using CT scans at various anatomical levels for opportunistic screening of sarcopenia has become a common practice, given their capability to measure sarcopenia and myosteatosis.[7 8] CT-based measurements of trunk muscle mass are shown to significantly impact balance function, fall risk and hip fracture rates, highlighting their potential in sarcopenia screening.[9–11] In current CT evaluations of lumbar trunk muscles, the L3 vertebral level is typically the preferred choice.[7] However, a study has shown that CT-based sarcopenia assessment at the L1 level compares favourably with previously established L3 level, further expanding the reach of opportunistic CT screening for sarcopenia.[12] Despite the promising results of various studies, a comprehensive comparison of lumbar trunk muscle CT measurements remains an area for further investigation.

In this study, CT parameters of trunk muscles at the L1–L5 vertebral levels are obtained, and their correlation with the SPPB and muscle strength (HGS) is analysed. The purpose of this study is to identify the optimal lumbar vertebral level for trunk muscle CT assessments in relation to physical function and muscle strength and to establish a basis for opportunistic CT screening for sarcopenia.

METHODS

Subjects

Participants in the present study were prospectively recruited from the SOY study (Sarcopenia and Osteoporosis Study of Yunnan, Clinical trial registration number: ChiCTR2100052153, http://www.chictr.org.cn/index.aspx) from April 2022 to December 2022 in the First People's Hospital of Yunnan Province. The ethics committee has approved the study (Approval number: KHLL2021-KY056), and all subjects have signed written informed consent forms. Inclusion criterion: participants over 50 years. Exclusion criteria were: (1) inability to move independently; (2) deformity of the lumbar spine and hip joint (eg, ankylosing spondylitis, severe scoliosis); (3) patients with metallic implants in vivo; (4) poor CT image quality, leading to an inability to analyse; (5) individuals with significant lesions in the area of interest measured by CT, such as infections, tumours, trauma, etc. Each participant underwent lumbar CT scanning, the SPPB and HGS assessments. The PASS power software (V.21.0.3, NCSS, LLC, Kaysville, Utah, USA; https://www.ncss.com/software/pass/) was used for sample size calculation in this study. The sample size was calculated using the CI method based on the Pearson correlation coefficient. A correlation coefficient of 0.3 (obtained from the preliminary pilot study) was used, alpha was set at 0.05 and the CI width was 0.15. In this case, at least 441 research subjects were needed. If a 10% attrition rate was considered, at least 485 research subjects should be needed.[13] CT acquisition and trunk muscle measurement Lumbar CT scanning (Siemens Force CT, Siemens Healthcare, Germany) was performed for all study participants. All scans were acquired in the supine position. The scan parameters are listed as follows: 120 kVp, 150 mAs, slice thickness: 1.5 mm, pitch 1.5 mm and 512×512 matrix. A single mid-transverse process plane at the L1–L5 vertebrae was measured on the cross-section.[14] If any artefacts (eg, ghosting) are present in the midline plane, the nearest upper or lower plane will be chosen instead. The specific muscle measurement was realised by OsiriX software (Lite V.10.0.2; Pixmeo, Geneva, Switzerland). The 'pencil' tool was chosen to outline the muscle contours. Next, skeletal muscle regions were further delineated semiautomatically using threshold segmentation within the Hounsfield unit (HU) intensity thresholds (−30 to 150 HU).[15] This threshold range was deemed optimal for identifying muscle tissue and fat.[16] Finally, the muscle cross-sectional area (CSA) (cm^2) and attenuation (HU) were calculated, with voxels outside the range of −30 to 150 HU being excluded. The muscle area and density measured by this approach were those of pure muscle tissue obtained after the adipose tissue within the intermuscular space had been eliminated. However, the influence of intracellular fat in muscle cells on muscle density remains unremovable. It was worth noting that the attenuation and area of trunk muscles at the L1–L2 level were measured directly without using the above threshold segmentation method, due to their small size and less fat infiltration. Muscle measurements at L3–L5 levels were conducted after the adipose tissue within the intermuscular space had been removed through the threshold segmentation method mentioned above[17] (figure 1). To minimise measurement errors due to layer selection, all muscle measurements were performed by a single investigator, who had received professional training in CT muscle imaging prior to the analysis.

Physical performance

The SPPB is a composite test that includes three components: 4 m gait speed (GS) test, five-times repeated chair sit-to-stand (CSTS) test and a balance test. The overall

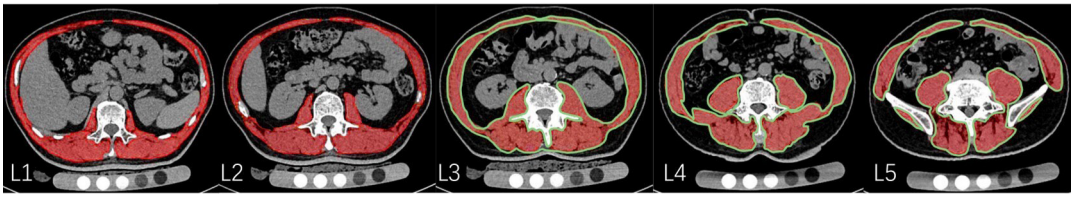

Figure 1 Trunk muscle measurement on CT. A single mid-transverse process plane at the L1–L5 levels was measured on the cross-section. Muscle measurements of L1–L2 level were measured directly, while those at L3–L5 levels were conducted after the adipose tissue within the intermuscular space had been removed through the threshold segmentation method. The red region represented the target muscle range, and the green lines denote the region of interest for muscle assessment through the threshold segmentation method.

score of SPPB is the sum of the scores of these three items, with a maximum score of 12. A lower score indicates poor physical functioning.[18–20] For the 4m-GS test, participants were required to walk a 4-metre distance at a normal pace, and their walking time was recorded with a stopwatch. This test was repeated once more, and the shortest time was taken as the test result. The CSTS assessment required participants to cross their arms over their chest and transition from a seated position to standing without assistance, with the time taken to complete the action measured over five repetitions. Both the 4m-GS and CSTS tests were scored on a scale from 0 to 4, with different time intervals corresponding to different scores. The balance test consists of three movements: semitandem, full-tandem and feet-together stand. Scores ranging from 0 to 4 are assigned after the completion of the action. Detailed operational guidelines for the SPPB were available on the official website.[21]

Muscle strength assessments

Accurate grip strength measurement requires using a calibrated handheld dynamometer under well-defined test conditions with interpretive data from appropriate reference populations.[22] This study used a Jamar dynamometer (Jamar, Los Angeles, CA) for HGS assessment. The patient assumed a seated position, with the elbow of the dominant hand bent at 90° to hold the handgrip dynamometer. Participants were instructed to squeeze the dynamometer as tightly and as long as possible or until the needle stopped rising. Once the needle stops rising, the participant can be instructed to stop squeezing. Two attempts with a 30-second interval between them were recorded in kilograms, and the maximum value will be chosen for further analysis.

Diagnosis of sarcopenia

Sarcopenia is defined as having low appendicular skeletal muscle index (ASMI), low muscle strength and/or low physical performance in this study, according to the Asian Working Group for Sarcopenia (AWGS), 2019.[1] The specific diagnostic threshold is listed as follows: (1) HGS male <28 kg, female <18 kg; (2) SPPB ≤9 and (3) muscle mass (ASMI assessed by dual-energy X-ray absorptiometry (DXA)): male <7.0 kg/m^2; female <5.4 kg/m^2.

Consistency assessment of observers

To demonstrate the stability of the measurement method, 20 subjects were randomly chosen for the consistency analysis before calculating all the data by the same evaluator. Consistency analysis was conducted on repeated measurements by the same observer (after a 2-week interval) as well as between two different observers.

Statistical analysis

All variables were presented as mean (SD). Differences between female and male participants were analysed using the Mann-Whitney U or T-test. Pearson/Spearman's correlation coefficient and multiple linear regression were constructed to estimate the associations of CT-based muscle measurement with SPPB and HGS. Additional body mass index (BMI) and age adjustments for all groups were also conducted. The intraclass correlation coefficient (ICC) was used to assess observer consistency. A p value of 0.05 was considered to be statistically significant. All analyses were performed using MedCalc Statistical Software V.18.2.1 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2018).

Patients and public involvement statement

In this study, patients and the public were not directly involved in the design, conduct, reporting, or dissemination plans of the research. However, the research team fully consider the interests of patients and the public to ensure that the study outcomes provide valuable health information for the relevant populations.

RESULTS

Baseline study characteristics

A total of 615 participants were included in the study, consisting of 191 men and 424 women. According to the diagnostic criteria for sarcopenia in this study, 31 people were diagnosed with sarcopenia, including 20 man and 11 woman. Additionally, 85 people were diagnosed with low HGS (27 men and 58 women) and 132 people were diagnosed with low SPPB (41 men and 91 women). The participants' demographic characteristics and CT-based muscle data are presented in online supplemental table 1. The male group exhibited larger CSA, higher muscle attenuation and greater HGS compared with the female

group. The participants were also categorised into the low SPPB group (below 12 points) and the normal group. A comparison of trunk muscle parameters between the two groups revealed that the low SPPB group had lower muscle density and smaller muscle area. This trend was consistent across the general, male and female groups (online supplemental table 2).

Correlation of trunk muscle parameters with physical function and muscle strength in the general population

Muscle density and area at all levels exhibited a moderate correlation with grip strength, among which the correlation of muscle area was more pronounced. Pearson correlation analysis showed that the correlation coefficient of muscle area at L1–L5 level with HGS was 0.65–0.66, p value <0.001 and that of muscle density was 0.42–0.49, p value <0.001. In the multiple linear regression analysis, the correlation β of muscle area was 0.66–0.68, p value <0.001 and that of muscle density with HGS was 0.48–0.54, p value <0.001. The muscle density at the L1 level ($\beta_{\text{L1 muscle density}}$=0.54, p value <0.001) and the muscle area at the L2/L3 levels demonstrated the strongest correlation with HGS ($\beta_{\text{L2/L3 muscle CAS}}$=0.68, p value <0.001).

In contrast, the correlation analysis with the SPPB was completely different, with only muscle density showing a weak correlation. The muscle density's correlation coefficient (r and β) was 0.09–0.12. The muscle density at the L1 level exhibited a higher correlation with SPPB than the muscle density of other vertebral levels ($\beta_{\text{L1 muscle density}}$=0.12, p value =0.01). The detailed data are shown in table 1.

Correlation of trunk muscle parameters with physical function and muscle strength in the sarcopenia group

In the correlation analysis with HGS, muscle area at each level from L1 to L5 was found to be statistically significantly correlated with HGS. The Pearson correlation coefficient of muscle area ranged from 0.40 to 0.58, p value <0.05, and the multiple linear regression correlation coefficient ranged from 0.32to 0.47, p value <0.05. In terms of muscle density, only the L1 and L5 levels showed statistically significant correlations with HGS (L1 muscle density with HGS: r =0.40, p value =0.03; β =0.54, p value =0.03; L5 muscle density with HGS: r =0.40, p value =0.03; β =0.47, p value =0.03). In the correlation analysis with SPPB, only muscle area at the L1 vertebral level has statistical significance (L1 muscle area with SPPB: r =−0.40, p value =0.04; β =−0.35, p value =0.04). Overall, the correlations between the muscle parameters of the L1 vertebrae in the sarcopenia group with HGS and SPPB were more pronounced than those at other levels. This indicates that CT muscle measurements at the L1 vertebral level might be a superior choice for opportunistic sarcopenia screening (table 2).

Besides the sarcopenia group, the research subjects were divided into the low SPPB group and normal SPPB groups. In the low SPPB group, no significant correlation existed between muscle area or density and SPPB. However, the correlation between muscle area and grip strength was stronger than the correlation between muscle density and grip strength. The adjusted correlation β of muscle CSA at L1–L5 was 0.45–0.55, p value <0.001, while the adjusted correlation β of muscle density at L1–L5 was 0.39–0.43, p value <0.001 (online supplemental table 3).

Correlation of trunk muscle parameters with physical function and muscle strength in the different gender groups

Correlation analysis results for the male group

Taking into account the significant difference in the number of male and female participants in this study, as well as the gender disparity in the prevalence of sarcopenia, gender-specific analyses were further conducted. In the male group, the correlation between muscle density with grip strength and SPPB was significantly higher than that with muscle area (online supplemental table 4). In the correlation analysis with HGS, the Pearson correlation coefficient ranged from 0.15 to 0.22, p value <0.05, and multiple linear regression correlation coefficient ranged from 0.16 to 0.25, p value <0.05. In the correlation analysis with SPPB, the Pearson correlation coefficient r ranged from 0.21 to 0.28, p value <0.01, and the multiple linear regression correlation coefficient β ranged from 0.23 to 0.31, p value <0.01. Each layer of muscle density from L1 to L5 was found to be statistically significantly correlated with HGS and SPPB. Among them, the correlation of muscle density with L1 layer was better than that of other layers (L1-HGS: r =0.22, p value =0.002; β =0.25, p value <0.001 and L1-SPPB: r =0.28, p value =0.001; β =0.31, p value <0.001).

The correlation between trunk muscle area and physical performance was weaker compared with that of muscle density, except for the muscle area at the L3 and L4 levels, which showed a weak correlation with HGS (L3: r =0.16, p value =0.02; β =0.19, p value =0.02 and L4: r =0.15, p value =0.03; β =0.18, p value =0.04). No significant correlation was found between the muscle area at other levels and HGS. Additionally, there was no statistically significant correlation between the muscle area at any level with the SPPB.

Correlation analysis results for the female group

Compared with the male group, the female group showed a different picture (online supplemental table 5=). CT-derived muscle CSA and attenuation at L1–L5 vertebral level were all statistically correlated with grip strength (r =0.18–0.22, p value <0.01; β =0.19–0.23, p value <0.001). Among all levels, the correlation at the L3 vertebral level was marginally higher than that at other levels (the muscle density of L3-HGS: r =0.19, p value <0.001; β =0.21, p value <0.001; the muscle area of L3-HGS: r =0.22, p value <0.001; β =0.23, p value <0.001). Moreover, an interesting observation was made in this study. Women with larger trunk muscle areas tend to be associated with higher grip strength which was slightly sensitive to muscle attenuation. To put it differently, the muscle area

Table 1 Correlation of CT-based trunk muscle with physical function and HGS in the general population

		Unadjusted β (95% CI)	R^2 (SE)	T (P value)	Adjusted β (95% CI)	R^2 (SE)	T (P value)
HGS (Kg)	L1 density (HU)	**0.47 (0.61 to 0.82)**	0.22 (7.76)	**13.12 (0.00)**	**0.54 (0.70 to 0.94)**	0.28 (7.45)	**13.48 (<0.001)**
	L1 CSA (cm^2)	**0.64 (0.24 to 0.30)**	0.41 (6.77)	**20.39 (0.00)**	**0.66 (0.25 to 0.31)**	0.46 (6.50)	**20.72 (<0.001)**
	L2 density (HU)	**0.49 (0.66 to 0.88)**	0.23 (7.69)	**13.65 (0.00)**	**0.53 (0.72 to 0.97)**	0.28 (7.46)	**13.43 (<0.001)**
	L2 CSA (cm^2)	**0.66 (0.23 to 0.28)**	0.44 (6.59)	**21.69 (0.00)**	**0.68 (0.24 to 0.29)**	0.47 (6.34)	**21.54 (<0.001)**
	L3 density (HU)	**0.47 (0.61 to 0.83)**	0.22 (7.76)	**13.15 (0.00)**	**0.51 (0.65 to 0.90)**	0.26 (7.59)	**12.44 (<0.001)**
	L3 CSA (cm^2)	**0.67 (0.23 to 0.28)**	0.44 (6.56)	**21.97 (0.00)**	**0.68 (0.24 to 0.23)**	0.48 (6.37)	**21.71 (<0.001)**
	L4 density (HU)	**0.45 (0.60 to 0.82)**	0.20 (7.84)	**12.46 (0.00)**	**0.48 (0.62 to 0.88)**	0.23 (7.70)	**11.46 (<0.001)**
	L4 CSA (cm^2)	**0.66 (0.23 to 0.28)**	0.44 (6.58)	**21.79 (0.00)**	**0.67 (0.24 to 0.28)**	0.47 (6.43)	**21.25 (<0.001)**
	L5 density (HU)	**0.51 (0.73 to 0.96)**	0.26 (7.56)	**14.61 (0.00)**	**0.53 (0.75 to 1)**	0.29 (7.42)	**13.80 (<0.001)**
	L5 CSA (cm^2)	**0.65 (0.25 to 0.30)**	0.42 (6.69)	**20.96 (0.00)**	**0.66 (0.25 to 0.30)**	0.46 (6.48)	**20.89 (<0.001)**
SPPB	L1 density (HU)	**0.23 (0.03 to 0.06)**	0.05 (1.15)	**5.74 (0.00)**	**0.12 (0.01 to 0.05)**	0.16 (1.09)	**2.69 (0.01)**
	L1 CSA (cm^2)	0.01 (-0.004 to 0.01)	−0.002 (1.19)	0.27 (0.79)	−0.02 (-0.01 to 0.003)	0.15 (1.09)	−0.54 (0.59)
	L2 density (HU)	**0.24 (0.03 to 0.07)**	0.05 (1.15)	**5.92 (0.00)**	**0.11 (0.01 to 0.05)**	0.16 (1.09)	**2.58 (0.01)**
	L2 CSA (cm^2)	0.06 (-0.001 to 0.01)	0.002 (1.18)	1.39 (1.67)	0.01 (−0.004 to 0.004)	0.15 (1.09)	0.18 (0.86)
	L3 density (HU)	**0.26 (0.04 to 0.07)**	0.07 (1.15)	**6.58 (0.00)**	**0.12 (0.01 to 0.04)**	0.16 (1.09)	**2.86 (0.004)**
	L3 CSA (cm^2)	**0.08 (0.00 to 0.008)**	0.01 (1.18)	**2.02 (0.04)**	0.03 (−0.003 to 0.005)	0.15 (1.09)	0.64 (0.52)
	L4 density (HU)	**0.26 (0.04 to 0.07)**	0.07 (1.15)	**6.57 (0.00)**	**0.11 (0.01 to 0.04)**	0.16 (1.09)	**2.60** (0.01)
	L4 CSA (cm^2)	**0.1 (0.001 to 0.01)**	0.01 (1.18)	**2.36 (0.02)**	0.04 (-0.002 to 0.01)	0.15 (1.09)	0.89 (0.38)
	L5 density (HU)	**0.22 (0.03 to 0.07)**	0.05 (1.16)	**5.51 (0.00)**	**0.09 (0.003 to 0.04)**	0.16 (1.09)	**2.24 (0.03)**
	L5 CSA (cm^2)	0.07 (0.00 to 0.01)	0.004 (1.18)	1.82 (0.07)	0.04 (−0.002 to 0.01)	0.15 (1.09)	0.95 (0.34)

Adjusted p value <0.05 is shown in bold.
Adjusted: adjusted for age and BMI.
CSA, cross-sectional area; HGS, handgrip strength; HU, Hounsfield unit ; SPPB, short physical performance battery.

Table 2 Correlation of CT-based trunk muscle with physical function and HGS in the sarcopenia group

		Unadjusted β (95% CI)	R^2 (SE)	P value	Adjusted β (95% CI)	R^2 (SE)	T (P value)
HGS (Kg)	L1 density (HU)	**0.39 (0.06 to 1.16)**	0.12 (10.63)	**2.27 (0.03)**	**0.54 (0.07 to 1.62)**	0.43 (8.54)	**2.24 (0.03)**
	L1 CSA (cm^2)	**0.37 (0.01 to 0.42)**	0.11 (10.71)	**2.16 (0.04)**	**0.32 (0.02 to 0.35)**	0.44 (8.50)	**2.3 (0.03)**
	L2 density (HU)	**0.37 (0.03 to 1.23)**	0.11 (10.71)	**2.16 (0.04)**	0.43 (-0.16 to 1.61)	0.39 (8.85)	1.68 (0.10)
	L2 CSA (cm^2)	**0.51 (0.11 to 0.48)**	0.24 (9.89)	**3.23 (0.003)**	**0.37 (0.05 to 0.375)**	0.47 (8.26)	**2.68 (0.01)**
	L3 density (HU)	**0.42 (0.11 to 1.24)**	0.14 (10.50)	**2.45 (0.02)**	0.37 (-0.23 to 1.43)	0.38 (8.94)	1.49 (0.15)
	L3 CSA (cm^2)	**0.57 (0.15 to 0.50)**	0.30 (9.50)	**3.71 (0.001)**	**0.41 (0.08 to 0.39)**	0.50 (8.04)	**3.01 (<0.01)**
	L4 density (HU)	**0.40 (0.08 to 1.22)**	0.13 (10.58)	**2.34 (0.03)**	0.31 (-0.30 to 1.29)	0.37 (9.03)	1.29 (0.21)
	L4 CSA (cm^2)	**0.59 (0.14 to 0.46)**	0.32 (9.34)	**3.90 (0.001)**	**0.39 (0.05 to 0.36)**	0.47 (8.25)	**2.70 (0.01)**
	L5 density (HU)	**0.40 (0.09 to 1.48)**	0.13 (10.59)	**2.32 (0.03)**	**0.47 (0.09 to 1.79)**	0.43 (8.53)	**2.26 (0.03)**
	L5 CSA (cm^2)	**0.61 (0.20 to 0.59)**	0.35 (9.13)	**4.16 (0.00)**	**0.47 (0.14 to 0.47)**	0.56 (7.57)	**3.71 (<0.01)**
SPPB	L1 density (HU)	0.30 (-0.04 to 0.29)	0.05 (2.53)	1.58 (0.13)	0.44 (-0.03 to 0.41)	0.25 (2.26)	1.76 (0.09)
	L1 CSA (cm^2)	−0.35 (-0.10 to 0.003)	0.09 (2.48)	−1.93 (0.07)	**−0.35 (−0.09 to 0.002)**	0.29 (2.20)	**−2.14 (0.04)**
	L2 density (HU)	0.30 (-0.04 to 0.30)	0.06 (2.53)	1.59 (0.12)	0.43 (-0.05 to 0.42)	0.24 (2.27)	1.65 (0.11)
	L2 CSA (cm^2)	−0.13 (-0.07 to 0.04)	−0.02 (2.63)	−0.68 (0.51)	−0.24 (-0.08 to 0.02)	0.21 (2.31)	−1.38 (0.18)
	L3 density (HU)	0.31 (-0.03 to 0.31)	0.06 (2.52)	1.68 (0.11)	0.32 (-0.09 to 0.36)	0.20 (2.32)	1.27 (0.22)
	L3 CSA (cm^2)	−0.02 (-0.06 to 0.05)	−0.04 (2.65)	−1.0 (0.92)	−0.15 (-0.07 to 0.03)	0.17 (2.36)	−0.85 (0.41)
	L4 density (HU)	0.31 (-0.03 to 0.31)	0.06 (2.52)	1.67 (0.11)	0.28 (-0.10 to 0.35)	0.20 (2.33)	1.18 (0.25)
	L4 CSA (cm^2)	0.17 (-0.03 to 0.07)	−0.01 (2.61)	0.90 (0.38)	−0.03 (-0.05 to 0.05)	0.15 (2.40)	−0.13 (0.90)
	L5 density (HU)	0.18 (-0.12 to 0.30)	−0.01 (2.61)	0.91 (0.37)	0.20 (-0.14 to 0.35)	0.18 (2.36)	0.87 (0.39)
	L5 CSA (cm^2)	0.05 (-0.05 to 0.07)	−0.04 (2.65)	0.25 (0.80)	−0.06 (-0.06 to 0.05)	0.15 (2.39)	−0.31 (0.76)

Adjusted p value <0.05 was shown in bold.
Adjusted: adjusted for age and BMI.
CSA, cross-sectional area; HGS, handgrip strength; HU, Hounsfield unit; SPPB, short physical performance battery.

may give a slight edge in grip strength assessment in the female group.

However, the association between SPPB and muscle area or muscle density was significantly weaker in the female group. After controlling for age and BMI, no statistically significant correlation exists between muscle area or muscle density and SPPB.

Consistency analysis

The repeated measurement by the same observer 2 weeks later (A1 vs A2) presented an intraclass correlation coefficient of 0.88–0.94 (trunk muscle CT assessment: ICC =0.89–0.94; HGS: ICC =0.88; SPPB: ICC =0.88, all p values <0.001). The interclass correlation coefficient between observers A and B was 0.86–0.98 (trunk muscle CT assessment: ICC =0.86–0.93; HGS: ICC =0.96; SPPB: ICC =0.98, all p values<0.001) (online supplemental table 6).

DISCUSSION

This study compared the association between trunk muscle composition at the L1–L5 vertebral levels with physical function and HGS among people over 50 years.

The research results indicated that the CT measurement of the muscles at the L1 vertebral level had a slightly better correlation with HGS and SPPB than other levels. This advantage was more pronounced in the sarcopenia group and the male group after the gender stratification of the research subjects. The results indicated that muscle CT measurement at the L1 level may better reflect physical function and muscle strength, making it a feasible option for opportunistic screening and early warning of sarcopenia.

Potential value of CT-based muscle density and muscle area with HGS and SPPB

In contrast to the widespread availability of CT, many medical institutions might not be equipped with DXA or bioelectrical impedance analysis, making it difficult to assess muscle mass in these facilities. Recent studies have suggested that CT could be a valuable tool for sarcopenia screening. The muscle area can reflect the degree of muscle fibre atrophy,[23] which is directly related to the severity of sarcopenia. However, the area of muscle is greatly affected by body shape, which is why skeletal muscle index (SMI, area/height),[2] an adjusted parameter, is derived. The SMI at the L3 level is often taken as the diagnostic cut-off for reduced muscle mass in sarcopenia.[7] In this study, muscle CSA at L1–L5 vertebral level all showed a statistical correlation with grip strength among the overall, female, sarcopenia and low SPPB groups. The sensitivity related to grip strength was superior to that of muscle density, as not all levels of muscle density in these groups were correlated with grip strength. The similarity in results across these groups may be attributed to the fact that a majority of the study participants were female (68.9%). A cohort study that included 214 subjects also found that the CSA of quadriceps femoris was correlated with muscle strength.[24] However, in the correlation analysis with SPPB, only the muscle area at the L1 level in the sarcopenia group showed a mild negative correlation with SPPB. A similar result was also reported at the L2 vertebral level in Anderson's study, which additionally indicated that larger trunk muscle size is associated with worse balance.[9] However, two studies both by Gregory *et al* did not reveal a similar correlation.[10 25]

Compared with muscle area and its derived indicators, Wang *et al* suggest that muscle density is a more sensitive indicator. Muscle density better reflected the pathological changes of sarcopenia by indicating the degree of adiposity within muscle cells and showed a stronger correlation with body function and muscle strength.[14] Increasing evidence indicated that trunk muscle attenuation accounted for a greater proportion of the variance in physical function compared with thigh muscle density.[9 10 25] The degeneration of trunk muscle was accompanied by functional capacity and reduced trunk extension strength,[10 11] increased back pain[25] and greater hyperkyphosis.[26] Efforts to improve and maintain mobility status should include attention to trunk muscle. A study demonstrated that trunk strengthening exercises can significantly improve multiple components of balance and functional ability in healthy older adults.[27] In both the male and sarcopenia groups of our study, the correlation between muscle density and HGS was significantly better than that with muscle area, which was consistent with prior research.[14 28] These findings were promising, highlighting the potential of muscle density as a diagnostic tool for sarcopenia. They also confirmed that muscle density was a more accurate reflection of muscle quality and function compared with muscle area. However, the advantage of muscle density in the female group was not remarkable. This might have been partly due to the effects of fat distribution in women. The redistribution of adipose tissue tended to reduce overall strength and functionality.[29 30] In this study, although the physical function and BMI of the female participants were similar to those of the males, their trunk muscle attenuation and muscle CSA were lower and smaller, respectively. This suggested a higher fat content within the muscles of women, which also agreed with previous reports.[31 32] The factors contributing to the sex-related intramuscular fat accumulation remain poorly understood.[32]

Comparison of the correlation between different layers of trunk muscles with HGS and SSPB

In the previous section, the differences in the correlation between muscle area and muscle density with HGS and SSPB were discussed. However, the optimal lumbar trunk muscle level for evaluating physical function and muscle strength remains uncertain. At present, different CT assessment levels have been proposed for different research objects and detection methods, but the research results have not been consistent. The AWGS 2019 recommended the L3 skeletal muscle index as the representative sarcopenia evaluation system, as it was closest to the total

skeletal muscle index.[1 7] However, two issues persisted at this level. First, the diagnosis of sarcopenia at the L3 level was predominantly achieved via the quantification of muscle mass. Nevertheless, in diagnosing sarcopenia, the evaluation of muscle function and strength was markedly more critical than the assessment of muscle mass.[19] Second, L3 was not included in several clinical CT protocols. Brian *et al* measured the muscle area and density at the T10–L5 vertebral levels in young people (18–40 years). They used the average minus two SD as the critical value for the diagnosis of sarcopenia. The study proposed that the L3 vertebral level was the best for diagnosing sarcopenia, followed by L2, L4, L5 and L1. Although their study also extensively measured the lumbar muscles, the research subjects were not actual patients with sarcopenia or populations prone to it, and no direct correlation analysis between lumbar muscles and SPPB and HGS was conducted.[33]

To explore the optimal lumbar vertebral level that could serve as a new indicator for the opportunistic screening or early warning of sarcopenia in the future, this research focused on the correlation between the CT-based composition of lumbar trunk muscles with physical function and muscle strength. Overall, the results of this study showed a degree of consistency across the entire population, the male group and the sarcopenia group. It was demonstrated that the CT measurement of the trunk muscle at the L1 vertebral body level was a more relevant indicator of physical function and HGS. Several additional studies have also supported the practicability of the L1 vertebral level for diagnosing sarcopenia.[34 35] Pickhardt *et al* also demonstrated that the L1 level for CT-based muscle measurements can better predict hip fracture or death than the L3 level in a cohort study.[12] The insignificant advantage of the L1 vertebral level in the female group may be attributed to complex factors, potentially including the composition of the research cohort and fat distribution. Larger sample sizes and more studies might be needed in the future.

Strengths and Limitations

A primary strength of this study was the acquisition of CT parameters for trunk muscles at the L1–L5 vertebral levels, rather than relying on a single slice. This made our research results more objective and reliable.

However, there were some limitations of this study. First, the majority of the research subjects in this study were middle-aged and elderly people, with a low proportion of sarcopenia (approximately 5%). Such a population structure might be the reason for the weak correlation of this study, as some normal individuals might have diluted the correlation between CT parameters and physical function and grip strength. Second, the sample size of male and female participants was not well matched, which may affect the comparison of sex-related research results. The sample size for either the male or female group was not large enough. This may be the reason why the correlation in gender stratification analysis was low.

Conclusion

Taking into account the correlation with HGS and SPPB simultaneously, as well as the feasibility of clinical protocols. CT-based muscle measurement at the L1 level was the optimal lumbar vertebral level for body function and HGS in this study. This enables the opportunistic screening of sarcopenia based on muscle assessment at the L1 level, which can be realised in routine clinical chest CT or abdominal CT. The potential value of this approach will be further amplified by the large number of CT examinations performed for a wide variety of clinical indications.

Data availability statement

Data are available on reasonable request via email to the corresponding author.

Contributors LL, GW and LW designed the study, developed the theoretical framework, supervised the project, and edited the writing. XL analysed the results and drafted the manuscript. LL, GW and XL financed the study. XL, MG, WW, YY, ZL, YG and XH completed the data collection, such as questionnaire information collection, scanning and data input and revised the manuscript. All authors discussed the results and commented on the manuscript. XL acted as guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and the study was reviewed and approved by the Ethics Committee of The First People's Hospital of Yunnan Province (ethical code: KHLL2021-KY056, 30 June 2021). Each participating site obtained institutional review board or ethics committee approval for data collection in accordance with the Health Insurance Portability and Accountability Privacy Act. Participants gave written informed consent to participate in the study before taking part.

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