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Validation of the Tendo Weightlifting Analyzer as a Method to Assess Muscular Power

Emily Janssen

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### Abstract

Context: Power is a strong indicator of physical fitness and functional status of older adults. The Tendo Weightlifting Analyzer is a safe, cost-effective method to measure power. Objective: The goal was to validate the Tendo as a measure of muscular power during a chair stand task. It was hypothesized that the Tendo would be a valid measure. Design: This study was a cross-sectional, correlational study with the subjects serving as their own control. Setting: All testing took place in the Human Performance Lab at the University of Arkansas. Patients or Other Participants: A total of 58 college-aged students from 18 to 30 years of age volunteered. Subjects were found and selected through various classes and verbal advertising around campus. The final pool of subjects included 37 females and 22 males averaging 21 years of age,  $71.44 \pm 14.60$  kg in mass and  $169.49 \pm 8.75$  cm in height. Interventions: Each subject was instructed to stand from a chair as quickly and as controlled as possible. While a motion analysis camera recorded the movement of the reflective markers on the right acromion process, greater trochanter, lateral epicondyle, lateral malleolus, calcaneus, and fifth metatarsal, the Tendo was connected to a belt on the subjects' waists and measured the velocity and power exhibited during the stand. Each subject completed this task five times with a one minute break between each stand. Researchers tracked the time and displacement of the markers to calculate the average power of the stand. The average of the five stands was taken for both the Tendo and the motion analysis. Main Outcome Measures: The resulting power collected from the computer was then compared to the power output from the Tendo. These two measures were then analyzed through a Pearson correlation and a t-test was performed to determine significance between the two methods. Results: Average power given by the Tendo was  $449.76 \pm 115.03$  watts. The motion analysis gave an average power of  $334.25 \pm 96.70$  watts ( $p < .001$ ). Significance was set at  $p <$

.05. A positive correlation of  $r = .72$  between the outputs of the two devices was also reported.

Conclusions: The significant difference between the power outputs from the Tendo and the motion analysis report indicated that the Tendo is not a valid measure for assessing muscular power during a chair stand. Future studies should focus on establishing reliability and validity for the Tendo across all generations and for power during other tasks.

## Introduction

Aging leads to a decrease in muscle mass, strength, and power as well as a decline in the overall ability to complete activities needed to function independently. These low levels of muscle mass, strength, and power contribute to poor functional fitness which prevents people from being able to carry out required daily tasks. While many studies focus on aging's consequence of the decline in strength, Hruda, Hicks, and McCartney (2003), believe more studies should focus on the depletion of muscular power instead, as many activities of daily living, such as standing from a seated position, are dependent upon muscle power. The decline in muscular power is a better indicator of functional potential and is more directly related to impaired physical performance than muscular strength. Foldvari et al. (2000) found that leg power is the highest correlated variable to the status of functionality in older adults. One of the most basic and easily tested measures of overall leg power is chair stand performance. Today, lower body muscular power is measured through motion analysis, the Nottingham Power Rig, and Keiser pneumatic machines. Motion analysis requires a great deal of time to set up and markers must be placed on the acromion process, greater trochanter, lateral epicondyle of the femur, and the lateral malleolus of every subject tested in order to track movement. The Keiser pneumatic machines allow for quick, easy adjustment of resistance but are quite expensive to purchase. The Nottingham Power Rig, however, allows for safe and accurate testing in the older and more frail populations. It measures explosive leg power from a seated position that isolates the leg muscles and allows minimal involvement of the back muscles. Each leg is measured by individually reducing the correlation with activities of daily living. High explosive leg power does reflect a decreased incidence of falling and a subject's risk of falling. However, the methodology does not mimic real-life situations as it does isolate the power measurement to

include only that of the leg. The Tendo Weightlifting Analyzer is another measure of muscular power. However, the Tendo has yet to be validated in this manner. It has been used in very few studies (Thompson et al., 2010; Stock, Beck, DeFreitas, & Dillon, 2011; Gresham-Fiegel, House, & Zupan, 2013). Each one focuses on measuring velocity in order to calculate the power output the subjects exhibited. Validation of the Tendo would allow for much easier, quicker, and cheaper measurements of muscular power. The Tendo would also provide future studies with a reliable and valid source for analysis of muscular power in both younger and older adults. Successful validation of the Tendo will support future studies' endeavors to find ways in which to improve the overall power and performance in activities of daily living.

## **Literature Review**

### **Sit-to-Stand Task**

Kelly, Dainis, & Wood (1976) and Rodosky, Andriacchi, & Andersson (1989) consider the ability to stand from a seated position to be one of the most important indicators of physical function. Of adults in the United States 64 years of age and older, over two million have difficulty independently rising from a chair (Dawson, Hendershot, & Fulton, 1987). Rising from a chair is an indicator that highly correlates to the functional independence and mobility of elderly persons and their daily life. The inability to successfully stand often leads to institutionalization for older adults (Schultz, Alexander, & Ashton-Miller, 1992). According to Ganea, Paraschiv-Ionescu, Bula, Rochat, & Aminian (2011), as people age, the sit-to-stand task becomes a more demanding functional task and a decrease in the ability to successfully complete this task reflects an elderly person's transition to frailty. In contrast, it has been found that a successful performance of a chair rising task is associated with a lower risk of falls as well as a

decreased risk in non-vertebral fractures (Dukas, Schacht, Runge, & Ringe, 2010). The sit-to-stand task is highlighted as an accurate determinant of one's ability to complete activities of daily living as it produces greater moment magnitudes at the hip and knees than those produced in stair-climbing or walking alone (Rodosky, Andriacchi, & Andersson, 1989). Overall the chair stand utilizes interactions between both the hip and knee joints which better represents diverse muscle actions and the demands placed on the body through activities of daily living (Bean et al. 2002). For the purposes of this study, the chair will be at the established standard height of 0.43 meters (Paul & Canning 2014).

### **Muscular Power**

To produce the movement required to complete a sit-to-stand task as well as other activities of daily living, power is produced by the legs and torso. Power is the ability to produce force quickly; it is the product of the force and the velocity of the muscle contractions (Bean, Herman, et al., 2002). With age, the ability to produce force quickly is lost due to atrophy of lower-body muscles. According to Bassey and associates (1992), muscle power is a very strong indicator in the performance of activities of daily living. Specifically, leg extensor power was found to be strongly correlated to the performance of walking, rising from a chair, and climbing stairs (Bassey et al., 1992). While functional independence is multifactorial, the strongest predictor of dependence is muscular power. Many studies have stated that power impairments have been identified as determinants of immobility more influential than strength impairments (Bean et al., 2003; Bean et al., 2002; Bean et al., 2010; Foldvari et al., 2000). Though many older studies focused on the significance of muscular strength in relation to dependence, Bean et al. (2003) determined that a low power output presents a risk of mobility problems two to three times greater than that presented by poor strength. Muscular power and strength differ once

again in their rate of decline; power exhibits a much quicker decline with age than that shown by strength. While older adults retain fifty percent of the strength of that of their younger counterparts, they demonstrate only twenty percent of the power displayed in younger populations (Foldvari et al., 2000). Peak leg power has been identified as an independent predictor of general self-reported functional status (Foldvari et al., 2000). That study also found a negative correlation between age and leg press power and function, which has been found to deteriorate more rapidly with age than upper body function. In contrast, it has been found that increases in muscular power outputs correlate with improvements in the musculoskeletal and nervous systems (Bean et al., 2010) as well as greater measures of bone density (Cousins et al., 2010). The correlation Herman and associates (2005) found between upper and lower limb power led to this belief that overall muscular power may be dependent upon neuromuscular mechanisms affected by age. These mechanisms include fiber type, the timing of motor unit firing, and the velocity of nerve conduction. A connection between age-related decline in muscular power and the declines in the musculoskeletal and nervous systems, reflect a possible cause to the age-related changes in power and provide source to begin examining solutions for lost muscular power. Because of these findings, some training protocols have been prescribed that focus on resistance and explosive movements in order to improve and prevent the loss overall muscular power. In focusing on the muscular power outputs, studies may be able to predict and identify those at risk for functional loss and disability, allowing for intervention before they become fully dependent (Kuo et al., 2006).

### **Tendo Weightlifting Analyzer**

Few studies have utilized the Tendo Weightlifting Analyzer as a means to measure power output. Of the projects using the Tendo, the majority have employed it as a reliable source to

measure velocity, but it has not yet been validated as a measure of muscular power during a sit-to-stand task. For example, Stock et. al. (2011) utilized the Tendo during a bench-press exercise to understand the test-retest reliability of barbell velocity. The velocity was then compared to different trials and the results indicated a moderate to high test-retest reliability. In another study, Thompson and associates (2010) used the Tendo as an indicator for the peak power during a bench press. These measurements were then analyzed through ratio and allometric scaling to determine its influence on normalizing peak power. Overall, the Tendo has been used mainly for the comparison of different trials to each other, which has confirmed the reliability of the Tendo. However, the Tendo has not yet been used for studying the relationships of power and velocity to any other measure. By validating the Tendo, future studies will know that the data being collected are not only reliable but the measurements are correct in relationship to what is being measured. Herman and associates (2005) stated the need for simple, appropriate and low cost devices that measure muscular power, specifically in clinical settings. Currently, to measure power in clinical settings, professionals must invest in large, sophisticated, and expensive pieces of equipment that can be difficult or even unsafe for use with certain individuals. For example, while the Keiser pneumatic machines are simple to adjust for desired resistance, they can often be unsafe for older, and more frail populations to use. Another popular and valid measure of power is the Nottingham Power Rig. This machine allows for power measurements to be gathered with the participant in a seated position that isolates the muscles of the leg and limits the involvement of muscles in the torso and back. Though the Nottingham Power Rig is significantly safer for the frail and elderly populations and does provide useful data, it does not support testing of action and movements that mimic those performed in daily living activities. If supported as a valid power measurement, the Tendo Weightlifting Analyzer will be both safe for

frail and elderly populations as well as allow for testing during motions that resemble those activities of daily life.

### **Methodology**

In order to accurately measure the validity of the Tendo Weightlifting Analyzer, its results must be compared in relation to an understood valid technique. For the case of this study, motion analysis using a high speed digital video camera was used to measure the speed and distance travelled during a sit-to-stand task to calculate the muscular power exerted during the motion. As a subject rose from the seated position, the motion analysis tracked the reflective markers to determine the velocity with which the stand was completed. Motion analysis also recorded the total displacement of both the markers and the subjects' center of mass. Each movement and change in center of mass was recorded by the camera. At the same time, the Tendo Weightlifting Analyzer was placed on the floor on the left side on the chair from which the subject stood and was connected to a belt around the subjects' waist. As the camera recorded the subjects' movement, the Tendo was also measuring the velocity and displacement of the stand. After the stand, the Tendo determined the total muscular power exerted during the stand and then compared it to the power calculated from the tracking done by the motion analysis. The participants in this study were 59 current undergraduate students at the University of Arkansas over the age of 18 years. The test was a series of five sit-to-stand tasks. After placing the reflective markers on each participant's right acromion process, greater trochanter, lateral epicondyle, lateral malleolus, calcaneus, and fifth metatarsal, a belt connected to the Tendo was fastened around their waist. The participants were then instructed to sit at the edge of the chair (0.43m in height) with their arms crossed over their chest. Then, each subject was informed to

stand as quickly and as controlled as possible. Between each stand a minute of rest was given. Every stand was recorded by both the motion analysis and the Tendo. This was repeated with all 59 participants. By measuring muscular power with the Tendo at the same time as with the motion analysis, it was easier to compare the data and determine the validity of the Tendo Weightlifting Analyzer.

After data collection, the power outputs from the Tendo were recorded and the velocity and displacement provided by the motion analysis was used to calculate the muscular power output. The results were then compared and the percent difference and percent error between the two values given were analyzed to determine whether or not the system is valid. All assessments were completed in one visit to the Human Performance Lab and took no longer than 1 hour.

### **Statistical Analysis**

The average of the five chair stands was used for all analyses. A dependent samples t-test was used to determine differences between the two power measurements. A Pearson correlation was then conducted in order to determine the relationship between the two measurements. Statistical significance was set at  $\alpha = .05$ . The t-test and the Pearson correlation were run for the entire group of 59 participants and again separately for both the males and the females.

### **Results**

The set of data were analyzed to determine if there was a significant difference in the power measured by the Tendo Weightlifting Analyzer and the computer motion analysis. It was also analyzed to establish the correlation between the two methods. The researchers ran the data

to determine if the two methods, the Tendo and the motion analysis, gave similar results for the entire population of the study and then again for males and females separately.

Table 1 reflects the overall demographics of the population. The females were an average of almost two years younger than the males in this study with the average age being 21 years old. The men were also taller and weighed more than the women on average, but the women had a higher average body fat percentage by about 13 percent. All of the population for this study were over the age of 18 and younger than 30 years old.

**Table 1.** Demographic Characteristics

Variable	Female n = 37	Male n = 22	Total Population n = 59
Age (years)	20.51 + 2.23	22.18 + 3.25	21.14 + 2.75
Weight (kg)	64.71 + 11.31	82.77 + 12.44	71.44 + 14.60
Height (cm)	165.58 + 8.36	176.09 + 4.36	169.49 + 8.75
BF (%)	34.51 + 5.63	21.54 + 9.36	29.67 + 9.56

*Note.* BF = body fat. Values are reported as means  $\pm$  SD. An alpha level of  $\leq .05$  was accepted as statistically significant.

Table 2 provides the statistical significance of the difference in the power measured by the Tendo Weightlifting Analyzer and the motion analysis. The significance was set at a value of  $p \leq .05$  and the data from both the overall population and the female population of the study reflected a value of  $p \leq .000$ . The males showed a p-value of .06. On average, the computer registered a higher measure of power than the Tendo by about 26% (female: 32%; male: 18%). These values reflect a clear statistical significance in the difference in the data given by the Tendo and the motion analysis. This statistical significance indicates that the Tendo Weightlifting Analyzer is not a valid method to assess muscular power.

**Table 2.** Differences in power measurements between motion analysis and the Tendo Weightlifting Analysis

Variable	Female <i>n</i> = 37	Male <i>n</i> = 22	Total Population <i>n</i> = 59
Computer Average Power (watts)	286.59 ± 68.62 *	414.41 ± 83.79	334.25 ± 96.70 *
Tendo Average Power (watts)	417.35 ± 116.02 *	504.27 ± 92.24	449.76 ± 115.03 *

*Note.* Statistical significance was set at a value <.05. The asterisk (\*) indicated a significance in the difference of the power measurements provided by the motion analysis and the Tendo.

Table 3 shows the correlation between the Tendo Weightlifting Analyzer and the motion analysis for the total study population, females, and males. The correlation between the two methods for the total population is  $r = .72$ , the females correlation was  $r = .85$ , and  $r = .41$  for males. The correlation value for the total population and the females reflected a strong positive correlation. However, the correlation value for the males was only moderately positive. This indicated a moderate to strong positive correlation for the Tendo and the motion analysis.

**Table 3.** Bivariate correlations between the Tendo and Motion Analysis power outputs

	Tendo (Total Population)	Tendo (Male)	Tendo (Female)
Population Computer	.72*	--	--
Computer (Male)	--	.41*	--
Computer (Female)	--	--	.85*

*Note.* Pearson’s correlations were used to determine relationships between variables. The asterisk (\*) indicated a significant positive correlation.

## Discussion

The ability to stand from a chair with significant power is vital for older adults. Greater power is related to being able to complete basic activities of daily living. By measuring power in older adults, one can predict their overall functionality and independence. However, current methods to measure power output are unsafe, expensive, or too complicated for the average person to use. The Tendo Weightlifting Analyzer appeared to be a viable solution to this issue. It is significantly cheaper than the motion analysis, cheaper than the Keiser pneumatic machines, and supports testing of action and movements that mimic those performed in daily living activities unlike the Nottingham power rig.

After conducting the chair stand test for 61 college-aged individuals, two individuals were removed from the data set for incomplete data. The resulting data reflected a significant difference between the two methods. This difference indicated that the Tendo Weightlifting Analyzer is not a valid measure for assessing muscular power during a chair stand of young adults. As the subjects stood from a seated position the motion analysis camera tracked their bodies' movement and velocity via reflective markers. The researchers then calculated the power generated as the subjects moved from sitting to standing. The Tendo simultaneously measured the distance and velocity the subject moved and, using the inputted mass, indicated the peak and average power produced during the stand. It was found that, for the entire population as well as the males and females separately, the power given by the Tendo and the motion analysis were moderately to strongly positively correlated. Though a moderate positive correlation was exhibited, the difference in the power indicated by the Tendo and that provided by the motion analysis was statistically significant; therefore, it was determined that the Tendo was not valid. The positive correlation reflected simultaneous increases in power given by both

devices. The statistics showed that though the Tendo values increased with the motion analysis values, the values were not close enough to infer the Tendo as a valid measure of power. On average, the Tendo presented a 74% higher value for power (watts). This was most likely due to the tracking of the data points. The motion analysis picked up forward movements that continued for a longer period of time than the Tendo. This longer time of motion decreased the overall power that was calculated using the motion analysis, whereas the Tendo did not recognize or utilize this extra time, during which no additional upwards movements were performed, in its calculation of power.

One of the main limitations of the study came in the placement of the reflective markers and the tracking of the data points from the motion analysis before calculating power. The acromion process and the greater trochanter are relatively large and allow for slight variation when placing the markers. This openness to interpretation could have affected the tracking and the calculations of power for the motion analysis. Similarly, the motion analysis required tracking of the points given by the reflective markers to determine the overall displacement and the time it took to travel that distance. The time, distance, and mass of each trial were used to calculate the power generated during the stand. There were three points at which the time and location were recorded: the first movement of the center of mass, the first upward or forward movement of the subject's hip, and then the final point at which the subject was fully still and erect. Each of these points was subjectively determined by a researcher who decided the first points of movement and the points at which movement ceased. It was possible that two differing researchers would have decided upon two different points of time and location which may have produced incorrect or different calculations of power.

When calculating power using the motion analysis and cinematography, the data points were used for starting and ending time and location. The end-points from the data tracking included the forward motion that each subject exhibited after the upward motion of their stand from the chairs. This forward motion had little to no effect on the total distance the subject traveled during their stand but contributed greatly to their overall time of motion. As the total time increased, the total power decreased. This may have been what allowed for the Tendo to provide higher measures of power when compared to the motion analysis.

Future studies should use two researchers when determining the points of initial and final movement in the motion analysis so as to decrease the margin of error for the measures of power. Some of the forward movement after the standing motion was picked up and accounted for by the motion analysis but not by the Tendo. This extra time negatively affected the power measures calculated from the motion analysis. Multiple researchers agreeing on a final point of motion should decrease the occurrence of this error and result in more accurate power measures. Other studies conducted using the Tendo Weightlifting Analyzer focused mainly on its use for weightlifting as opposed to measuring power during activities of daily living. These other studies also set out to establish the reliability of the Tendo and not the validity. The Tendo is a very affordable and basic tool used to assess both power and velocity. Future studies should focus on establishing reliability and validity for the Tendo across all generations of age and for power during tasks other than weightlifting.

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