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Consistency of Leg Extension Power Assessments in Older Men: The Osteoporotic Fractures in Men (MrOS) Study

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Abstract

Objective—To examine the consistency of the Nottingham power rig in assessing leg extension power (LEP) in older men, assessed between different examiners with adjustment for the order of measurement (time) and clinic.

Design—55 men (mean 73 yrs) enrolled in the Osteoporotic Fractures in Men study had maximum LEP of each leg measured at baseline, and remeasured 1 week later.

Results—There was a significant effect of time ($P < 0.01$). The second visit had an average increase in LEP (right leg 14.2 watts; left leg 16.5 watts). After accounting for the effect of time, a low coefficient of variation was observed between-examiners (right leg 3.49%; left leg 3.46%).

Conclusions—Data from the 2 timepoints corresponded reasonably well. The effect of time and fatigue should be considered when performing this measurement. The Nottingham power rig is a reproducible measure of LEP in a multi-site study of older men.

Keywords

Leg Extension Power; Reliability; Muscle; Strength

INTRODUCTION

Leg extension power (LEP) is defined as the ability of the leg extensor muscles to perform work over periods of half a second or less¹. LEP has been shown to be related to mobility,² instrumental activities of daily living,³ and has been identified as a risk factor for falls.⁴ This measurement is also thought to be related to functional activities such as stair climbing.^{1,5} LEP has also been shown to be more influential to physical performance than simple measures of strength.^{2,6} There are a number of different methods for measurement of lower extremity power, and no one method has been used as the universal accepted measurement.⁷ Measurement of strength using dynamometers have been shown to be more variable than measures of LEP.⁸

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The Nottingham power rig is a device used to measure LEP.¹ To obtain the estimate of power, the participant is seated in an adjustable seat and presses a foot pedal until the leg is extended. This pedal accelerates a flywheel, and it is this average power in watts that is measured. This exercise uses similar angles of the hip, knee, and ankle to rising from a chair.¹ This measure is preferable for the elderly because it requires less balance from the participant than other measures (jumping, stair climbing, walks).^{1,9-11} Also, the seat on the machine is suitable for those with back problems.^{2, 9-11}

Because of its hypothesized relationship to falls, mobility, performance, and fractures, LEP is a measurement gathered in the Osteoporotic Fractures in Men Study (MrOS), a longitudinal study designed to examine the risk factors of osteoporotic fractures in older community-dwelling men.¹² Between-participant variability of LEP was thus of interest. In addition, there were multiple examiners who performed the LEP measurements, so between-examiner variability was also important.

Previously, small studies have addressed the repeatability of the measurement of LEP using the Nottingham power rig, finding a low coefficient of variation (9-16%) between repeat measurements, taken approximately 1 week apart.^{1,8,9,13} A limitation to these studies is that none took into account the order in which the measurement was performed. It is also unclear whether or not the same examiner was used to obtain both measurements on the same participant. There have been no studies to our knowledge that have examined the repeatability of the measurement of LEP in a population of older community-dwelling men.

The MrOS study provides a unique opportunity to investigate the consistency of repeating the measurement of LEP using the Nottingham power rig in community-dwelling older men. This consistency substudy involved multiple examiners at 2 clinical sites. Consistency of the measurement was assessed between different examiners (between-examiner variability) and between participants (between-participant variability), with adjustment for the order of the measurement (time) and clinic.

METHODS

Participants

From March 2000 to April 2002, 5995 men aged 65 and older were recruited to participate in the MrOS study at six US clinical centers in Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, CA; the Monongahela Valley near Pittsburgh, PA; Portland, OR; and San Diego, CA. Men were ineligible for the study if at the time of enrollment they were younger than age 65 years, had a history of a bilateral hip replacement or were unable to walk without the assistance of another person.¹⁴ The institutional review board at each clinical site approved the study protocol and written informed consent was obtained for all participants.

In order to assess the between-examiner consistency and between-participant variability, the participant returned to the clinical site for a repeat measurement of LEP. To reduce the burden of this extra visit, the second LEP measurement was performed in a convenience sample of 55 participants at the Pittsburgh, PA and Portland, OR sites. MrOS participants at these sites were asked if they were willing to return for an additional set of measurements for LEP. Recruitment for this subset continued until the target sample size was met at each site. Each of these 55 participants had their full initial baseline exam, lasting approximately 2.5 to 3 hours, plus a second exam that consisted only of the LEP measures approximately 1 week later (mean $\pm$ SD: 7.4 $\pm$ 1.8 days). The second exam was conducted a week later to allow for recovery from possible fatigue caused by the initial exam.^{1,8,11}

In order to increase our statistical power, each examiner was paired with another examiner at the same clinical site 3 times and with themselves 4 times. There were 3 examiners at the Portland site, 4 at the Pittsburgh site. Therefore, there were 55 pairings; 27 paired an examiner with another examiner at the clinical site and 28 paired the examiner with themselves. The clinical sites were given a schedule to track these pairings in order to insure the correct number of the specific examiner-pairs were obtained for this subgroup.

Nottingham Power Rig LEP Measurements

All clinic staff performing the LEP measures completed formal, centralized training with the Nottingham power rig and passed a certification test. It has been previously reported that a maximum for LEP was obtained within 9 replicates, typically by the 5th replicate, with an apparent steady improvement until the participant became familiar with the machine.^{1,8,9} Therefore, at both the baseline visit and the repeat consistency visit the participant was required to complete 9 replicates of the leg extension power test on each leg. The protocol did not require that a specific sequence be used when assessing the LEP of the right and left leg, for example, it was not required to measure the right leg first, then the left. The outcomes examined are those that would be used most in future analyses in the MrOS study: the maximum power over the 9 replicates for the right leg, the left leg, or either leg. For each outcome we calculated the difference in LEP measurements between the first and repeat visits to show the direction of the difference.

Other Measurements

Other measurements were used to describe the subset of 55 and to compare the subset to the remaining MrOS population. This information was gathered from all participants at the baseline visit. Smoking status, self-rated health, and ethnicity were reported on a self-administered questionnaire at the baseline visit. Physical activity was measured using the Physical Activity Scale for the Elderly (PASE).¹⁵ Functional status was assessed from information on five instrumental activities of daily living (IADL) which included walking 2 to 3 blocks on level ground, climbing 10 steps, preparing meals, doing heavy housework, and shopping for groceries or clothing.^{16,17} Body weight was measured using a standard balance beam or digital scale and height was measured with a wall mounted Harpenden stadiometer (Holtain, Dyfed, UK). Height and weight were used to calculate body mass index (BMI) as weight in kilograms divided by the square of height in meters. Walking speed measured using a standardized six meter walking course. Bone mineral density (BMD) was measured using Hologic 4500 dual energy x-ray absorptiometry (DXA) machines.

Statistical Analysis

The group selected for the consistency substudy was not a strict random sample, so comparability of this subgroup to the remaining cohort was examined. Differences in baseline characteristics between the subgroup selected and the remaining MrOS cohort were compared using t-tests for continuous variables with normal distributions, Wilcoxon rank-sum tests for continuous variables with skewed distributions, and chi-squared tests for categorical data.

Comparisons between the repeat LEP measurements were examined using paired t-tests. Mean differences of LEP measurements between visits were shown to examine the magnitude and direction. Bland-Altman plots were presented to assess systematic bias in the differences.¹⁸ As plots were similar, only the plot for the maximum of either leg is shown.

Also of interest is whether there is a significant effect of clinic site and time (order of measurement). Simple linear regression cannot be used because the model assumption of

independence of the observations is violated due to the repeated measurements within an individual participant. Therefore, to examine whether our training on the use of the Nottingham power rig had been successful and uniform across examiners, we used a mixed models approach with the following model:

$$y_{ijk} = \mu + \text{clinic}_{(0,1)} + \text{visit}_j + \text{participant}_i + \text{examiner}_k + e_{ijk}$$

i=participant, 1 through 55
j=main visit=0, repeat visit=1
k=examiner, 1 through 7
Clinic: 0=clinic 1, 1=clinic 2

fixed effects: clinic, visit

random effects: participant, examiner, residual

With this model, the grand mean is represented by μ . The visit fixed effect represents the systematic offset from the grand mean that is attributed to time. The clinic fixed effect represents systematic offset from the grand mean attributed to the clinic (the combination of the fact that examiners are different at each clinical site; there are differences in the populations at the clinical site; and the machines may be calibrated differently). The participant random effect represents the between-participant variation. The examiner random effect represents the between-examiner variation. The remaining variance estimated by e_{ijk} represents the combination of within-examiner variance over time, the variance within-participant, and the variance attributed to the machine.

The summary measures of interest from this model are the coefficient of variation (CV) between-examiners and between-participants. These were calculated as $100 * (\text{standard deviation between-examiner}) / \text{mean}$ and $100 * (\text{standard deviation between-participant}) / \text{mean}$ respectively. A similar CV for the remaining variance was also calculated. The means in the denominator are taken from the mean of the entire MrOS population because this is the best estimate of what the true mean would be for our population. 95% confidence intervals for these CVs were obtained using a bootstrap approach.¹⁹

The consistency substudy was designed to have 80% power to detect if the examiner variance divided by the residual variance of the measurement was a ratio of 1 or more. Therefore, we had 80% power to detect a variance larger than that attributed to random error.

All statistical analyses were preformed using SAS software, version 9.1 (SAS Institute, INC., Cary, NC).

RESULTS

Baseline Characteristics

The sample of 55 men had a mean age of 73 years, 96.3% were Caucasian, and the average LEP maximum of either leg was 206.0 +/- 60.8 watts. The average LEP maximum for the entire MrOS cohort of 5995 men was: right leg 198.89 +/- 63.95 watts; left leg 198.14 +/- 61.59 watts; either leg 208.31 +/- 63.09 watts. There were no significant differences in the baseline characteristics or outcome measures of LEP between the consistency subgroup and the remaining MrOS cohort ($p > 0.05$ for all). On average, men in the sample were slightly more active (PASE score 164.1 vs. 146.3 $p = 0.06$) and had a slightly higher walking speed (1.3 vs. 1.2 m/s, $p = 0.06$) than the remaining men in the MrOS cohort. (Table 1)

Basic Comparisons of LEP from the First to Second Visit

There was a statistically significant mean difference for the LEP measurements between the visits for all LEP outcomes ($p < 0.01$). The maximum LEP for the left leg had the largest average difference between the first measure and the repeat measure (watts, right leg: -14.2 ± 31.28 ; left leg: -16.1 ± 31.35 ; either leg -14.5 ± 31.63). Of the LEP outcome measures of interest, about 65% of the participants have a smaller first measurement than the second measurement (right leg 65.5%, left leg 65.5%, either leg 63.6%). This systematic bias towards a larger second measurement can also be seen in the Bland-Altman plot of maximum LEP (Figure 1). There does not appear to be a systematic difference driven by the size of the LEP: the plot appears randomly distributed about the mean difference. Because there was a potential learning effect or fatigue at the initial visit, assessment was needed to see if there was a systematic change in LEP at the second visit when studying the difference of the measurements at the 2 timepoints.

CVs and the Effect of Time (Visit) and Clinic

As shown in Table 2, there is a statistically significant systematic effect of time (visit) for all 3 LEP outcomes ($p < 0.01$). On average, there is a 14.2 to 16.7 watt increase in LEP comparing the second visit to the first. There is a significant clinic effect for the measurement of LEP in the right leg. An average offset of 32.96 watts is attributed to clinic. CVs for between-examiner consistency range from 2.6% to 3.5%, with the best consistency for the outcome of maximum power of either leg. The CVs representing the combination of within-examiner variance, within-participant variance, and machine variance range from 10.6% to 10.9%. These CVs are considerably smaller than the CVs for between-participant differences (range 24.5% to 25.5%). When these results were further adjusted by the potential confounders age, BMI, smoking status, number of IADLs, and self-reported health status the estimates for CVs remained similar.

DISCUSSION

Although there was not perfect agreement between the repeat measurements of the LEP as measured with the Nottingham power rig, the coefficients of variation for the between-examiner consistency were low. The two measurements on the right leg were slightly more consistent than that of the left, which may be due to leg dominance. In our substudy, all men were right-handed, which tends to correlate at over 90% to foot dominance.²⁰ In this short term follow-up of approximately 1 week there was a significant effect of time (visit). This systematic difference between the first and second visit for the LEP measures may be due to additional fatigue at the first visit caused by the length of time spent in the clinic and other measures performed. Perhaps the participants tended to perform better on the LEP at the second visit simply because it was the only measured obtained. Protocols for measurement of LEP using this device should be aware that timing of the measurement and fatigue could influence the result of the measure. Instructions for the collection of the data should include order of collection as it pertains to other data also collected during the clinic visit. Alternatively, there may be a learning effect that would explain the higher scores at the repeat visit. Other consistency studies of the Nottingham power rig found no such differences,^{1,8,9} but these studies included only small subgroups of elderly men. There was a significant clinic effect for the measurement of LEP of the right leg, so adjustment for clinic site may be needed when analyzing LEP data collected with this device.

This analysis has several strengths. The consistency study was slightly larger in comparison to others previously performed, and was able to separate the effect to time and the coefficients of variance from between the examiners and between the participants.

There are also limitations to this analysis. This analysis was performed on older, predominantly Caucasian men so results may not be generalizable to women or men of other age groups or ethnicities. This study only examines the consistency of measurement of LEP by the Nottingham power rig, and is not applicable to other instruments used to measure lower extremity power. This study was only performed at 2 out of the 6 clinical sites. Results may not be generalizable to the other clinical sites, although all clinical sites received the same training on the use of the Nottingham power rig. Also, those participants who had the most difficulty with the measurement may have refused to return for the repeat visit. The reliability of the LEP measurement may decrease with age. Of the previous studies, the highest coefficient of variation was found in the study comprised of men and women at least 80 years old (CV=16%).⁹ In our study, among the 17 men who were 75 years old or older, the between-examiner CV for the maximum of either leg increased to 4.79%.

In conclusion, data from the 2 measurements of the LEP corresponded well, and the maximum LEP of either leg was more repeatable than the maximum of the left or right leg separately. The Nottingham power rig provides a reproducible measure of leg extension power in a multi-site study of older community-dwelling men.

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FIGURE 1.

Bland-Altman Plot of Maximum LEP, Either Leg

Dashed lines represent the 95% confidence intervals, solid line is the mean difference.

TABLE 1

Baseline Characteristics

Characteristic	Reliability Subset (N=55)	Remaining MrOS Cohort (N=5940)	p-value
Age, years [†]	73.0 +/- 4.4	73.7 +/- 5.9	0.24
Race [‡]			
Caucasian	52 (96.3)	5310 (89.4)	0.50
African American	1 (1.9)	243 (4.1)	
Asian	0	191 (3.2)	
Other	1 (1.9)	197 (3.3)	
Body mass index, kg/m ² [†]	27.7 +/- 4.01	27.4 +/- 3.9	0.49
Total hip bone mineral density, g/cm ² [†]	0.975 +/- 0.150	0.957 +/- 0.140	0.35
Smoking status [‡]			
Never	24 (44.4)	2225 (37.5)	0.55
Past	28 (51.9)	3511 (59.1)	
Current	2 (3.7)	204 (3.4)	
Self-reported health status [‡]			
Poor/very poor	0	97 (1.6)	0.59
Fair	6 (11.1)	754 (12.7)	
good/very good	48 (88.9)	5088 (85.7)	
Number of IADL impairments (0-5) [†]	0.2 +/- 0.5	0.4 +/- 0.9	0.13
PASE score [†]	164.1 +/- 67.4	146.3 +/- 68.3	0.06
Walking speed, m/s [†]	1.3 +/- 0.2	1.2 +/- 0.2	0.06
Leg extension power outcomes, watts ^{‡*}			
Maximum power, right leg	198.3 +/- 60.5	199.0 +/- 64.0	0.93
Maximum power, left leg	192.6 +/- 58.5	198.2 +/- 61.6	0.50
Maximum power, either leg	206.0 +/- 60.8	208.3 +/- 63.1	0.79

[†] expressed as mean +/- standard deviation;

[‡] expressed as number (percent)

* LEP for consistency subgroup based on the first measurement obtained

P-values for continuous data are the result of a t-test for normally distributed data, Wilcoxon rank sum test for skewed data. P-values for categorical data are the result of a chi-square test.

TABLE 2

Results from Mixed Model for Consistency of LEP Assessment (N=55 participants)

	Maximum Power, Right Leg	Maximum Power, Left Leg	Maximum Power, Either Leg
Fixed Effects (watts):			
Grand mean	185.35	183.96	196.89
Effect of time	14.24*	16.45*	14.67*
Effect of clinic	32.96*	23.90	24.91
Variance Estimates (shown as standard deviation):			
SD for between-examiner	6.95	6.86	5.33
SD for between-participant	50.50	50.53	50.96
SD for (within-examiner + within-participant + machine)	21.69	21.50	22.09
Coefficient of Variation, %, (95% CI):			
CV, between-examiners	3.49 (0, 4.92)	3.46 (0, 4.73)	2.56 (0,4.10)
CV, between-participants	25.38 (23.06, 26.82)	25.50 (23.00, 26.80)	24.46 (22.59, 25.79)
CV, within-examiners + within-participant + machine)	10.90 (9.84,11.56)	10.85 (10.01, 11.44)	10.60 (9.77,11.21)

*
p<0.05