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Assessing the potential of hand grip strength as an indicator of spinal muscle size

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In order to assess how well hand grip strength can predict spinal muscle size and to determine if scaling improves prediction Biobank data was acquired consisting of hand grip strength, age, height, body mass and abdominal magnetic resonance images for 150 age-matched male and female participants. The cross-sectional area of the multifidus and erector spinae was measured from the images at the L3/L4 level. Correlation strength and prediction errors were quantified for muscle size predicted from hand grip strength, age, height, and body mass. The effect of scaling muscle area by height and height squared was also determined. All variables correlated significantly with spine muscle size. The strongest correlator was hand grip strength ($r = 0.61$, $p < 0.05$) with a prediction error of 678 mm2. The strength of the correlations was reduced when muscle areas were scaled. Hand grip strength can predict spine muscle size in male and female participants; however, the confidence intervals on the predicted values are larger than would be expected from measuring muscle size directly using imaging technologies. Scaling by height or height squared does not improve the ability of hand grip strength to predict muscle size.

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Assessing the potential of hand grip strength as an indicator of spinal muscle size

Abstract

In order to assess how well hand grip strength can predict spinal muscle size and to determine if scaling improves prediction, Biobank data was acquired consisting of hand grip strength, age, height, body mass and abdominal magnetic resonance images for 150 age-matched male and female participants. The cross-sectional area of the multifidus and erector spinae was measured from the images at the L3/L4 level. Correlation strength and prediction errors were quantified for muscle size predicted from hand grip strength, age, height, and body mass. The effect of scaling muscle area by height and height squared was also determined. All variables correlated significantly with spine muscle size. The strongest correlator was hand grip strength ($r = 0.61$, $p < 0.05$) with a prediction error of 678 mm^2. The strength of the correlations was reduced when muscle areas were scaled. Hand grip strength can predict spine muscle size in male and female participants; however, the confidence intervals on the predicted values are larger than would be expected from measuring muscle size directly using imaging technologies. Scaling by height or height squared does not improve the ability of hand grip strength to predict muscle size.

Keywords

1) Paraspinal Muscles
2) Hand grip strength
3) Anthropometry
4) UK Biobank

Introduction

The muscles that support the spine play a key role in controlling movement and stabilising posture, and their capacity to generate force to achieve this role is an important indicator of health. Stronger spine muscles are associated with a lower risk of developing health problems such as low back pain [1] or experiencing falls [2], and have been associated with various strain injury risks in sports [3]. Ageing and disease are often accompanied by a decline in muscle strength [4], which, in the spine, can lead to functional limitations, such as reduced mobility and disability.

Assessing the health and function of spine muscles is commonly performed by considering their size. A muscle's force-generating capacity depends upon the number and size of the muscle fibres contained within it, which directly relates to the muscle's cross-sectional area [4]. Many studies report that muscle size reflects muscle functional capability [2] and use spinal muscle size as a measure of strength [5-6].

Spinal muscle size can be measured from medical images, but these methods have limited applicability for large-scale use. Medical imaging technologies such as magnetic resonance imaging (MRI) and computed tomography (CT) have been used to measure spinal muscle size in many studies [7-9]. These technologies allow the size of individual spinal muscles to be assessed in vivo and have been found to give reliable measurements of cross-sectional area and volume [10-11]. However, they have significant drawbacks regarding their availability and cost, and, in the case of CT, the use of ionising radiation. These drawbacks can limit their applicability, particularly if they are intended to be used in a screening capacity that demands high levels of patient throughput.

Attention has subsequently turned to whether it is possible to infer muscle spine muscle size, and hence muscle capacity, by undertaking low-cost indirect measurements, including hand grip strength (HGS). HGS is a measurement widely utilised to indicate muscle functionality throughout the body. It is assessed using a dynamometer that measures compressive muscle strength in kilograms and has previously been used to investigate the impact of various disorders and conditions, such as sarcopenia and their relation to factors such as sex, age, and race [12-15].

Studies have demonstrated an association between hand grip strength and the size of individual muscles in the body; however, the evidence for a relationship with the spinal muscles is limited. Although an association has been demonstrated between hand grip strength and back strength in various cohorts [1, 16-18], only one study has investigated the relationship between hand grip strength and spine muscle size [7] and this has focussed on male participants alone. Furthermore in considering relationships between muscle size and hand grip strength, issues of scaling may be important. It is generally assumed that larger people have bigger muscles, and scaling of muscle size is often employed to counter this effect, so results are not skewed because of varying participant sizes. The most appropriate method for scaling the muscle area is one of discussion [19] with some studies scaling by height [13, 20] and some by height-squared [8, 20-21]. The relevance of scaling in any relationship between handgrip strength and spinal muscle size is unclear.

The aim of the current study was therefore to assess how well hand grip strength can predict spinal muscle size in male and female participants and to determine whether scaling muscle size would improve the ability of hand grip strength to predict spine muscle size.

Methods

Dataset

The study operated under the ethical approval already granted to the UK Biobank and did not require separate ethical approval. Data was obtained from the UK Biobank, a resource that includes data from more than 500,000 participants aged 40 to 70, with details of the data collected for the Biobank cohort further described in Sudlow et al., [22]. Various phenotypical measurements are available in the UK Biobank data, including anthropometrical and physical measures as well as magnetic resonance imaging (MRI) of the abdomen for some participants, allowing the lumbar spine muscles to be visualised. Measurements of hand grip strength, height, and body mass, were recorded on the same day as the MRI scans were obtained and together these constitute all of the data variables that were extracted from the Biobank data for the current study.

Only participants who had undergone MR scans of the abdomen, who had undertaken the HGS test, who had a body mass index in either the healthy or overweight category (18.5 kg m^{-2} to 30 kg m^{-2}) and who had no underlying health conditions, were considered for inclusion in the current study. Exclusion criteria included smoking, neurological disorders, vascular disease, cancer, pulmonary, diabetes, digestive diseases, thyroidal disease, osteoporosis, and a history of falls (as assessed by the Biobank health and lifestyle questionnaire).

One hundred and fifty participants were selected, with equal numbers of males and females matched for age between 47 and 70 years. Participants were only included if the MR imaging slice corresponding to the L3/L4 level of the lumbar spine could be confidently identified, as described below. Hand grip strength values for left and right hands were averaged for each participant.

Image analysis

MR scan data were downloaded from the UK biobank database and opened in ImageJ software [23]. The slice closest to the level of the L3/L4 disc in the lumbar spine was selected using a method similar to that proposed by Kiefer, et al. [24], where the top of the iliac crest was used as a landmark for finding the slice at the level of the L4/L5 disc. The slices in a superior direction were then viewed until the L3/L4 disc could be identified.

Images were then magnified to 300%, and the cross-sectional areas of the erector spinae and multifidus muscle were determined by manually drawing around the muscles using the freehand selection tool. The areas were converted from pixels to mm^2 using the image pixel dimensions of 2.2 x 2.2 mm specified in the image header file.

Scaling

Three approaches were taken with scaling the measurements of muscle cross-sectional area to assess which would result in the strongest relationship between hand grip strength: unscaled muscle area, muscle area scaled by height (= muscle area/height), and muscle area scaled by height squared (= muscle area/height^2).

Statistical Analysis

Independent t-tests were undertaken to compare the male and female groups for age, height, body mass, hand grip strength and muscle area. Pearson correlations were calculated to assess the strength of the association between muscle area and the other variables (hand grip strength, age, height, and body mass) for the male, female and combined groups. Correlations were categorised as being strong (r = 0.6 – 0.8), moderate (r = 0.4 – 0.6), weak (r = 0.2 – 0.4) or very weak (r = 0 – 0.2). Regression analysis was undertaken to quantify the prediction error (standard error of the estimate) and percentage error (standard error of the estimate divided by the mean) when using hand grip strength, age, height, or body mass to predict muscle area.

Results

While being matched for age, the male and female groups had significant differences in all other variables, with participants in the male group tending to be taller and heavier with greater hand grip strength and larger spine muscle area (Table 1).

Hand grip strength, age, height, and body mass correlated significantly with unscaled muscle area in the combined group (Figure 1). However, the strength of the association between the variables differed, with hand grip strength exhibiting a strong correlation and age, height, and body mass exhibiting weak to moderate correlations (Table 2). The variation in strength of association was reflected in the prediction errors, which varied from 678 mm^2 when hand grip strength was used as a predictor to 828 mm^2 when age was used (Table 3).

When male and female groups were considered separately, all variables correlated significantly with unscaled muscle area apart from age in the female group (Figure 1). The strength of the associations, however, tended to be lower than in the combined group, varying from very weak to moderate; in both cases, hand grip strength did not have the strongest association (Table 2). Furthermore, the errors in the male group tended to be higher than in the female group (Table 3).

Considering muscle area scaled by height and height squared, the correlation with hand grip strength (Figure 2) remained. However, there was a trend for the strength of the association with age, height, and body mass to be reduced compared to the unscaled area (Table 2). The percentage errors were similar to those found for unscaled muscle areas (Table 3).

Discussion

The aims of this study were to assess how well hand grip strength can predicted spine muscle size in male and female participants and to determine the effects of scaling. In general, the results indicated a significant correlation between hand grip strength and spinal muscle area for both male and female participants; however, the strength of the correlation was greatest when the groups were combined. Scaling did not improve the ability of hand grip strength to predict muscle area.

The hand grip strengths of the male and female participants in our sample are consistent with values from large cohort studies reported in the literature [13], suggesting that our sample is representative of a larger population. Although we were not able to establish this in our study, previous studies have shown hand grip strength to have high test-retest reliability, with reported intraclass correlation coefficients of 0.99 and errors of around 3 % [14-15]. Furthermore, by averaging the left and right-hand values, we expect to improve the precision of the raw data. Similarly, measurements of muscle size from MR images are expected to have high reliability [10-11].

The main finding of our study, that hand grip strength correlates with spine muscle size, is similar to a previous study despite differences in the design and analysis. The previous study by Dallaway et al. [7] involved only male participants, two additional muscles (the psoas and the quadratus lumborum) and considered the dominant and non-dominant hand grip strength separately. In our study, a strong correlation was shown in the combined male and female group and a moderate correlation for the separate male and female groups. Within the individual groups, muscle area was marginally more correlated with other measures (body mass for the male group and height for the female group) but the difference was small.

Although hand grip strength emerged as a better predictor of muscle size than the basic anthropometric measures of age, height, and body mass, the size of the prediction interval was found to be relatively large compared to direct methods of measuring muscle size. For example, the error in predicting muscle area from hand grip strength in the combined group was 678 mm^2 (Table 3), which gives a 95% prediction interval of 1356 mm^2. Based on the average muscle size of our participants, this equates to a percentage prediction interval of around 30%, which is substantially higher than the typical errors incurred when measuring muscle size directly from magnetic resonance and CT images [10-11].

The usefulness of hand grip strength in predicting spinal muscle size will, therefore, depend on the purpose of the measurement. It is unlikely to be adequate for discriminating between individuals or for assessing the effects of an intervention on an individual participant where changes in muscle size are reported to be less than 10% [9, 25]. However, when comparing different groups or assessing the effects of interventions on groups, a high prediction interval may be acceptable when the sample size is sufficiently large.

Furthermore, despite its potential limitations for assessing spine muscle size, hand grip strength still has a potential role in assessing spine muscles if strength, rather than size, is being assessed. Hand grip strength has been found to correlate significantly with back and trunk strength [16-18] and to be associated with a lower risk of vertebral fracture [26] and a lower incidence of low back pain [27]. Although changes in muscle size following an intervention can be moderate, changes in strength can be much higher, with one study reporting a 26% increase in back muscle strength that was accompanied by an increase in hand grip strength of 13% [28]. The causality of these relationships has not been established, but hand grip strength is likely to perform better than measures such as age, height and body mass, which are expected to change little over the course of an intervention.

Our analysis of the relationship between hand grip strength and muscle size used three approaches to scaling muscle area and found the strongest associations were generally with unscaled area compared to area scaled by height or height squared. One explanation for the stronger correlation with unscaled muscle area is that hand grip strength itself scales with height [13], and thus, attempting to scale both variables may diminish the correlation. Scaling muscle cross-sectional area by height or height squared is commonly used to perform normalisation in studies that assess, for example, sarcopenia [20] and has been used in previous studies that have investigated the relationships between muscle size and hand grip strength [7-8]. However, these studies have considered muscle volume, which may exhibit a different relationship from that of cross-sectional areas. In a study on the psoas muscle, the association between hand grip strength and muscle volume was greater when the volume was adjusted for height, height-squared, or height-cubed compared to the unscaled volume [8], but no association was found for scaled muscle area.

Conclusion

Hand grip strength is more strongly associated with spine muscle size than age, height or body mass in male and female participants. However, the confidence intervals on the predicted values are larger than would be expected from measuring muscle size directly using imaging technologies, with spinal muscle size predicted from hand grip strength having a confidence interval of 1400 mm^2, a value sufficiently large as to make such predictions unsuitable for individual participants. Scaling by height or height squared does not improve the ability of hand grip strength to predict muscle size.

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Tables

Table 1. Summary statistics of the participant characteristics for the male and female groups together with the results (p-value) of independent t-tests comparing the means of the two groups.

Table 2. Pearson correlation coefficients for the relationships between muscle size and hand grip strength, age, height and body mass for the combined, male, and female groups. Statistically significant correlations ($p < 0.05$) are indicated by *.

Table 3: The standard error of the estimate (STDE) and its percentage of the mean (%STDE) for each predictor of spine muscle size in the combined, male and female groups. HGS = hand grip strength.

Figure legends

Figure 1. The distribution of spine muscle area in males and females as a function of hand grip strength, age, height, and body mass.

Figure 2. The distribution of spine muscle size (unscaled, scaled by height, and scaled by height squared) in males and females as a function of hand grip strength.

Table 1. Summary statistics of the participant characteristics for the male and female groups together with the results (p-value) of independent t-tests comparing the means of the two groups.

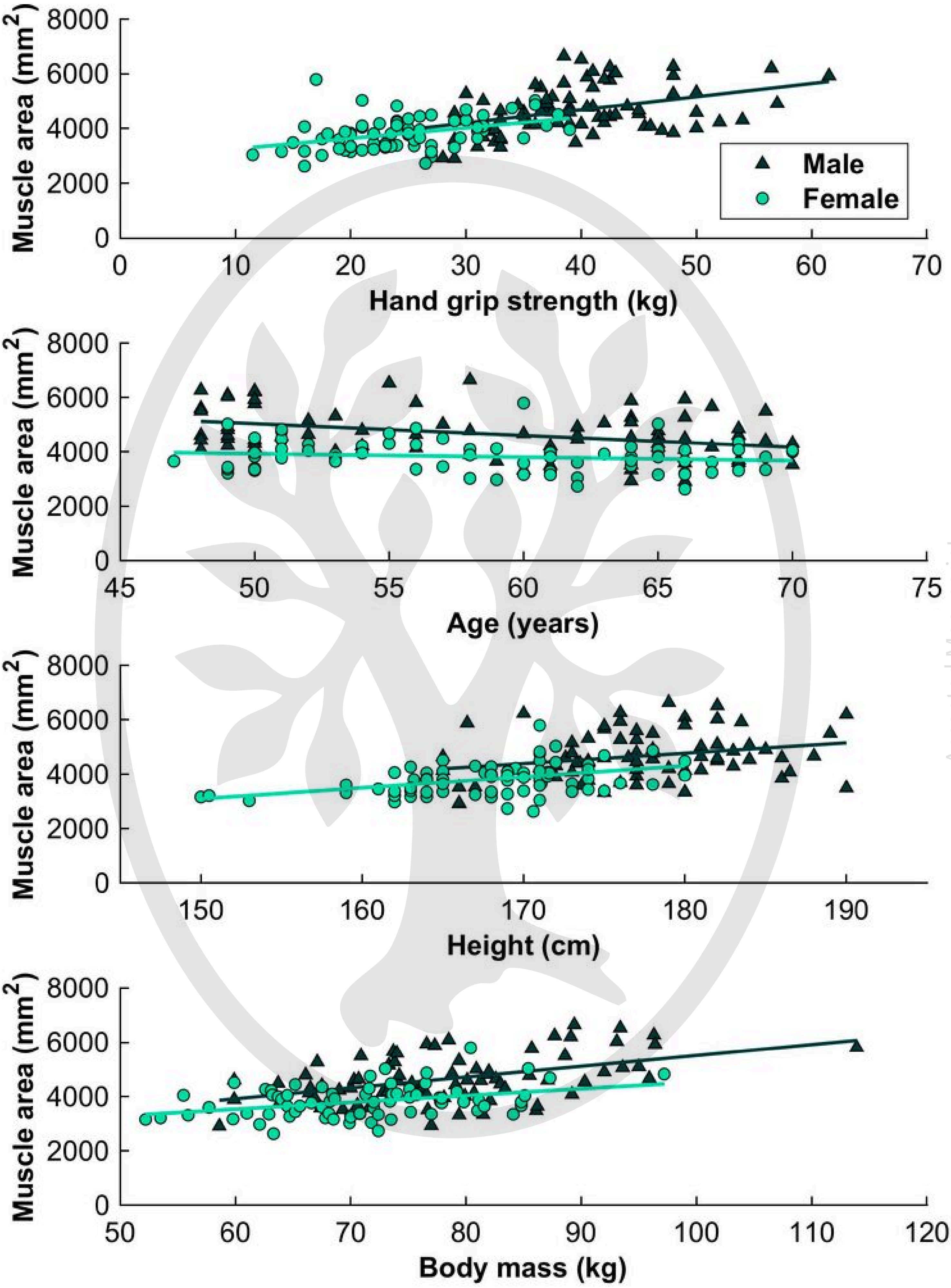
	Male (mean ± sd)	Female (mean ± sd)	p-value
Age (years)	59 ± 7	58 ± 7	0.77
Height (cm)	177 ± 6	168 ± 6	< 0.001
Body mass (kg)	79 ± 10	71 ± 9	< 0.001
Hand grip strength (kg)	40 ± 7	25 ± 6	< 0.001
Muscle area (mm^2)	4664 ± 868	3822 ± 579	< 0.001
Muscle area scaled by height (mm^2 cm^{-1})	26 ± 5	23 ± 3	< 0.001
Muscle area scaled by height-squared (mm^2 cm^{-2})	0.15 ± 0.03	0.14 ± 0.02	< 0.001

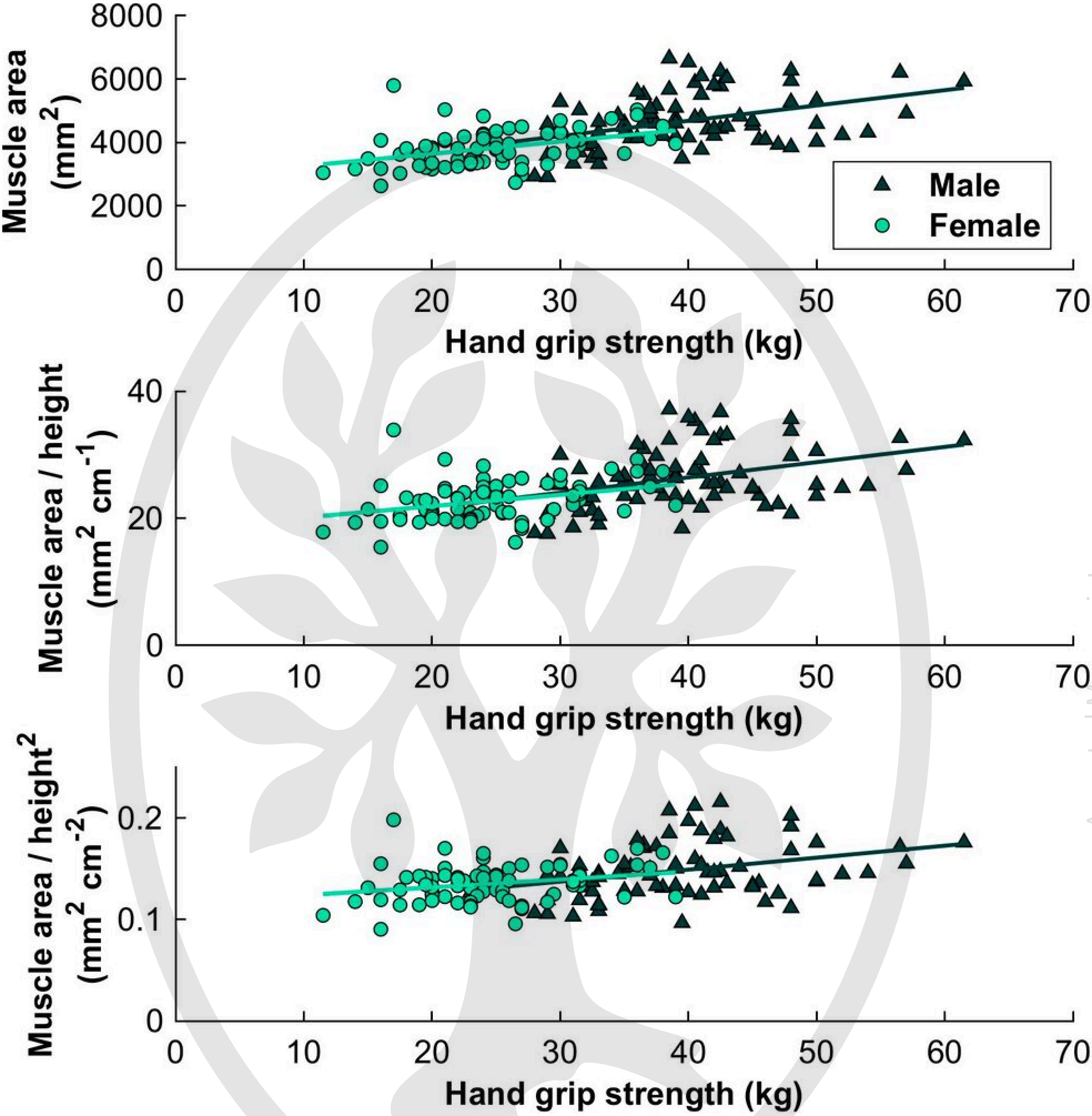
Table 2. Pearson correlation coefficients for the relationships between muscle size and hand grip strength, age, height and body mass for the combined, male, and female groups. Statistically significant correlations ($p < 0.05$) are indicated by *.

		Combined group (n = 150)	**Male group (n = 75)**	**Female group (n = 75)**
Muscle area	Hand grip strength	0.61*	0.41*	0.40*
	Age	-0.23*	-0.37*	-0.15
	Height	0.52*	0.26*	0.41*
	Body mass	0.53*	0.47*	0.37*
Muscle area scaled by height	Hand grip strength	0.52*	0.37*	0.34*
	Age	-0.24*	-0.38*	-0.12
	Height	0.35*	0.09	0.20
	Body mass	0.44*	0.38	0.29*
Muscle area scaled by height squared	Hand grip strength	0.40*	0.32*	0.25*
	Age	-0.24*	-0.38*	-0.07
	Height	0.12	-0.09	-0.05
	Body mass	0.32*	0.28*	0.18

Table 3: The standard error of the estimate (STDE) and its percentage of the mean (%STDE) for each predictor of spine muscle size in the combined, male and female groups. HGS = hand grip strength.

		Combined group		Male group		Female group	
		STDE	%STDE	STDE	%STDE	STDE	%STDE
Muscle area	HGS	678	16	797	17	535	14
	Age	828	20	813	17	576	15
	Height	726	17	843	18	532	14
	Body mass	723	17	773	17	545	14
Muscle area scaled by height	HGS	3.8	15	4.5	17	3.0	13
	Age	4.3	18	4.4	17	3.2	14
	Height	4.2	17	4.8	18	3.1	14
	Body mass	4.0	16	4.4	17	3.1	14
Muscle area scaled by height squared	HGS	0.022	16	0.026	17	0.018	13
	Age	0.023	16	0.025	17	0.018	14
	Height	0.024	17	0.027	18	0.018	14
	Body mass	0.023	16	0.026	18	0.018	13


Muscle area (mm^2)
8000
6000
4000
2000
0
0 10 20 30 40 50 60 70
Hand grip strength (kg)
Male
Female
45 50 55 60 65 70 75
Age (years)
150 160 170 180 190
Height (cm)
50 60 70 80 90 100 110 120
Body mass (kg)



Muscle area (mm^2)
8000
6000
4000
2000
0
Male
Female
0
10
20
30
40
50
60
70
Hand grip strength (kg)
Muscle area / height (mm^2 cm^-1)
40
20
0
Hand grip strength (kg)
Muscle area / height^2 (mm^2 cm^-2)
0.2
0.1
0
Hand grip strength (kg)