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

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### 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<sup>2</sup>. 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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3



## 4 Abstract

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16 Scaling by height or height squared does not improve the ability of hand grip strength to predict muscle  
17 size.

## 19 Keywords

- 20 1) Paraspinal Muscles
- 21 2) Hand grip strength
- 22 3) Anthropometry
- 23 4) UK Biobank

## 24 Introduction

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

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

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

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

49 Studies have demonstrated an association between hand grip strength and the size of individual muscles  
50 in the body; however, the evidence for a relationship with the spinal muscles is limited. Although an  
51 association has been demonstrated between hand grip strength and back strength in various cohorts [1,  
52 16-18], only one study has investigated the relationship between hand grip strength and spine muscle  
53 size [7] and this has focussed on male participants alone. Furthermore in considering relationships  
54 between muscle size and hand grip strength, issues of scaling may be important. It is generally assumed  
55 that larger people have bigger muscles, and scaling of muscle size is often employed to counter this  
56 effect, so results are not skewed because of varying participant sizes. The most appropriate method for  
57 scaling the muscle area is one of discussion [19] with some studies scaling by height [13, 20] and some  
58 by height-squared [8, 20-21]. The relevance of scaling in any relationship between handgrip strength  
59 and spinal muscle size is unclear.

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

## 64 **Methods**

### 65 **Dataset**

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

73 scans were obtained and together these constitute all of the data variables that were extracted from the  
74 Biobank data for the current study.

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

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

## 85 **Image analysis**

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

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

## 95 **Scaling**

96 Three approaches were taken with scaling the measurements of muscle cross-sectional area to assess  
97 which would result in the strongest relationship between hand grip strength: unscaled muscle area,  
98 muscle area scaled by height (= muscle area/height), and muscle area scaled by height squared (=  $\text{muscle area/height}^2$ ).  
99

## 100 **Statistical Analysis**

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

## 109 **Results**

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

113 Hand grip strength, age, height, and body mass correlated significantly with unscaled muscle area in the  
114 combined group (Figure 1). However, the strength of the association between the variables differed,  
115 with hand grip strength exhibiting a strong correlation and age, height, and body mass exhibiting weak  
116 to moderate correlations (Table 2). The variation in strength of association was reflected in the

117 prediction errors, which varied from 678 mm<sup>2</sup> when hand grip strength was used as a predictor to 828  
118 mm<sup>2</sup> when age was used (Table 3).

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

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

## 128 **Discussion**

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

134 The hand grip strengths of the male and female participants in our sample are consistent with values  
135 from large cohort studies reported in the literature [13], suggesting that our sample is representative of a  
136 larger population. Although we were not able to establish this in our study, previous studies have shown  
137 hand grip strength to have high test-retest reliability, with reported intraclass correlation coefficients of  
138 0.99 and errors of around 3 % [14-15]. Furthermore, by averaging the left and right-hand values, we  
139 expect to improve the precision of the raw data. Similarly, measurements of muscle size from MR  
140 images are expected to have high reliability [10-11].



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

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

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

162 Furthermore, despite its potential limitations for assessing spine muscle size, hand grip strength still has  
163 a potential role in assessing spine muscles if strength, rather than size, is being assessed. Hand grip  
164 strength has been found to correlate significantly with back and trunk strength [16-18] and to be  
165 associated with a lower risk of vertebral fracture [26] and a lower incidence of low back pain [27].  
166 Although changes in muscle size following an intervention can be moderate, changes in strength can be

167 much higher, with one study reporting a 26% increase in back muscle strength that was accompanied by  
168 an increase in hand grip strength of 13% [28]. The causality of these relationships has not been  
169 established, but hand grip strength is likely to perform better than measures such as age, height and body  
170 mass, which are expected to change little over the course of an intervention.

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

## 183 **Conclusion**

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

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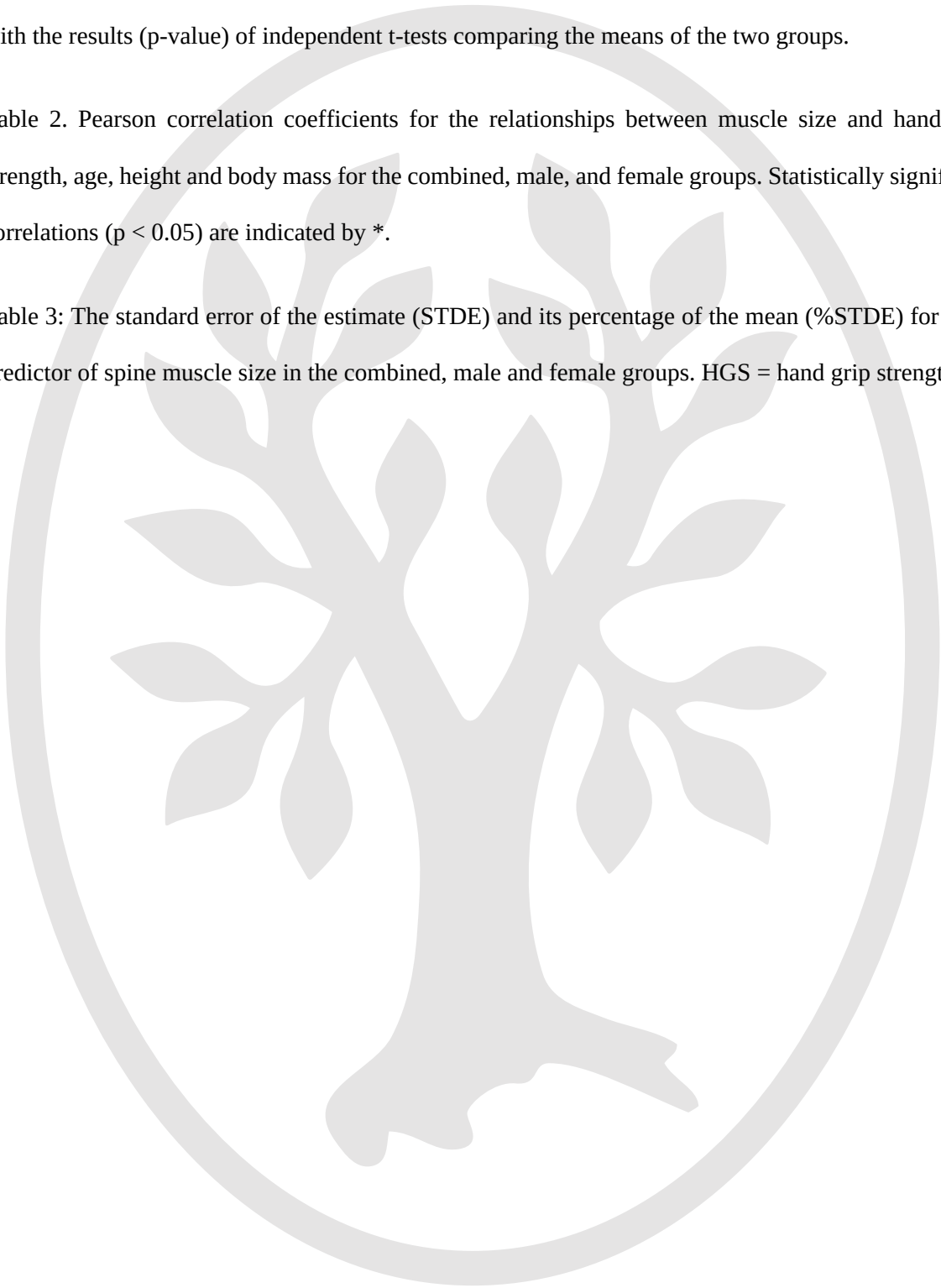
261 **Tables**

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

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

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

269



270 **Figure legends**

271

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

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

276



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.

	<b>Male</b>	<b>Female</b>	<b>p-value</b>
	<b>(mean ± sd)</b>	<b>(mean ± sd)</b>	
<b>Age (years)</b>	59 ± 7	58 ± 7	0.77
<b>Height (cm)</b>	177 ± 6	168 ± 6	< 0.001
<b>Body mass (kg)</b>	79 ± 10	71 ± 9	< 0.001
<b>Hand grip strength (kg)</b>	40 ± 7	25 ± 6	< 0.001
<b>Muscle area (mm<sup>2</sup>)</b>	4664 ± 868	3822 ± 579	< 0.001
<b>Muscle area scaled by height (mm<sup>2</sup> cm<sup>-1</sup>)</b>	26 ± 5	23 ± 3	< 0.001
<b>Muscle area scaled by height-squared (mm<sup>2</sup> cm<sup>-2</sup>)</b>	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 \*.

		<b>Combined group (n = 150)</b>	<b>Male group (n = 75)</b>	<b>Female group (n = 75)</b>
<b>Muscle area</b>	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*
<b>Muscle area scaled by height</b>	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*
<b>Muscle area scaled by height squared</b>	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
<b>Muscle area</b>	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
<b>Muscle area scaled by height</b>	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
<b>Muscle area scaled by height squared</b>	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



