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Is chair rise performance a useful measure of leg power?

Rebecca Hardy, PhD[1], **Rachel Cooper, PhD**[1], **Imran Shah, MSc**[1], **Stephen Harridge, PhD**[2], **Jack Guralnik, PhD**[3], and **Diana Kuh, PhD**[1]

[1]MRC Unit for Lifelong Health and Ageing, Department of Epidemiology and Public Health, Division of Population Health, University College London, UK

[2]Division of Applied Biomedical Research, King's College London, UK

[3]Laboratory of Epidemiology, Demography, and Biometry, National Institute on Aging, Bethesda, MD, USA

Abstract

Background and Aims—Chair rise performance, which is simple to assess in a home or clinic setting, has been used as a method of predicting leg power deficit in older adults. More recently chair rise performance has been assessed in younger populations as a baseline for assessment of subsequent age-related declines in function and power. However, as rising from a chair repeatedly not only requires lower limb strength and power but also good balance and coordination, it may not be purely a measure of leg power especially among these younger, well functioning groups who are yet to experience age-related declines and deficits in function. The aim of this study was to assess whether chair rise performance can be considered as a predictor of leg power, and hence of deficits in this, in men and women in mid-life. We assessed the relationship of chair rise performance with leg extensor power (LEP) measured using the Nottingham Power Rig (NPR), and with standing balance performance.

Methods—LEP was measured in a clinic setting in a sub-sample of 81 men and 93 women from the MRC National Survey of Health and Development, a nationally representative cohort born in Britain in 1946. The time taken to rise from a chair 10 times and standing balance time were assessed during home visits at the same age.

Results—Increasing LEP was associated with better chair rise performance among those who completed 10 chair rises in ≥15 seconds, after adjustment for body size (p=0.008). Better standing balance performance was associated with better chair rise performance in men, but not women.

Conclusions—That LEP and standing balance are both related to chair rise time in men suggests that chair rise time should not be thought of purely as a proxy measure of leg power in middle-aged populations. This has implications for longitudinal studies which want to study age-related decline in chair rise performance.

Keywords

physical performance; standing balance; leg extensor power; chair rises

Introduction

As individuals move from mid- to old age, good lower limb function is vital for the maintenance of physical capability at levels which are adequate to ensure an independent

Corresponding author: Dr Rebecca Hardy, r.hardy@nshd.mrc.ac.uk, Tel: +44 (0)20 7670 5713, Fax: +44 (0)20 7580 1501, MRC Unit for Lifelong Health and Ageing, 33 Bedford Place, London, WC1B 5JU, UK.

and healthy life. This is demonstrated by studies showing lower body function to be an important component of physical capability, lower levels of which are associated with increased risk of subsequent morbidity, disability, hospitalization and death.(1–5) The absolute level of lower limb function in older people depends not only on the rate of age-related decline, but also on the level of peak performance achieved earlier in adult life. Hence, longitudinal studies of ageing with repeated measures of physical performance from early or mid-life are ideally required to assess the relative importance of peak levels achieved as well as the relative and absolute rates of decline. This is important when assessing the level of function at any given time and when interpreting the factors that may influence these processes across the whole life course. The objective measurement of lower limb muscle strength and power has, however, proved difficult in large population-based studies as it has traditionally required laboratory facilities. Tests of chair rising performance which can easily be carried out in participants' homes and involve the timing of a specified number of rises from a seated to standing position have been used, particularly in older populations, to detect deficits in leg power.(6) The predictive value of chair rising ability in older populations has been shown as poor performance on chair rise tests in older populations has been found to be associated with subsequent functional limitations, morbidity and mortality.(1;4;5;7)

The Nottingham Power Rig (NPR),(8), developed for use in the Allied Dunbar National Fitness Survey (ADNFS),(8;9) was designed to provide a safe and rapid method for assessing lower limb power in a functionally relevant fashion across the whole adult age range. Validation studies have shown that leg extensor power (LEP) obtained using the NPR is closely related to knee extension power measured using an isokinetic dynamometer.(8) In test re-test studies, LEP has a reliability coefficient of 0.97, and a coefficient of variation of 9.4 % in naïve adults aged 20–86 years unused to athletic exercise.(8) The NPR has not been widely used in large population-based studies because despite being simple to operate, it is bulky and heavy and so not suitable for home visits. In the few studies of older individuals (i.e. 65 years and over) (10–13) which have measured LEP and examined its relationship with chair rise performance, the two measures have been found to be correlated, but there are no studies considering the association in younger populations. It therefore remains unclear whether chair rise performance and LEP are associated at younger ages. Elucidating this is important given that while deficits in leg power may be the major factor contributing to chair rise performance at older ages, other factors may influence chair rise performance of younger individuals whom exhibit fewer deficits in function. Rising from a chair repeatedly not only requires lower limb strength and power but also good balance and coordination and so another factor which may contribute to, and be predictive of, chair rise performance is standing balance.

The aim of the present study was to assess whether chair rise performance could be considered solely as a measure of leg power, and deficits in this, in men and women in mid-life, and therefore be used be used as a baseline for assessment of subsequent age-related decline in leg power. We investigated this by examining the relationship between chair rise performance and LEP in a sub-sample of men and women aged 53 years drawn from the MRC National Survey of Health and Development (NSHD).(14) We then investigated whether chair rise performance was independently associated with LEP and standing balance time after adjustment for body size. We also aimed to assess whether the relationships were different for men and women because women have lower LEP than men(9) and have shorter average height and lower average weight which may influence performance on chair rising.(15)

Methods

Study population

The NSHD is a prospective cohort study of a socially stratified sample (n=5362) of all births that took place in England, Scotland and Wales during one week in March 1946. The whole cohort has been followed up over 20 times, most recently at 53 years, when 3035 (83% of the target sample) men and women provided information and most (n=2989) were visited in their homes by trained nurses. These home visits included measurement of height, weight, chair rises and standing balance. The cohort members participating in the survey at age 53 years were representative in most respects of the British born general population.(14) Of the original cohort, 43% were not contacted at 53 years because they were either living abroad (11%), had withdrawn from the study previously (12%), had died (9%), or were untraced or refused the latest home visit (11%). In addition to the home visit, 325 of the target sample were invited to one of five General Practice clinics (drawn from the MRC General Practice Framework) for further measurements, including LEP using the NPR. Survey members invited were those living closest to the participating clinics. A total of 212 (65% of those invited) agreed to attend. All subjects gave informed consent and ethical permission was obtained for the survey.

Physical characteristics at age 53y

Height was measured to the nearest 0.5 cm using a portable stadiometer (CMS, London). Body weight was measured to the nearest 0.5kg without shoes and in light clothing.

Physical performance measurements

The standardised protocols for measurement of chair rising and standing balance at age 53y have been described in detail elsewhere(16) and brief descriptions are given below.

Chair rising—This was assessed as the minimum time taken in seconds, measured using a stop watch, to complete 10 cycles of rising from a chair until standing fully erect and then sitting down again with arms folded across the chest. The reciprocal of the time taken (multiplied by 100) was used in analyses so that a good performance was represented by a high score, consistent with the other performance measures.

Standing balance—This was assessed using a stopwatch as the longest time in seconds (up to a maximum of 30s) for which each subject could stand on their preferred leg with their eyes closed. Standing balance times were transformed using a natural logarithm to normalize the distribution.

Leg extensor power—Participants were seated on the NPR(8) with arms folded and their inactive leg resting loosely on the floor. They were instructed to push as hard and fast as possible against a large pedal from a flexed knee position to almost full extension with the seat position adjusted for each individual to ensure this. The push caused a heavy flywheel to spin with the final velocity detected by an opto-switch. Average power was calculated from the recorded terminal velocity of the flywheel assuming that acceleration was constant.(8) Two practice attempts were followed by three maximal attempts with strong verbal encouragement from the nurse. The maximum value was used in analyses expressed in both absolute terms and normalized to body mass (LEP/kg).

Statistical methods

There were 174 individuals (81 men and 93 women) with a complete set of valid measurements. Multivariable regression models for normally distributed outcomes were

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used to estimate the association of each of LEP, standing balance, height and weight with chair rise performance. Sex and a categorical variable indicating the clinic attended were also included in each model as covariates in order to adjust for differences in performance between men and women and in measurement between clinics. Interactions between sex and LEP and between sex and standing balance were used to test whether the relationships differed significantly between men and women. In order to obtain sex-specific partial correlation coefficients between chair rise performance and both LEP and balance adjusted for body size, two models, both including chair rise performance, height and weight were then run. One included LEP as an explanatory factor and the other included balance. A further multivariable regression model (i.e. the fully adjusted model) was fitted including all these explanatory variables and any significant interactions. Evidence of non-linearity of the relationships was assessed by including quadratic as well as linear terms of the explanatory variables.

Analyses were repeated, for comparability with other studies, using LEP/kg instead of LEP. In fully adjusted models using LEP/kg, weight was not included as LEP/kg is already adjusted for weight.

Results

On average, men had better LEP than women and this remained the case after adjustment for weight (LEP/kg). They also performed better on standing balance tests, but not chair rising (Table 1).

LEP was not related to chair rise performance in a model adjusting only for clinic and sex (Table 2, Figure 1). Higher balance time was associated with better chair rise performance with some suggestion that this association was stronger in men than women (p=0.09 for sex interaction) (Figure 2). Weight and height were both negatively associated with chair rise performance after adjustment for clinic and sex (Table 2). When adjusted for height and weight, the partial correlation coefficient (r) between balance and chair rise performance was significant in men (r=0.27, p=0.01), but not women (r=-0.04, p=0.7).

In fully adjusted models there was still evidence of a difference in the relationship between balance time and chair rises between men and women (test of sex interaction, p=0.03). There was also some evidence of a different relationship between LEP and chair rise performance between the sexes (p=0.06 from likelihood ratio test for improvement in fit of adding linear and quadratic sex interaction terms). Hence, for clarity, separate fully adjusted models were fitted for men and women (Table 2). In these fully-adjusted models a U-shaped association was observed (p=0.04 for quadratic term) between LEP and chair rise performance among men with those of average leg power doing less well at chair rising than men with low or high leg power (Figure 1a). There was no evidence of an association between LEP and chair rising among women. Balance time was positively associated with chair rise performance but only in men (Figure 2).

A number of observations which exerted a strong influence on the shape of the relationship between LEP and chair rise performance in men were identified. There were 6 men with high performance on the chair rise test (completion of 10 chair rises in 14 seconds or under) but low LEP (figure 1); removal of these observations resulted in the quadratic term becoming non-significant. It may, therefore, be that a relationship between LEP and chair rises only exists below a certain chair rise performance threshold. In total, there were 10 individuals (7 men and 3 women) who completed the 10 chair rises in 14 seconds or under. Hence, we repeated the analyses excluding these 10 observations. In this restricted sample, LEP was linearly and positively related to chair rise performance after adjustment for clinic

(Table 3). The partial correlation coefficient after adjustment for height and weight was 0.30 for men (p=0.01) and 0.14 for women (p=0.2). After adjustment for weight, height and standing balance performance, the association remained (Table 3) with a per 10watts increase in LEP related to a 0.05 (95% CI=0.01, 0.08) unit increase in chair rise performance (Table 3). The difference in the association between men and women decreased in the fully adjusted model (p=0.9 for sex by LEP interaction) due to the association among women getting stronger after adjustment for body size. Further, there was no longer any evidence of a non-linear relationship among men. LEP explained 4% of the variation in chair rise performance in this model (total variation explained=19%). Consistent with the initial analyses, better standing balance performance was associated with better chair rise performance in men only in the fully adjusted model (p=0.007 for sex interaction) (Table 3).

Similar results were obtained when using LEP/kg as the outcome (results not presented). The initial association between LEP and chair rise performance was slightly stronger (after adjustment for clinic and sex only) due to the stronger relationship among women as weight is also accounted for in the outcome.

Discussion

In this general population sample aged 53 years, better LEP was correlated with better chair rise performance after adjustment for sex, height, weight and standing balance, among those who completed 10 chair rises in 15 or more seconds. Better standing balance performance was associated with better chair rise performance in men, but not women.

The mean LEP/kg of participants in ADNFS between the ages of 45 and 54 years (3.93LEP/kg in men, 2.57LEP/kg in women)(9) were considerably higher than in the present study. Given that the NSHD cohort is at the higher end of this age range, the mean would be expected to be somewhat lower. It may also be that maximum performance LEP was not achieved in NSHD or that the NPRs used in NSHD measured consistently lower than those used in ADNFS or that the participants in ADNFS were a self-selected healthy sample. However, there was a strong positive correlation between grip strength, a simple measure of muscle strength available in NSHD, and LEP which suggests that the LEP measure still ranks individuals in the correct order for muscle power. Further, similar gender differences in LEP were found in both NSHD and ADNFS: mean LEP/kg for women was 65% of that of the men in both studies.(9) While the single-leg balance task with eyes closed used in this study is relevant to the investigation of the physiological mechanisms underlying balance, the functional significance of this test in relation to chair rise performance may be limited. However, this measure of standing balance would be expected to be highly correlated with the balance mechanism involved in chair rising. A limitation of our study is that only a sub-sample of the overall NSHD cohort had LEP measured as the NPR can only be used in a clinic setting. However, the sample size is larger than in some previous studies relating leg power with chair rise performance(10;11), and the sample are all of the same age. Further, the sub-sample did not differ significantly in physical function measures or body size from the national cohort from which they were recruited. Another potential limitation is that LEP was measured in 5 clinics and so measurement was not fully standardized, although we did adjust for clinic in the regression analyses.

The initial U-shaped association between LEP and chair rise performance, in particular the better chair rise performance of men with low LEP compared to those with average LEP, is difficult to explain and it may be a chance finding. Removal of the 7 men with the best chair rise performances resulted in a significant positive linear relationship being observed. It may be that at this high level of chair rise performance in a mid-life sample, no association exists between LEP and chair rises. It has previously been suggested that associations may only exist below a certain threshold of power.(17) In that analysis, the time to complete 5 chair stands was associated with knee extensor and hip flexor strength only below 10 and 15 kg, respectively, in a sample of the most disabled women living in the community aged 65 years and older. While our findings suggest a threshold for chair rise performance rather than LEP they may not be directly comparable with those from the previous study. The women in the other study, as well as being older with more disability, were required to perform fewer chair rises and this makes the test less dependent on other factors such as balance than in our study.

Our findings, on removal of men and women with the fastest chair rise times, agree with those from previous studies in older age samples where better LEP has been associated with better chair rise performance.(10–13) Because of the older age ranges (80–99 years,(10) 65–89 years(11) and 65–95(12)), participants in most previous studies were only required to perform 1(10), 3(11) or 5(12) chair rises. Although our middle-aged participants were required to complete 10 chair rises so that the task is less like the single brief push in the leg rig, an association was still observed. This does highlight issues relating to the assessment of age-related change over long periods of time, if participants are asked to perform fewer chair rises at older ages. The fact that the association between LEP and chair rises in women strengthened after adjustment for body size, and particularly weight, can be explained by the contrasting associations of body weight with chair rise and LEP. Higher weight was associated with better LEP, but with poorer chair rise performance. This is as expected, since heavier individuals are more likely to have larger muscles and are better able to accelerate the inertial load in the NPR. In chair rising, body weight carries a penalty as the body mass to be lifted is greater and this penalty was more noticeable among the women in NSHD.

In our final combined model, LEP explains 4% of the variation in chair rise performance suggesting that chair rise tests, when undertaken in middle-aged populations, cannot be thought of solely as a proxy measure for lower limb power and as an indicator of leg power deficit. Better standing balance performance was also related to better chair rise performance in men, indicating that other aspects of physical function also play a role in influencing chair rising performance at this age. That balance is only associated with chair rising performance in men may be due to their greater leg power, which means that LEP is less discriminative in regards to chair rising performance. In the full NSHD sample, previous analyses have shown that chair rise performance at age 53y was related to a wide range of important explanatory factors including health, physical activity, social class, childhood developmental factors and to longitudinal change in certain domains of cognitive function.(15;16;18) Hence, chair rise performance in middle-age exhibits sufficient variation to distinguish different levels of physical functioning suggesting that it is a useful measure in middle-aged cohorts. Our findings are consistent with those from a large study of men and women aged 75 years and over which found that sit-to-stand performance was influenced by multiple physiological and psychological processes as well as strength, concluding that chair rising represents a particular transfer skill.(19)

Conclusions

Better LEP was related to better chair rise performance in a cohort of middle-aged men and women after adjustment for body size, as has previously been shown in older samples. That LEP and balance are both related to chair rise time in men suggests that chair rise time should not be thought of purely as a proxy measure of leg power and deficits in leg power in middle-aged samples. This finding has implications for the interpretation of age-related decline in chair rise performance since it may increasingly become a measure of leg power deficit with age.

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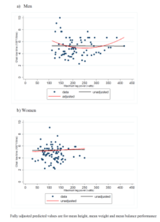

Figure 1.

A scatter plot of chair rise performance against LEP and the predicted association between LEP and chair rise performance after adjustment for clinic only and in the fully adjusted model (including weight, height, standing balance and clinic).

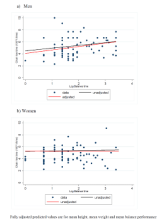

Figure 2.

A scatter plot of chair rise performance against LEP and the predicted association between LEP and standing balance performance after adjustment for clinic only and in the fully adjusted model (including weight, height, chair rise performance and clinic).

Table 1

Descriptive statistics for the physical measurements by sex – overall sample and stratified by clinic attended

	Mean (standard deviation) [a]Median (inter-quartile range)		
Physical measures	**Men (n=81)[c]**	**Women (n=93)[d]**	**p-value[b]**
Chair rise time (s)[a]			
Total sample	21 (16–26)	21 (18–26)	0.19
clinic 1	20 (15–27)	18 (18–19)	
clinic 2	20.5 (16–24)	19 (18–25)	
clinic 3	20 (18–27)	24 (21–26)	
clinic 4	23 (17–26)	19.5 (17.5–21)	
clinic 5	21 (15–27)	23 (20–30)	
Balance time (s)[a]			
Total sample	5 (4–10)	4 (2–7)	0.03
clinic 1	6 (4–8)	4 (3–6)	
clinic 2	11 (4–46)	4 (2–5)	
clinic 3	4 (3–6)	5 (2–8)	
clinic 4	5 (3–7)	3 (2.5–4)	
clinic 5	7 (4–27)	5 (3–9)	
Leg power (watts)			
Total sample	216.2 (65.9)	118.3 (39.5)	<0.001
clinic 1	243.4 (67.4)	138.3 (33.1)	
clinic 2	200.5 (50.3)	104.1 (40.0)	
clinic 3	237.0 (63.4)	130.7 (51.2)	
clinic 4	171.9 (45.8)	99.4 (31.9)	
clinic 5	242.5 (82.5)	123.4 (33.3)	
Leg power/kg			
Total sample	2.6 (0.7)	1.7 (0.5)	<0.001
clinic 1	2.9 (0.9)	2.0 (0.4)	
clinic 2	2.6 (0.7)	1.5 (0.5)	
clinic 3	2.6 (0.6)	1.8 (0.6)	
clinic 4	2.6 (0.6)	1.5 (0.5)	
clinic 5	2.9 (0.7)	1.8 (0.5)	
Weight (kg)			
Total sample	84.0 (14.0)	70.9 (13.1)	<0.001
clinic 1	87.9 (21.5)	69.2 (8.6)	
clinic 2	78.3 (12.1)	71.4 (15.7)	
clinic 3	89.6 (11.7)	74.2 (14.6)	
clinic 4	81.3 (10.4)	65.5 (7.7)	
clinic 5	82.8 (12.2)	71.5 (13.1)	
Height (cm)			
Total sample	175.6 (7.5)	162.6 (6.8)	<0.001

Physical measures	Mean (standard deviation) [a]Median (inter-quartile range) Men (n=81)[c]	Women (n=93)[d]	p-value[b]
clinic 1	172.3 (6.4)	166.7 (6.5)	
clinic 2	173.4 (8.2)	160.0 (6.5)	
clinic 3	177.0 (7.1)	159.5 (5.4)	
clinic 4	176.9 (7.1)	161.5 (6.1)	
clinic 5	178.6 (7.9)	164.8 (7.0)	

[a]Median (inter-quartile range)

[b]p-value from test of sex difference

[c]Total number of men=81 (clinic 1=13, clinic 2=18, clinic 3=21, clinic 4=18, clinic 5=11)

[d]Total number of women=93 (clinic 1=9, clinic 2=22, clinic 3=15, clinic 4=12, clinic 5=35)

Table 2

Mean differences in chair rise time (reciprocal of chair rise time in seconds * 100) in 81 men and 93 women by leg power, weight, height and balance time from multivariable models.

	Adjusted for clinic and sex [a]		Fully adjusted [b]	
	Regression coefficient (95% confidence intervals)	**p-value**	**Regression coefficient** (95% confidence intervals)	**p-value**
LEP (10 watts)				
Both sexes	0.005 (−0.036,0.047)	0.8	-	
Men	-			
Linear (per 10 watts)			−0.33 (−0.64,-0.02)	0.04
Quadratic ((per 10 watts)^2)			0.0065 (0.0004,0.0127)	0.04
Women [c]			0.24 (−0.51,0.99)	0.5
Balance time (ln(s))				
Both sexes	0.268 (0.003,0.532)	0.05	-	
Men	-		0.57 (0.10, 1.04)	0.02
Women	-		−0.004 (−0.34,0.32)	0.98
Weight (kg)				
Both sexes	−0.019 (−0.034,−0.004)	0.02	-	
Men	-		−0.02 (−0.05,0.01)	0.15
Women	-		−0.02 (−0.04,0.01)	0.13
Height (cm)				
Both sexes	−0.024 (−0.053,0.006)	0.1	-	
Men	-		−0.03 (−0.08,0.02)	0.24
Women	-		0.00 (−0.04,0.04)	0.99

[a] Each variable included in a model separately and adjusted for clinic and sex

[b] Fully adjusted model includes LEP, balance time, height, weight and clinic. Separate models fitted for men and women because of the significant sex interaction for standing balance time and almost significant sex interaction with LEP.

[c] Linear term only as quadratic is non-significant.

Table 3

Mean differences in chair rise time (reciprocal of chair rise time in seconds * 100) in 74 men and 90 women who completed 10 chair rises in > 14 seconds by leg power, weight, height and balance time from multivariable models. All models also include a clinic variable.

		Adjusted for clinic and sex [a]		Fully adjusted [b]	
		Regression coefficient (95% confidence intervals	**p-value**	**Regression coefficient (95% confidence intervals**	**p-value**
LEP (per 10 watts)					
	Both sexes	0.047 (0.012,0.082)	0.008	0.05 (0.01,0.09)	0.008
Balance time (ln(s))					
	Men	0.56 (0.24,0.89)	0.001	0.44 (0.11,0.77)	0.01
	Women	−0.07 (−0.36,0.22)[d]	0.6	−0.16 (−0.46,0.14) [c]	0.3
Weight (kg)					
	Both sexes	−0.013 (−0.026,0.000)	0.05	−0.02 (−0.04,0.00)	0.02
Height (cm)					
	Both sexes	−0.021 (−0.046,0.005)	0.1	−0.02 (−0.04,0.01)	0.3

[a] Each variable included in a model separately and adjusted for clinic and sex (and sex by balance time in relevant model because of significant interaction)

[b] Fully adjusted model includes LEP, balance time, height, weight, clinic, sex and balance time by sex interaction

[c] calculated from model including sex interaction