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Grip and Knee Extension Muscle Strength Reflect a Common Construct among Adults

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Abstract

Introduction—Both grip and knee extension strength are often used to characterize overall limb muscle strength. We sought to determine if the measures actually reflect a common construct.

Methods—The isometric grip and knee extension strength of 164 healthy men and women (18–85 years) were measured bilaterally using standard procedures. Pearson correlations (r), Cronbach alpha, principal components analysis and multiple regression/correlation were used to investigate the dimensionality of the measures.

Results—Left and right grip forces and knee extension torques were highly correlated, internally consistent, and loaded on a single component. Gender and age explained the variance in both measures, but height added to the explanation of grip strength, whereas weight added to the explanation of knee extension strength.

Conclusion—Among healthy adults, grip and knee extension strength reflect a common underlying construct. The measures, however, are affected differently by height and weight.

Keywords

Muscle; strength; measurement; grip; knee

Introduction

Muscle strength, the maximal force or torque that can be brought to bear on the environment, is an important physical performance variable at the level of body function.[1] Sufficient strength is necessary for the performance of activities requiring the acceleration or deceleration of body segments or the body as a whole.[2–5] Strength is also a predictor of numerous health outcomes such as mortality, future disability, post-operative complications, and resource utilization.[6] Although many studies describe the measurement of limb muscle strength, two actions (hand-grip and knee extension) are probably measured more often than

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any other, particularly in population-based cohort studies.[7–13] Both grip and knee extension strength have been used to characterize overall limb muscle strength of individuals. Whether this is appropriate has been questioned but not resolved. [14] The purpose of this study, therefore, was to determine whether grip and knee extension muscle strength reflect a common construct across a wide age range of adult men and women.

Materials and Methods

This research was part of the validation phase of the NIH Toolbox for the Assessment of Neurological and Behavioral Function, an investigation designed to identify a brief yet comprehensive battery of portable, low-cost and lay-administered measures of cognitive, motor, sensory, and emotional health and function for use in large cohort studies.[15] This study used motor domain data gathered by trained testers at 2 participating sites (University of Connecticut and Rehabilitation Institute of Chicago). The institutional review boards at both sites approved the study.

Participants

Men and women between 18 and 85 years participated in this investigation. All participants provided written informed consent. Inclusion required that participants be fluent in English, able to walk without an assistive device, and be free of cardiovascular, pulmonary, musculoskeletal, or neuromuscular problems that would prevent standing from a chair or climbing steps.

Procedures

Basic demographic (age, gender) and anthropometric (height, weight) data were gathered prior to strength testing. Thereafter, in random order, isometric grip and knee extension strength were measured as part of a larger battery of tests. For both measurements each participant performed a submaximal warm-up effort and 2 maximal efforts with each limb. Hand-grip strength was measured with a Jamar hand-grip dynamometer (HGD) according to the protocol recommended by the American Society of Hand Therapy.[16] Specifically, participants were tested while they were seated, their arms were against their sides, their elbows were flexed 90 degrees, and the HGD was in the second handle position. Such measurements have been reported to demonstrate high intersession test-retest reliability.[17] Knee extension strength was measured with a Biodex isokinetic dynamometer (IKD) while participants were seated and stabilized with straps in the IKD test chair with their knees at 90 degrees. The intersession test-retest reliability of knee extension strength measurements acquired with the Biodex is well established.[18]

Statistical Analysis

All analysis was conducted using the Statistical Package for Social Sciences (SPSS version 18.0) and the MedCalc software programs. The best of the 2 maximal efforts for grip and knee extension strength on each side was used for all analysis. Standard descriptive statistics were calculated for demographic, anthropometric and strength data. Pearson correlations, Cronbach alpha and principal components analysis were first used to investigate whether grip and knee extension strength represented the same or different constructs. Based on these findings and our desire to reduce the risk of type 1 error, total strengths (left plus right) were then calculated for both grip and knee extension. Thereafter, the relationships of various demographic and anthropometric explanatory variables with the total grip and knee extension strengths were examined to further explore the dimensionality of grip and knee extension strength. This analysis involved Pearson correlations and forward multiple regression (correlations).

Results

Of 164 participants, 106 were women and 58 were men. Most (127) were white, but 17 were black, 14 were Asian, and 6 were of other ethnic backgrounds. Age and anthropometric information for the participants is summarized in Table 1. Most of the participants were young (47 were 18 to 29 years), but 34 were 30 to 45 years, 28 were 46 to 64 years, 27 were 65 to 74 years, and 28 were 75 to 85 years. A summary of the participants' strength measurements is shown in Table 2. Pearson correlations between the strength measures are shown in Table 3; they range from .772 to .957 regardless of measure (grip or knee) or side (left or right). The Cronbach alpha for the four measures was .938. Principal components analysis identified a single dominant component for the four measures. That component had an Eigenvalue of 3.54 and explained 88.4% of the construct variance. The loadings of the individual strength measures on the component ranged from 0.933 to 0.948. Figure 1 presents a scatterplot of the summed grip and knee extension strength measures.

Table 4 reports the Pearson correlations between the explanatory variables and total strength variables. Gender and age had significant negative correlations with both grip and knee extension strength (r= −0.370 to −0.765). This means that female gender was associated with less strength, more so for grip than for knee extension. It also means that increasing age was associated with less strength, similarly for knee extension and grip as measured. Height and weight had significant positive correlations with strength (r= 0.445 to 0.659), meaning that more height and weight were accompanied by greater strength. In multiple regression (correlation) analysis, gender, age and height contributed to the explanation of total grip (R= 0.824). However, if knee extension strength was accounted for, it explained the vast majority of the variance in grip strength (R = 0.809). In combination with gender and age its correlation with grip strength was only slightly higher (R= 0.872). In multiple regression (correlation) analysis, gender, age and weight (R= 0.793) contributed to the explanation of total knee extension strength. If, however, grip strength was accounted for, it explained the majority of variance in knee extension strength (R= 0.809). In combination with age and weight its correlation with knee extension strength was only slightly higher (R= 0.851).

Discussion

To investigate whether grip strength and knee extension strength represent a common construct (ie, limb muscle strength), we began our analysis with the calculation of Pearson correlations. Others have used Pearson correlations to examine the relationship between grip strength and knee extension strength and have obtained results similar to ours (r= 0.772 to 0.805). Specifically, Samson et al tested 155 apparently healthy individuals 20 to 90 years and found correlations between isometric grip strength and isometric knee extension strength of 0.70 for men and 0.82 for women.[13] Norman et al studied 189 adult patients with cancer and found a correlation of 0.752 between isometric measures of nondominant grip strength and right knee extension strength.[8] To more thoroughly investigate the dimensionality of the strength measures we also calculated Cronbach alpha and performed principal components analysis. The findings of both (a high alpha and a single dominant component) reinforce that grip strength and knee extension strength of the left and right sides represent a single construct, that is, limb muscle strength. These findings would seem to justify the use of either grip strength or knee extension strength of either side as an indicator of overall limb muscle strength, at least among apparently healthy adults. Given the portability, low cost, and simplicity of hand-grip dynamometry, its use as a sole measure is compelling.

Nevertheless, several considerations should provoke caution regarding use of grip strength or knee extension strength alone to characterize limb muscle strength. First, the correlations between left and right grip strength (0.952) and between right and left knee extension strength (0.957) were significantly higher (p<.001) than the correlations between grip and knee extension strength of the same or contralateral sides (0.772 to 0.805). This finding, along with previous research,[14] suggests that a measure obtained from a lower limb may provide a better indication of the strength of the contralateral lower limb than a measurement obtained from an upper limb and vice versa. Second, while a single measure such as grip strength may be sufficient to characterize strength, it does not provide a logical explanation of why an individual may have difficulty performing a task such as sit-to-stand, which does not utilize the muscles involved in gripping. Third, factors known through previous research to be related to muscle strength,[13,19–22] were not totally consistent in their influence on grip and knee extension strength in this study. While only gender appeared to be a potential issue in bivariate analysis, multiple regression analysis showed that height had more of an effect on grip strength, and weight had more of an effect on knee extension strength. Why this is the case is uncertain, except that greater weight puts more of a demand on the knee extensors during weight-bearing activities such as sit-to-stand. The knee extensors, therefore may adapt to greater body weight by getting stronger. There would be no need for grip strength to increase concomitant with weight.

This study has several limitations tied to the participants tested. First, the sample was relatively small and one of convenience. In the norming phase of the NIH Toolbox, a larger population-based sample will be employed. Second, the participants were healthy. The relationship between their grip and knee extension strengths, while also present in some patient groups,[8,13] might not be found in patients with injuries or diseases with regional effects (eg, spinal cord injury with paraparesis). Finally, this study involved only adults. Whether the findings generalize to children is not known.

Conclusions

The findings of this study suggest that for healthy adults isometric measures of grip and knee extension strength reflect a common underlying construct, that is, limb muscle strength. Nevertheless, differences in activities requiring grip and knee extension strength and the findings of our analysis preclude a blanket advocacy for using either alone to describe the limb muscle strength of tested individuals.

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Abbreviations

HGD	Hand Grip Dynamometer
IKD	Isokinetic Dynamometer

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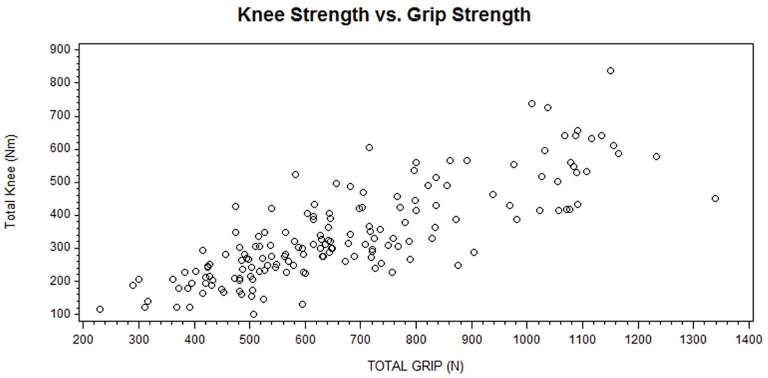

Figure 1.

Scatterplot illustrating the relationship between grip and knee extension strengths.

Table 1

Description of study participants

Variable	Total (n= 164) Mean (SD) Range	Men (n= 58) Mean (SD) Range	Women (n= 106) Mean (SD) Range
Age (yr)	48.8 (21.7) 18–85	45.6 (20.2) 18–85	50.6 (22.4) 18–85
Height (m)	1.68 (.10) 1.50–2.08	1.78 (.08) 1.57–2.08	1.63 (.07) 1.50–1.78
Weight (kg)	72.7 (16.1) 42.5–120.6	83.6 (16.6) 48.4–120.6	66.8 (12.5) 42.5–188.8

Table 2

Descriptive statistics for strength variables

Strength Variable	**Sides**	**Mean (SD) Range**
Grip force (N)	Left	326.0 (113.4) 106.3–636.9
	Right	349.9 (119.6) 124.5–702.8
	Total	675.9 (230.2) 230.9–1339.7
Knee extension torque (Nm)	Left	170.4 (73.1) 52.5–420.0
	Right	171.7 (71.8) 39.7–416.4
	Total	342.1 (143.4) 100.9–836.4

Table 3

Pearson correlations (95% confidence intervals) between strength measures[*]

	Grip: left	**Grip: right**	**Knee extension: left**
Grip: right	.952 (.936–.965)		
Knee extension: left	.782 (.715–.835)	.772 (.702–.828)	
Knee extension: right	.805 (.744–.853)	.805 (.743–.853)	.957 (.941–.968)

[*] All correlations are significant at p< .001.

Table 4

Pearson correlations (95% confidence intervals) between explanatory and strength variables*

Explanatory Variable	Total Grip Strength	Total Knee Strength
Gender	−.765 (−.822, −.693)	−.659 (−.737,−.562)
Age	−.370 (−.495, −.230)	−.440 (−.555, −.307)
Height	.659 (.563, .738)	.639 (.538, .721)
Weight	.445 (.313, .560)	.524 (.403, .623)

[*] All are significant at p<.0001,

[**] Gender, age, height;

[***] Gender, age, weight