

Is quadriceps muscle strength a determinant of the physical function of the elderly?

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Abstract. [Purpose] To determine the relationships of the quadriceps rate of torque development and the time to peak torque with the physical function of the elderly. [Subjects and Methods] Twenty-one subjects participated in this study. Quadriceps strength was measured using isometric and isokinetic torque tests. Time to peak torque and rate of torque development were calculated from the torque time curve of the isokinetic and isometric torque tests, respectively. Physical activities were measured using 4 physical activity tests. Pearson correlation coefficients were used to examine the relationships among the variables. [Results] The time to peak torque showed significant correlations with all measures of physical activity tests. Rate of torque development showed significant correlation with the timed stair-climbing test. Isometric and isokinetic torques had no significant correlations with any of the physical activity tests. [Conclusion] Time to maximum torque and the rate of torque development might be more important than peak torque in determining the physical function of the elderly.

Key words: Elderly, Rate of torque development, Quadriceps muscle strength

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INTRODUCTION

Aging is associated with sarcopenia, which is defined as the reduction of muscle strength and size^{1, 2)}. The number of muscle fibers in the muscles decreases with aging³⁾, explaining the loss of muscle mass. Aging is also associated with reduction in the size of muscle fibers⁴⁾. Furthermore these age-related structural changes within the elderly muscles are associated with less force production. Loss of skeletal muscle mass, strength and quality have negative impacts on physical function. Weakness of the lower extremities has been associated with difficulties in rising from a chair, getting out of bed^{5, 6)}, slow gait speed⁷⁾, balance problems and increased risk of falls⁸⁾. These functional impairments can lead to loss of physical functional independence⁹⁾.

Several studies have examined the effect of lower extremity strength on physical function and found maximal quadriceps muscle strength is a key variable. In one study Wolfson et al.⁸⁾ found that knee extensor weakness is an important factor in the occurrence of falls among nursing home residents. Also Alexander et al.¹⁰⁾ indicated that more knee extension torque is required to rise from a low chair than from a high one and during fast rising compared to slow. Tsubaki et al.¹¹⁾ and Nakano et al.¹²⁾ found knee extension

strength decreased while the time to perform the timed up and go test increases with aging among elderly people.

Wolfson et al.⁸⁾ defined the concept of physiological reserve for strength as the difference between the maximum force a muscle can generate and the necessary force to implement a specific activity. The maximum force of the muscles is not required to perform activities of daily living. Suetta et al. found the time the muscles take to generate maximum force is around 400–600 msec¹³⁾. However, this time is longer than needed to prevent a fall incident. Accordingly, rapid rise in force development might be more important than maximum force during limited time actions. To our knowledge, no studies have examined the association of physical function with time to peak torque and the rate of torque development (RTD). The purpose of this study was to determine the relationships of quadriceps RTD and time to peak torque with physical functions of the elderly.

SUBJECTS AND METHODS

Subjects

The subjects were between 65–80 years of age and could walk independently without the use of assistive devices. Subjects were excluded if they had uncontrolled hypertension, a history of cardiovascular disease, a history of neurological disease, a history of chronic or significant respiratory disease, inflammatory arthritis, muscle disease, a history of quadriceps tendon rupture or patellar fracture, received a corticosteroid injection to the quadriceps muscle or patellar tendon within one year, were long-term users of corticosteroid medication, or were currently participating in a regular strengthening exercise program. The Institutional Review

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Board (IRB) of the University of Pittsburgh approved all of the study procedures and all the subjects signed an informed consent form before participating in the study.

Methods

This study had a cross sectional design and aimed to determine the relationships between quadriceps muscle isometric and isokinetic strength, quadriceps muscle RTD, and time to peak quadriceps muscle torque output and the functional performance of community dwelling older adults.

Quadriceps muscle strength was measured using maximum isometric and isokinetic torque tests. Those tests were performed on an isokinetic dynamometer (Biodex System 3 Pro, Shirley NY, USA). Subjects sat on the isokinetic dynamometer with their hips flexed at 90 degrees. Straps secured the trunk to prevent movement confounding the quadriceps torque output. Then subjects were positioned so that the lateral femoral epicondyle of the knee joint was aligned with the rotational axis of the dynamometer. The force-sensing arm was secured to the ankle. The subjects' limbs were weighted for gravity correction.

For the maximum isometric quadriceps muscle torque, the knee being tested was positioned in 70° of flexion. Subjects were asked to exert as much force as possible while trying to extend the knee against the force-sensing arm of the dynamometer. The subjects performed 2 warm-up submaximal isometric contractions followed by 2 maximal isometric contractions by each leg. Each contraction was held for 5 seconds and there was a 30 second rest between repeated contractions. The highest maximum torque of the 2 contractions was selected for each leg, and then the average maximum isometric torque of both legs was calculated and used in the analysis.

Maximum isokinetic quadriceps muscle torque was measured at 60 degrees per second. Subjects were asked to exert as much force as possible while extending the knee against the force-sensing arm of the dynamometer through the range from 90 to 0 degrees of flexion. Each subject performed 2 practice trials followed by 4 maximum voluntary contractions. The test was performed on the dominant leg. The trial with the highest isokinetic quadriceps muscle was used in the analysis.

Rate of torque development (RTD) was calculated from the torque time curve of the isometric torque test. RTD represents the slope of the initial phase of the torque time curve (change in torque / change in time) at maximum isometric torque relative to the onset of contraction. Onset of contraction was defined as the point on the torque time curve that was above the baseline by 2.5% of the maximum isometric torque¹⁴.

Time to peak torque was calculated from the torque time curve of the isokinetic torque test at 60 degrees per second.

Physical function was assessed using 4 performance based physical activity tests: the timed stair climb test, the timed ramp up test, the timed up and go test, and the 4-m walking time test.

For the timed stair climb test, the subjects were instructed to climb a flight of stairs consisting of 11 steps with a tread height of 17 cm, as fast as possible. The time to climb the flight of stairs was recorded. Subjects were given 1 practice

trial, followed by 2 test trials. The trial with the shortest time was used in the analysis.

For the timed ramp up test, the subjects were instructed to walk as fast as possible up a ramp with a 3.66 m length and a 0.32 m rise. The time to walk up the length of the ramp was recorded. Subjects were asked to perform 1 practice trial followed by 2 test trials. The trial with the shortest time was used in the analysis.

For the timed up and go test, the subjects sat on a standard height chair with armrests. On the command "go" they stood up and walked 3 m (to a mark on the floor), turned around, walked back to the chair and sat down. A stopwatch was used to measure the time from the command "go" to the time when the subject sat down⁵. Subjects performed 1 practice trial followed by 2 test trials. The trial with the shortest time was used in the analysis.

For the four-meter walking time test, the subjects were asked to walk 4 m at their regular speed. The time to complete the 4 m was recorded. Subjects performed 1 practice trial followed by 2 test trials. The trial with the shortest time was used in the analysis.

Statistical analysis was performed using SPSS version 20 (IBM, SPSS statistics 2009). Pearson correlation coefficients were used to examine the relationships among the variables.

RESULTS

Twenty-one subjects participated in this study (females 61.9%). Subjects' baseline characteristics of age, height, weight and examination variables are provided in Table 1. The results of the correlation coefficients are presented in Table 2. Time to peak isokinetic torque showed significant, moderate to strong, positive correlations with all measures of the physical function tests. RTD showed a significant strong negative correlation with the timed stair climbing test. However, maximum isometric and isokinetic torque showed insignificant, weak to moderate, negative correlations with all physical activity tests.

DISCUSSION

The present study examined the relationships between physical function and both RTD and time to peak torque. Aging is associated with structural changes within the muscles such as reduced muscle mass and atrophy of the muscle fibers, which might be associated with the reduced muscle strength. This reduction in muscle strength might have an effect on the maximum strength to physical function relationship.

In the present study, isometric and isokinetic peak torques showed very little correlation with physical function. They only explained 0.5–14.3% and 0.3–9% of the variability of the physical functional tests, respectively, and the results were not significant. These findings are consistent with those reported by Brown et al.¹⁵ who showed there was a weak and insignificant relationship between hip, knee and ankle strength and functional activity variables.

During fast movements like avoiding falls and climbing stairs quickly, a short contraction time might not allow the muscle to reach its maximum force. Therefore, RTD

Table 1. Demographic variables and the outcome variables examined

	Mean (SD)	Range
Age (years)	71.3 (4.6)	65–80
Height (m)	1.7 (0.1)	1.4–1.8
Weight (kg)	77.4 (15.5)	48–108
Isokinetic peak torque (N.m) dominant	126.4 (45.0)	48.5–229.2
Time to peak torque (msec)	601.4 (128.5)	410–940
Average isometric peak torque (N.m)	163.6 (57.7)	64.3–255.6
Average RTD (N.m/sec)	108.7 (64.3)	38.5–230.6
Average timed stair climbing (sec)	4.7 (0.9)	2.9–6.1
Average timed ramp up (sec)	2.2 (0.3)	1.5–2.9
Average timed up and go (sec)	7.1 (1.1)	5.6–9.2
Average 4 meters walking time (sec)	3.1 (0.6)	2.3–4.2

RTD: rate of torque development

Table 2. Correlation coefficients between the outcome variables

	Stair climbing	Ramp up	Timed up & go	4-m walking	Isometric torque	Rate of torque development	Time to peak torque	Isokinetic strength
Stair climbing	1	0.78**	0.74**	0.53*	-0.38	-0.57*	0.59**	-0.30
Ramp up		1	0.82**	0.45*	-0.15	-0.29	0.49*	-0.14
Timed up & go			1	0.61**	-0.14	-0.22	0.45*	-0.12
4-m walking				1	-0.07	-0.12	0.49*	-0.06
Isometric strength					1	0.84**	-0.21	0.95**
Rate of force development						1	-0.32	0.80**
Time to peak torque							1	-0.26
Isokinetic strength								1

** p< 0.01, *p< 0.05

becomes very important for functional performance since it gives valuable information on the level of muscle force during the early phase of muscle contraction.

The strong positive correlation between RTD and the timed stair climbing test emphasizes the importance of the RTD. It was able to significantly explain 32.6% of the variability of the stair-climbing test. Time to peak torque was the only variable that showed significant, moderate to strong, correlations with all physical activity tests. It was able to significantly explain 20.3–35.2% of the variability of all physical activity tests.

It might appear that quadriceps muscle strength is a factor related to the performance of functional activities; however, the performance of daily activities does not require maximum force production from muscles. According to the results of this study, for the elderly, RTD might be a more important factor than muscle strength itself. Furthermore, these findings might have an impact on the way training programs for the elderly, are implemented, suggesting that training programs should focus on strength training in short periods of time in order to improve muscles' RTD.

We have to consider the potential limitations for this study. First, the sample size was relatively small. A larger sample would have allowed us to explore the associations using more sophisticated statistical analysis such as regres-

sion analysis, which would have allowed compensating confounding variables. Second, the quadriceps muscle was the only muscle used to establish the relationship between muscle strength, RTD, and physical function. The quadriceps muscle is an important muscle in the lower extremities but it is not the only active muscle during the performance of daily activities. Future studies should include the other lower extremity muscles, e.g. the hamstrings and the calf muscles, in a larger study sample to examine the relationships between RTD, muscle strength, and physical function.

In conclusion, the ability to activate a muscle quickly might play an important role in the performance of physical activities by the elderly population. The time taken to reach maximum torque and the rate of torque development might be more important measures than peak torque in determining the physical functional status of the elderly.

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