Can sit-to-stand muscle power explain the ability to perform functional tasks in adults with severe obesity?

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Abstract

This study examined the relationship between sit-to-stand (STS) power and physical function in adults with severe obesity. Thirty-eight adults (age: 44 ± 12 years; body mass index [BMI]: 45.2 ± 7.8 kg/m^2) completed evaluations of STS power, strength and functional performance. STS power was measured with a wearable inertial sensor, strength was assessed with the isometric mid-thigh pull, and function was measured with the timed up-and-go (TUG), six-minute walk test (6MWT) and 30-s chair STS. Power and strength (normalised to body mass) entered regression models in addition to age, gender, BMI and physical activity (daily step count). Power displayed large univariate associations with TUG ($r = 0.50$) and 30-s chair STS ($r = 0.67$), and a moderate association with 6MWT ($r = 0.49$). Forward stepwise regression revealed that power independently contributed to TUG ($\beta = -0.40$, $p = 0.010$), 30-s chair STS ($\beta = 0.67$, $p < 0.001$) and 6MWT performance ($\beta = 0.27$, $p = 0.007$). Power also appeared to be a superior determinant of function compared with strength. Power generated via the STS transfer largely underpins the ability to perform functional tasks in adults with severe obesity, although intervention studies are required to investigate a potentially causal relationship.

Introduction

Obesity is a public health concern of epidemic proportions. The prevalence of obesity continues to escalate amongst most demographics and is a major risk factor for a raft of health conditions including type 2 diabetes mellitus, cardiovascular disease and certain types of cancer (Dobbins, Decorby, & Choi, 2013; Ng et al., 2014). In addition, the carriage of excess body fat leads to modifications in the gait pattern and a decreased functional capacity (Shultz, Byrne, & Hills, 2014). For example, obese individuals walk with a more extended knee at faster walking speeds (Lerner, Board, & Browning, 2014). This results in a greater proportion of body mass supported by the aligned skeleton rather than the knee extensor musculature. Consequently, there is an increased risk for pathology at the knee, which often leads to musculoskeletal pain and a decreased motivation to exercise (Shultz, Anner, & Hills, 2009). Functional limitations experienced by the obese are therefore major impediments to engagement in physical activity. Currently, the physical factors underpinning obesity-related impairments in function are poorly understood.

Compared with their non-obese counterparts, individuals with obesity experience a reduction in lower-limb strength when normalised to body mass (Tomlinson, Erskine, Morse, Winwood, & Onambele-Pearson, 2016). It has been widely postulated that this strength deficit leads to compensatory movement patterns and a reduced capacity to perform basic daily tasks (Hills, Hennig, Byrne, & Steele, 2002; Shultz et al., 2014). Interestingly, the ability to generate muscle power appears to be reduced to a greater extent than muscle strength in adults with obesity (Hilton, Tuttle, Bohnert, Mueller, & Sinacore, 2008; Lafortuna, Maffiuletti, Agosti, & Sartorio, 2005). This suggests that power may be a critical factor underpinning the functional limitations imposed by obesity. Nevertheless, to our knowledge, only one study has examined the functional relevance of power. Carvalho et al. (2015) reported that lower-limb strength and power were both significantly related to performance during a six-minute step test in obese women. However, this study only employed zero-order correlations, which do not account for the mediating effect of other covariates. For instance, habitual physical activity influences chair-rise performance independent of age and body mass (Landi et al., 2018). Adjusting for physical activity has been shown to distort the relationship between obesity and muscle strength (Rolland et al., 2004). Age (Tomlinson, Erskine, Morse, Winwood, & Onambele-Pearson, 2014) and gender (Lafortuna et al., 2005) also mediate the effects of obesity on muscle contractile function. Regression analyses are required to identify the independent contributions of strength and power to functionality after adjusting for well-established confounding variables.

Common methodologies that are used to measure power include the Nottingham power rig, isokinetic dynamometry and pneumatic resistance machines (Balachandran, Krawczyk, Potiaumpai, & Signorile, 2014; Carvalho et al., 2015; Strollo et al., 2015; Vasconcelos et al., 2016; Ward et al., 2014). Although these techniques quantify power with the high reproducibility, they do not mimic functional daily activities and therefore the power generated in these movements may not be transferable to real-life settings. More recently, linear position transducers (LPTs) have been employed to measure power in functional performance tasks such as the sit-to-stand (STS) transfer (Gray & Paulson, 2014). Given that independently functioning adults perform ~60 chair rises per day (Dall & Kerr, 2010), the STS transfer reflects lower-extremity function and is relevant to activities of daily living. However, the requirement of a cable and high financial costs limit the use of LPTs within many practical settings.

The use of a wearable inertial sensor (PUSH^{TM}) has emerged as a popular method of measuring power in well-trained populations (Balsalobre-Fernandez, Kuzdub, Poveda-Ortiz, & Campo-Vecino, 2016; Banyard, Nosaka, Sato, & Haff, 2017). In a cohort of professional youth rugby league players, PUSH^{TM} recently obtained a valid and reliable measurement of power at 20% of one repetition maximum (1RM) in the free-weight back squat (Orange et al., 2018). The wearable device circumvents many limitations of other power-measuring techniques because it is relatively economical (~£220 per unit), does not require a cable attachment and is worn inconspicuously on the individual's forearm. Despite this potential, the device is yet to be evaluated on its ability to measure power via functional tasks.

The primary purpose of this study was to examine the relationship between STS power and physical function in adults with severe obesity after adjusting for muscle strength, age, body mass index (BMI), gender and habitual physical activity. We also aimed to evaluate the test-retest reliability of a wearable inertial sensor to measure velocity and power generated via the STS transfer.

Methods

Participants

Participants were recruited from a Tier 3 specialist weight management service. All participants were required to be aged ≥18 years and have a BMI of over 40 kg/m^2 or between 35 and 40 kg/m^2 with a serious comorbidity (such as type 2 diabetes or sleep apnoea). Involvement in this study was not permitted if any of the following exclusion criteria were met: unstable chronic disease state, prior myocardial infarction or heart failure, poorly controlled hypertension (≥180/110 mmHg), uncontrolled supraventricular tachycardia (≥100 bpm), participation in a structured exercise regime, body mass of above 200 kg, severe peripheral neuropathy, pre-existing severe physical disability or any other musculoskeletal or neurological condition that could affect their ability to complete the testing. Participants were informed of the experimental procedures to be undertaken prior to signing an institutionally approved informed consent document to participate in the study. Ethical approval for the study was granted by the Sports, Health and Exercise Science Ethics Committee at the University of Hull.

Study design

This study used a cross-sectional, observational design to determine whether STS power explained the ability to perform functional tasks in adults with severe obesity. Participants visited the laboratory on two separate occasions. During the first visit, demographic and anthropometric information were collected, followed by the evaluation of STS power, muscle strength and functional performance. In the second visit, at least seven days following the first visit (7.4 ± 0.8 days [range: 7 to 10 days]), the STS power test was repeated to assess test-retest reliability.

Demographic and anthropometric measurements

A medical questionnaire was used to collect demographic and clinical data. Anthropometric measurements were then taken including body mass, height, and waist and hip circumference. The participants' habitual level of physical activity was also characterised by determining the mean number of steps walked each day. After the first visit to the laboratory, all participants were given a pedometer (Yamax Digiwalker SW-200, YAMAX, Bridgnorth, Shropshire, UK) to wear on their dominant hip and recorded the number of steps they walked daily for seven days. Recording commenced immediately upon waking and finished before bed each night, with the step count reset to zero again the next morning. Instructions were given to maintain their usual physical activity levels during this seven-day period. The Yamax SW-200 pedometer has been shown to estimate step counts within 1-3% of actual steps (Crouter, Schneider, Karabulut, & Bassett, 2003; Rowlands, Stone, & Eston, 2007; Schneider, Crouter, Lukajic, & Bassett, 2003) and is considered highly valid ($r = 0.87$) in free-living overweight and obese adults (Barriera et al., 2013).

Functional performance

Six-minute walk text (6MWT)

Participants walked at their own maximal pace back and forth along a flat 30-m surface, covering as much ground as they could in six minutes. All instructions and monitoring adhered to the guidelines provided by the American Thoracic Society (2002). The 6MWT has previously been shown to be highly reliable in obese outpatients (ICC = 0.96; SEM = 25.0 m) (Larsson & Reynisdottir, 2008) and in our laboratory (ICC = 0.98; SEM = 13.7 m) (Northgraves, Hayes, Marshall, Madden, & Vince, 2016).

Timed up-and-go (TUG)

Participants sat in a firm bariatric chair (height, 48 cm; depth, 56 cm; width, 69 cm) and were required to stand up, walk three meters before turning 180° around a cone and returning to the chair to sit down. Participants were instructed to perform the test as quickly as possible but in a controlled manner, with time recorded in seconds. TUG is a basic measure of functional mobility (Podsiadlo & Richardson, 1991) and has demonstrated high test-retest reliability in our laboratory (ICC = 0.97; SEM = 0.22 s) (Northgraves et al., 2016).

Thirty-second chair STS

The 30-s chair STS is a reliable measure of lower extremity function (Jones, Rikli, & Beam, 1999). Using the same bariatric chair as the TUG, participants began seated and were subsequently instructed to rise to a full standing position (legs straight) and then return to the seat (full weight on chair) with both arms crossed against the chest. A practice trial of two repetitions was given to check correct form. The total number of stands performed correctly was recorded for analysis.

Muscle strength

Muscle strength was assessed with the isometric mid-thigh pull (IMTP) test using an analogue dynamometer (Takei Scientific Instruments Co. Ltd., TKK 5002 Back-A, Tokyo, Japan). The height of the handle was individually adjusted so that the bar rested midway up the thigh and there was 145° of knee flexion (Dos'Santos, Thomas, Jones, McMahon, & Comfort, 2017), which was measured with geometry. Participants then maximally extended their knees and trunk for three to five seconds without bending their back. Two trials were performed with a two-minute rest period in between and the maximum value used for analysis. The IMTP demonstrated excellent within-session reliability in this study (ICC = 0.98; SEM = 5.6 kg).

STS power

The STS power test was administered in a firm bariatric chair using the same technique as the 30-s chair STS test. Participants performed a warm-up of two repetitions to familiarise themselves with performing the upwards phase with maximal intended velocity. Subsequently, three repetitions were performed separated by 60 seconds of rest. Participants were instructed to maintain their arms crossed against their chest and stand up as quickly as possible from a seated position, before returning to the initial seated position in a controlled manner (see supplemental online material). Additional trials were performed if the arms moved away from the chest. A wearable inertial sensor (PUSH^{TM}, PUSH Inc., Toronto, Canada) was used to measure mean power (MP), peak power (PP), mean velocity (MV), and peak velocity (PV) in the upwards phase of each STS repetition.

Data analyses

The wearable inertial sensor (PUSH^{TM}) consisted of a 3-axis accelerometer and a gyroscope that provides six degrees in its coordinate system. The device was worn on the participant's right forearm, 1-2 cm distal to the elbow crease, with the main button located proximally. The method used to calculate MV, PV, MP and PP has been described previously (Orange et al., 2018). The maximum value of the three repetitions (fastest mean concentric velocity) was used for analyses. We chose to include only MP in the regression analyses to avoid having highly correlated variables in the regression models, and we have previously shown MP to be the most valid metric at 20% of 1RM in the back squat ($r = 0.91$) (Orange et al., 2018). MP and strength were normalised to body mass because these relative values are more pertinent to individuals with obesity than absolute values (Tomlinson et al., 2016). Daily step counts were divided by 1000 before being entered into the regression analysis to improve the readability of the unstandardised coefficients.

Sample size

The sample size was calculated using G*Power software (version 3.1, Universität Düsseldorf, Düsseldorf, Germany). Given the type of statistical analysis (linear multiple regression), partial $R^2 = 0.49$; $\alpha = 0.05$, $1-\beta = 0.95$; predictors = 6, a priori sample size for statistical significance was calculated as 29 participants. The very large effect size is equivalent to a Pearson correlation coefficient (r) of 0.7 (Cohen, 1988; Hopkins, 2000a), which was chosen based on a previous study that reported a very strong correlation ($r > 0.7$) between STS MP and the 30-s chair STS test in sarcopenic older adults (Glenn, Gray, & Binns, 2017).

Statistical analyses

Relative reliability was determined with the intraclass correlation coefficient (ICC) using custom-designed Microsoft Excel spreadsheets (Hopkins, 2015). ICC estimates of <0.5, 0.50 to 0.74, 0.75 to 0.89, and ≥0.9 were considered poor, moderate, good and excellent, respectively (Koo & Li, 2016). Absolute reliability was examined with the standard error of measurement (SEM) using the formulae $SD_{diff}/\sqrt{2}$ (Hopkins, 2000b), and was also expressed as a percentage of the mean ($SEM_{\%}$).

Regression analyses were conducted using SPSS for Windows (IBM SPSS, version 24.0, Chicago, IL). Data were first inspected visually and statistically to assess whether the assumptions for regression analyses were met (including linearity, homoscedasticity, normality, multicollinearity, outliers and independence of observations). We compared baseline characteristics between males and females with independent samples t-tests (continuous data) and chi-squared tests (nominal data). Univariate associations between functional performance tasks (TUG, 30-s chair STS, 6MWT) and the independent variables were described using the Pearson correlation coefficient. The point-biserial correlation coefficient (r_{pb}) was used for nominal variables (gender). For discussion purposes, correlation coefficients of <0.10, 0.10 to 0.29, 0.30 to 0.49, 0.50 to 0.69, and ≥ 0.70 were considered trivial, small, moderate, large and very large, respectively (Hopkins, 2000a). All variables with a univariate association at the level of $p < 0.15$ were then entered into appropriate multiple and forward stepwise regression models. A critical *p*-value of 0.15 aligns with previous studies (Foldvari et al., 2000; Suzuki, Bean, & Fielding, 2001), is often the default value used by statistical software for entry into forward stepwise regression models, and ensured that potentially important variables were not prematurely discarded (Bendel & Afifi, 1977). The proportion of variance in the dependent variable explained by the independent variables was reported with adjusted R squared (R^2_{adj}). The alpha level indicating statistical significance was set at $p < 0.05$.

Results

A total of 38 participants (age: 43.6 ± 12.3 years [range: 20 to 68 years]; BMI: 45.2 ± 7.8 kg/m^2 [range: 36.4 to 70.7 kg/m^2]) volunteered to participate in the study and completed both visits to the laboratory. Participant characteristics are presented in table 1.

*****INSERT TABLE 1 HERE*****

Reliability

Measurements of MP and PP demonstrated excellent relative reliability (ICC > 0.90), while the reliability for MV and PV data were considered good (ICC > 0.75) (figure 1). Absolute SEM values (mean, 95% CI) were as follows: MV (0.07, 0.06 to 0.09 m·s^{-1}), PV (0.14, 0.12 to 0.18 m·s^{-1}), MP (86, 70 to 112 W), PP (194, 158 to 250 W).

*****INSERT FIGURE 1 HERE*****

Univariate associations

Power displayed a large negative association with TUG ($r = -0.50$), a large positive association with 30-s chair STS ($r = 0.67$) and a moderate positive correlation with 6MWT ($r = 0.49$). Strength was moderately associated with all three functional tasks. Univariate associations are displayed in table 2 and scatterplots are presented as supplemental online material.

*****INSERT TABLE 2 HERE*****

Regression analyses

Multiple and stepwise regression models were constructed with all variables that had a univariate association of $p < 0.15$. The assumptions of linearity and homoscedasticity were confirmed by visual inspection of scatterplots. Visual inspection of Q-Q plots also suggested normal distribution of data. Independence of observations was confirmed by a Durbin-Watson statistic (range: 1.87 to 2.10). Examination of casewise diagnostics revealed no outliers or influential points in the model. Finally, the Variance Inflation Factor (VIF) for all data was <3, indicating a low level of multicollinearity.

Timed up-and-go

BMI, physical activity, power and strength accounted for 34% of the variance in TUG performance ($r = 0.64$, $p = 0.001$). These same variables were then entered into a forward stepwise regression model; power and strength were the only factors that contributed independently to TUG performance ($r = 0.57$, $p = 0.001$), accounting for 29% of the variance (table 3). Power alone explained 22% of the variance in performance.

*****INSERT TABLE 3 HERE*****

Thirty-second chair STS

The combination of age, physical activity, power, and strength explained 48% of the variance in 30-s chair STS performance ($r = 0.73$; $p < 0.001$). Forward stepwise regression revealed that power was the only independently contributing variable ($r = 0.67$, $p < 0.001$), accounting for 44% of the variance (table 4).

*****INSERT TABLE 4 HERE*****

Six-minute walk test

BMI, gender, physical activity, power and strength were entered into the multiple regression and explained 71% of the variance in 6MWT performance ($r = 0.87$, $p < 0.001$). Subsequently, a forward stepwise regression revealed that BMI, power, physical activity and strength independently contributed to 6MWT ($r = 0.86$, $p < 0.001$), accounting for 72% of the variance in performance (table 5).

*****INSERT TABLE 5 HERE*****

Discussion

The main finding of this study was that STS power independently contributed to all assessments of physical function in adults with severe obesity. Muscle power also appeared to be a superior determinant of functional performance compared with muscle strength, specifically in the TUG and 30-s chair STS. Importantly, all measurements of velocity and power obtained by the wearable inertial sensor were highly reliable.

We are the first to show that the power generated via the STS transfer is related to functional performance in adults with severe obesity. STS power displayed large univariate associations with TUG ($r = -0.50$) and 30-s chair STS test ($r = 0.67$), and a moderate positive association with 6MWT ($r = 0.49$). Previously, Carvalho et al. (2015) reported a large positive correlation ($r = 0.50$) between isokinetic lower-limb power (normalised to body mass) and performance during a six-minute step test in obese women. We have extended these findings by adjusting for strength, age, BMI, gender and physical activity in regression analyses. Forward stepwise regressions revealed that STS power independently contributed to all assessments of physical function. For example, power alone accounted for almost one half of the variance in 30-s chair STS performance ($R^2_{adj} = 0.44$, $\beta = 0.67$, $p < 0.001$). These findings suggest that STS power is a critical determinant of function for adults with severe obesity. This has important practical implications for assessing functional capacity in clinical settings where limited time and space are limited. Considering an average physician's visit lasts 15 minutes and covers six different topics (Tai-Seale, McGuire, & Zhang, 2007), conducting a battery of functional tests may not be feasible. The STS power test takes less than one minute to complete, and the inertial sensor provides immediate performance feedback. Hence, practitioners may use STS power as a quick and reliable proxy for functional status in severely obese adults.

The wearable inertial sensor demonstrated good to excellent reliability for all measurements of velocity and power (ICCs = 0.83-0.91). The device provides estimates of power using inverse dynamics. Linear accelerations are measured in the upward phase of the STS and velocity is calculated by integrating acceleration with respect to time. Power is then determined as the product of force (i.e. body mass x acceleration) and velocity (Orange et al., 2018). By normalising power to body mass, variation in relative power is accounted for by variation in acceleration and velocity. Therefore, the relevance of STS power to functional performance is underpinned by kinematic factors.

Many authors have postulated that reduced lower-limb strength is largely responsible for the obesity-related deficits in functional capacity (Hills et al., 2002; Lerner et al., 2014; Shultz et al., 2014). Indeed, this study found moderate univariate associations between strength and all measures of functional performance. Muscle strength was also an independently contributing variable to TUG ($\beta = -0.30$, $p = 0.046$) and 6MWT performance ($\beta = 0.28$, $p = 0.007$).

Notwithstanding the importance of muscle strength, our data indicate that power may be a superior determinant of function in adults with severe obesity. STS power was the only factor that independently contributed to 30-s chair STS performance and displayed larger associations with TUG and 30-s chair STS compared with strength. This suggests that specifically targeting muscle power within training interventions, in addition to or instead of muscle strength, may enhance physical function in the obese population. Preliminary evidence with sarcopenic obese adults suggests that power training improves functionality to a greater extent than traditional slow-speed resistance exercise (Balachandran et al., 2014), although this finding has recently been contested (Vasconcelos et al., 2016). Further intervention studies are required to investigate the potential causal relationship between muscle power and functional performance in severely obese adults with and without sarcopenia.

The IMTP test involves a static isometric contraction, which does not replicate the dynamic muscle contraction involved in functional performance tasks. Thus, the specificity of the strength test may have contributed to the results. Alternative laboratory-based methods include the use of the leg press or isokinetic knee extension. However, many adults with severe obesity cannot achieve the range of knee flexion required in the leg press exercise due to restrictive abdominal adiposity. Strict standardisation of knee flexion is essential because leg press 1RM has been shown to improve by 59% when the starting knee angle increases from 80° to 100° (Moura, Borher, Prestes, & Zinn, 2004). In addition, isokinetic dynamometry does not replicate the contraction-type or multi-jointed movement patterns involved in functional tasks. Therefore, the IMTP may represent the most feasible option for assessing multiarticular strength in adults who are severely obese. The IMTP also showed high reliability in this study (ICC = 0.98) and isometric strength shows high construct validity in the obesity literature (Maffiuletti et al., 2007).

BMI was negatively related to 6MWT performance (*r* = -0.69), explaining 46% of the variance alone. This finding agrees with previous research reporting BMI to be the most important factor explaining 6MWT distance in obese adults (Hulens, Vansant, Claessens, Lysens, & Muls, 2003; Larsson & Reynisdottir, 2008). The majority of studies also show that obese individuals have a slower walking velocity and shorter stride length compared with their non-obese counterparts (Hills, Byrne, Wearing, & Armstrong, 2006; Pataky, Armand, Müller‐Pinget, Golay, & Allet, 2014; Spyropoulos, Pisciotta, Pavlou, Cairns, & Simon, 1991). Hence, the present study provides further evidence of the negative effects that obesity imposes on ambulatory function.

Physical activity was not independently related to the TUG or 30-s chair STS. Previous research has shown that physical activity influences lower-limb strength in obese adults, possibly through a chronic overload stimulus (Rolland et al., 2004). Physical activity is less likely to impact power capabilities, however, because leisure-time activities typically involve slow sustained contractions (e.g. walking), particularly in obese subjects (Hills et al., 2006). Given that power was the most important determinant of TUG and 30-s chair STS, this may explain why physical activity did not contribute to the performance of these tasks. It is also important to note that we used step counts as a surrogate measure of physical activity, which do not consider the intensity or type of exercise, nor the amount of sedentary time. Even so, there is ample evidence supporting the validity of pedometer-measured step counts (Tudor-Locke, Williams, Reis, & Pluto, 2002). Moreover, participants in this study were not engaged in structured exercise or any other form of leisure-time physical activity. Therefore, step counts were likely an accurate representation of habitual physical activity in this cohort.

This study does have some limitations. The study sample included participants with a wide range of BMIs (36-71 kg/m^2), ages (20 to 68 years) and comorbidities. Consequently, this sample may not be representative of a particular demographic. However, all participants were recruited from a Tier 3 weight management service and we adjusted for age, BMI, physical activity and gender in regression analyses. As a result, the functional relevance of power is independent of these confounding variables, which increases the generalisability of our findings. It has been suggested that there should be 15 to 20 participants per predictor variable in a regression analysis (Schmidt, 1971). Nevertheless, we estimated sample size with a power analysis; given the large positive correlation between STS power and the 30-s chair STS test ($r = 0.67$), the statistical power achieved in the multiple regression was computed by G*Power as: $1-\beta = 0.98$. We also quantified the proportion of variance explained by the models with adjusted R^2 (rather than the conventional R^2), which is not influenced by sample size (Austin & Steyerberg, 2015).

Conclusions

To conclude, the power generated via the STS transfer (when normalised to body mass) independently contributed to all assessments of physical function. While strength was also important for function, muscle power was a superior determinant of TUG and 30-s chair STS performance. This suggests that STS power largely underpins the ability to perform daily activities in adults with severe obesity. Practitioners can use STS power, quantified with a wearable inertial sensor, as a quick and reliable proxy for functional status. A single assessment of STS power may be particularly useful in clinical settings where limited time and space preclude physicians from administering a battery of tests. Practitioners should also consider specifically targeting muscle power within training interventions, in addition to or instead of muscle strength, to preferentially enhance physical functioning in adults with severe obesity. However, further intervention studies are required to investigate a potentially causal relationship.

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Disclosure statement

No potential conflict of interest was reported by the authors

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Table captions

Table 1. Baseline characteristics of study participants

Table 2. Univariate associations between independent variables and functional tasks

Table 3. Forward stepwise regression analysis with TUG performance as the dependent variable

Table 4. Forward stepwise regression analysis with 30-s chair STS performance as the dependent variable

Table 5. Forward stepwise regression analysis with 6MWT performance as the dependent variable

Figure captions

Figure 1. Reliability of power and velocity measurements in the sit-to-stand (STS) transfer. Forest plots display the intraclass correlation coefficient (ICC, panel A) and standard error of measurement as a percentage of the mean ($SEM_{\%}$, panel B). MV = mean velocity; PV = peak velocity; MP = mean power; PP = peak power.

Data are presented as mean ± 95% confidence intervals.

Table 1. Baseline characteristics of study participants

	Total (n = 38)	Female (n = 23)	Male (n = 15)	*p*-value
Demographics				
Age (years)	43.6 ± 12.3	40.9 ± 12.7	47.7 ± 10.9	0.096
Body mass (kg)	127.8 ± 25.4	122.4 ± 26.9	136.1 ± 21.1	0.106
Height (cm)	167.9 ± 8.6	163.0 ± 5.9	175.3 ± 6.8	<0.001*
BMI (kg/m^2)	45.2 ± 7.8	45.9 ± 9.0	44.2 ± 5.7	0.530
WC (cm)	128.0 ± 14.1	123.1 ± 14.8	135.5 ± 9.0	0.006*
Waist to hip ratio	0.94 ± 0.10	0.88 ± 0.04	1.04 ± 0.07	<0.001*
Habitual PA (step count)	5951 ± 2754	6236 ± 2948	5513 ± 2459	0.436
Physiological				
TUG (s)	6.6 ± 1.1	6.8 ± 1.1	6.5 ± 0.9	0.388
30-s chair STS (reps)	11.7 ± 2.7	11.6 ± 2.6	11.9 ± 3.1	0.691
6MWT (m)	504 ± 76	488 ± 81	528 ± 63	0.119
STS power (W)	746 ± 262	657 ± 213	883 ± 278	0.008*
STS power$_{BM}$ (W/kg)	5.8 ± 1.8	5.4 ± 1.7	6.5 ± 1.8	0.078
IMTP strength (kg)	78.9 ± 47.9	48.7 ± 23.2	125.3 ± 37.6	<0.001*
IMTP strength$_{BM}$ (kg)	0.62 ± 0.37	0.41 ± 0.19	0.95 ± 0.32	<0.001*
Clinical				
Systolic BP (mmHg)	139.9 ± 17.0	138.0 ± 18.8	142.7 ± 14.0	0.413
Diastolic BP (mmHg)	86.1 ± 9.0	85.4 ± 10.1	87.2 ± 7.1	0.550
Resting HR (bpm)	71.7 ± 8.9	70.6 ± 8.8	73.5 ± 9.0	0.320
Prescription medications	3.1 ± 3.2	2.6 ± 3.0	3.7 ± 3.5	0.298
Type 2 diabetes (n)	9	3	6	0.056
OSA (n)	14	4	10	0.002*

BMI = body mass index; WC = waist circumference; TUG = timed up-and-go; STS = sit-to-stand; 6MWT = six-minute walk test; $_{BM}$ = normalised to body mass; IMTP = isometric mid-thigh pull; BP = blood pressure; HR = heart rate; bpm = beats per minute; PA = physical activity; OSA = obstructive sleep apnoea. * indicates significant difference between genders ($p < 0.05$).

Data are presented as mean ± SD.

Table 2. Univariate associations between independent variables and functional tasks

	TUG		30-s chair STS		6MWT	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value
Age	0.15	0.377	-0.37	0.023	0.05	0.783
BMI	0.35	0.030	-0.08	0.641	-0.69	<0.001
Gender	-0.14	0.388	0.07	0.691	0.26	0.119
Habitual PA	-0.25	0.130	0.29	0.074	0.35	0.032
Power_{BM}	-0.50	0.002	0.67	<0.001	0.49	0.002
$\text{Strength}_{\text{BM}}$	-0.43	0.007	0.33	0.046	0.49	0.002

TUG = timed up-and-go; STS = sit-to-stand; 6MWT = six minute walk test; *r* = Pearson correlation coefficient; BMI = body mass index; PA = physical activity; $_{\text{BM}}$ = normalised to body mass.

Table 3. Forward stepwise regression analysis with TUG performance as the dependent variable

	Model 1 $R^2_{adj} = 0.22$			Model 2 $R^2_{adj} = 0.29$		
	B	β	*p*	B	β	*p*
Power_{BM}	-0.30	-0.50	0.002	-0.24	-0.40	0.010
Strength_{BM}				-0.87	-0.30	0.046

TUG = timed up-and-go; $_{BM}$ = normalised to body mass; R^2_{adj} = adjusted R squared; B = unstandardised coefficient; β = standardised coefficient; *p* = *p*-value.

Table 4. Forward stepwise regression analysis with 30-s chair STS performance as the dependent variable

	Model 1 $R^2_{adj} = 0.44$		
	B	β	*p*
Power_{BM}	1.1	0.67	<0.001

STS = sit-to-stand; $_{BM}$ = normalised to body mass; R^2_{adj} = adjusted R squared; B = unstandardised coefficient; β = standardised coefficient; *p* = *p*-value.

Table 5. Forward stepwise regression analysis with 6MWT performance as the dependent variable

	Model 1 $R^2_{adj} = 0.46$			Model 2 $R^2_{adj} = 0.60$			Model 3 $R^2_{adj} = 0.65$			Model 4 $R^2_{adj} = 0.72$		
	B	β	*p*	B	β	*p*	B	β	*p*	B	β	*p*
BMI	-6.7	-0.69	<0.001	-6.1	-0.62	<0.001	-5.9	-0.61	<0.001	-5.3	-0.55	<0.001
Power_{BM}				17.1	0.40	0.001	15.4	0.36	0.001	11.7	0.27	0.007
Habitual PA							6.9	0.25	0.017	8.1	0.29	0.003
Strength_{BM}										57.8	0.28	0.007

6MWT = six-minute walk test; BMI = body mass index; $_{BM}$ = normalised to body mass; PA = physical activity; R^2_{adj} = adjusted R squared; B = unstandardised coefficient; β = standardised coefficient; *p* = *p*-value

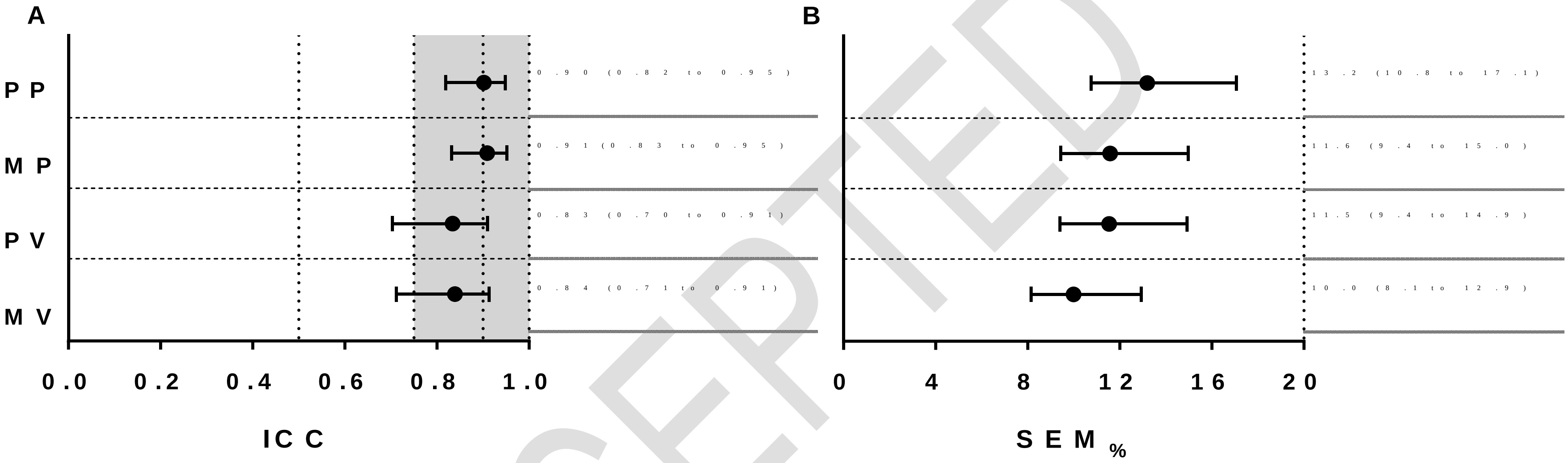
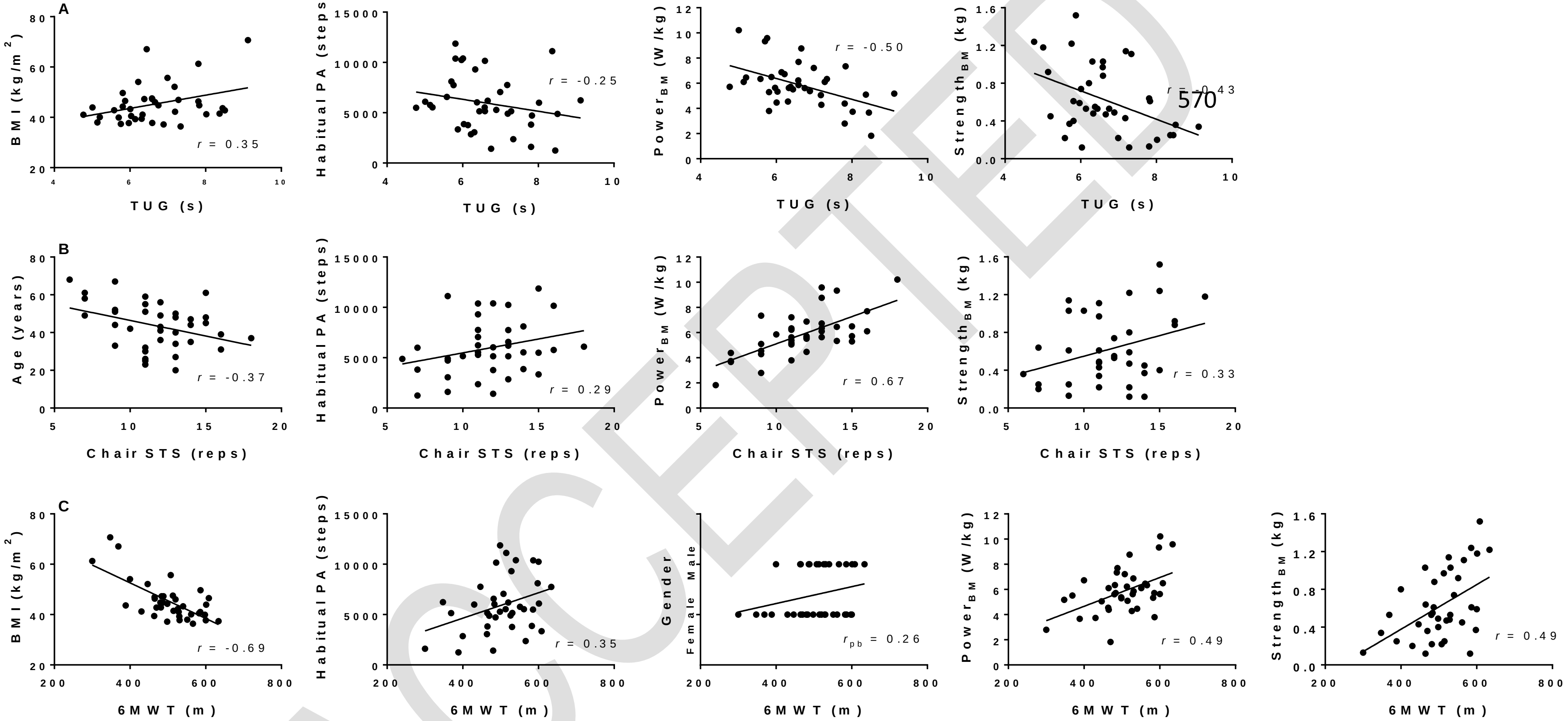


Figure 1. Reliability of power and velocity measurements in the sit-to-stand (STS) transfer. Forest plots display the intraclass correlation coefficient (ICC, panel A) and standard error of measurement as a percentage of the mean (SEM%, panel B). MV = mean velocity; PV = peak velocity; MP = mean power; PP = peak power.

Data are presented as mean ± 95% confidence intervals.

Supplemental Digital Content

Photograph of the sit-to-stand power test. The wearable inertial sensor is worn on the participant's right forearm, 1-2 cm distal to the elbow crease, with the main button located proximally.



Multiple regression models were constructed with predictor variables that displayed univariate associations at the level of $p < 0.15$. Scatterplots show univariate associations between these predictor variables and timed up-and-go (TUG; panel A), 30-s chair sit-to-stand (STS; panel B), and six-minute walk test (6MWT; panel C). BMI = body mass index; PA = physical activity; $_{\mathrm{BM}}$ = normalised to body mass. r = Pearson correlation coefficient; r_{pb} = point-biserial correlation coefficient.