

Reproducibility of the Jumping Mechanography As a Test of Mechanical Power Output in Physically Competent Adult and Elderly Subjects

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OBJECTIVES: To compare the reproducibility of the newly developed jumping mechanography with other physical tests.

DESIGN: Study 1: Repeated testing with an interval of 2 weeks to assess the short-term repetition error. Study 2: Testing on 5 successive days to assess learning effects.

SETTING: Geriatric clinic, Esslingen, Germany.

PARTICIPANTS: Study 1 had 36 subjects aged 24 to 88; Study 2 had 22 subjects aged 19 to 86. Locomotor competence in all subjects was assessed using the ability to walk unaided and to perform a tandem stand and tandem walk.

MEASUREMENTS: The test battery consisted of timed up and go, freely chosen gait speed, maximum gait speed, chair-rising test, and maximum power in jumping mechanography.

RESULTS: All subjects performed the jumping mechanography without major problems. Study 1: Of all tests, maximum power in jumping mechanography depicted the smallest intrasubject short-term error (3.6%), the largest intersubject coefficient of variation (45.4%), and the greatest test-retest correlation coefficient ($r = 0.99$). Study 2: The only tests for which the learning effects were confined to the 1% range were the maximum gait speed test and the maximum power in jumping mechanography.

CONCLUSION: Assessment of maximum power in jumping mechanography appears to have good test-retest reliability with negligible learning effects. Moreover, it results in a comparatively large intersubject variability, which makes it an interesting method in the assessment of aging effects in middle-aged to older subjects and patients. *J Am Geriatr Soc* 52:128–131, 2004.

Key words: geriatrics; rehabilitation; biomechanics; muscle power

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Locomotion and balance, which have been assessed using various performance tests, are substantially compromised with advancing age.¹ Most commonly used tests are walking at different paces,² standing in different positions,^{3,4} turning around,⁴ or rising from a chair.⁵ Such tests, alone or in combination, are widely used in epidemiological and clinical studies.^{6–10} It has been shown that combined impairments in different physiological subsystems cause locomotor disability.¹¹

Most of these tests have been designed to objectively assess tasks that are relevant to daily activities in older people.^{12–14} They have been shown to be predictive of future development of locomotor disability,¹⁵ but different research groups have used different procedures, sometimes with differing instructions for the same test. The timed up and go test, for example, is sometimes performed without an arm rest.⁷ Even more importantly, it is not clear as to what extent different tests measure similar neuromuscular impairments.

The authors sought a test that focuses on muscular power output, can discriminate subjects over a wide range of performances, and can be performed with the simplest set of possible instructions. One of the authors developed a mechanographic system to assess muscle force, velocity, and thus power from the ground reaction force.

This mechanographic device was applied to a simple jumping paradigm in different subjects, such as elite athletes and frail elderly patients. Even subjects as old as 90 with moderate control of balance, sometimes incapable of performing the chair-rise test, are able to perform this test. This study reports on the short-term error and on learning effects of the jumping mechanography, comparing them with standard tests of locomotor performance.

METHODS

Two studies were designed for this test. In the first one, the short-term error was assessed using repeated testing with an intervening interval of 2 weeks. In the second study, learning effects were investigated by testing subjects on 5 consecutive days. Before inclusion in the study, all subjects gave their written informed consent.

Study Subjects

Twenty-two women and 14 men participated in the first study. The subjects had a mean age ± standard deviation (SD) of 60.8 ± 19.0 (range 24–88). The women had a mean height of 165.3 ± 4.9 cm and a mean weight of 64.6 ± 10.8 kg. The men had a mean height of 173.4 ± 6.7 cm and a mean weight of 78.6 ± 12.7 kg.

In the second study, 11 women and 11 men with a mean age of 59.7 ± 16.1 (range 19–86) participated. The women had a mean height of 157.7 ± 6.0 cm, a mean weight of 56.4 ± 6.12 kg, and a mean body mass index (BMI) of 22.6 ± 1.9 kg/m². The men had a mean height of 174.6 ± 5.8 cm, a mean weight of 71.7 ± 9.2 kg, and a mean BMI of 23.5 ± 2.6.

Testing

Testing was performed at the same time of day and in the same order: timed up and go test, freely chosen gait speed, maximum gait speed, chair-rise test, and jumping mechanography. During the maximum gait speed and chair-rise tests, subjects were verbally encouraged. Maximum gait speed, chair-rise test, and jumping mechanography were performed three times, and the best result was taken.

The timed up and go test was performed as previously reported.¹⁴ The maximum and freely chosen gait speed were measured over a distance of 10 m with additional distance for acceleration and deceleration. Time was measured manually. The chair-rise test was performed as described previously:³ on a chair 45 cm high without arm rests and as the time taken to stand up and sit down five times at maximum speed without using the arms and under continual verbal encouragement.

Jumping was performed as counter-movement jump (i.e., brief squat before the jump) with freely moving arms. The instruction was to jump with the head and chest as high as possible. This test was performed on a ground reaction force platform with a personal computer and an integrated analog-digital board and software (Novotec Medical, Pforzheim, Germany). This system computes the subject's vertical velocity by integrating the ground reaction force, as described in principle earlier.^{16,17} Body mass and starting point are assessed during quiet stance immediately before the jump. Instantaneous power is calculated as the product of force and velocity. In the present study, only the peak

power during the acceleration phase (during concentric contraction of antigravity muscles) has been analyzed.

Data Processing and Statistical Analysis

Results of gait speed, chair-rise test, and the timed up and go test (in seconds) were inverted (seconds⁻¹) to yield measures of speed, which in human locomotion is proportional to the whole-body power output. This inversion was necessary to make the results of the former tests statistically comparable with jumping mechanography in linear correlation analysis.

In Study 1, the short-term repetition error (E_{ST}) in percent was assessed for all variables and subjects as

$$\text{Short-term error} = 100 \times ((\text{Absolute}(x_1 - x_2)) / ((x_1 + x_2) / 2))$$

where x₁ is the value of the test and x₂ the value of the retest. As a measure of the variation of variable x between subjects, the coefficient of variation (CV) in percentage was computed from the mean of x over all subjects and its SD as

$$CV_x = 100 \times \text{SD}(x) / \text{mean}(x)$$

Finally, correlation analysis was performed between values of test and retest and between the different tests to reveal to which extent the different tests measure similar information.

For Study 2, the learning error E_{LE} (in percentage) was computed as

$$E_{LE} = 100 \times (x_n - x_1) / x_1$$

where x_n is the nth measurement of variable x in one subject. For all five tests investigated, the x_n were tested against 0 with Student *t* test.

Statistical analyses were conducted with SPSS software, PC version 10.0 (SPSS Inc., Chicago, IL). Diagrams were prepared with XAct software, version 6.02 (SciLab, Hamburg, Germany). Significance was assumed if *P* < .05.

RESULTS

Study 1

The short-term error was largest for the timed up and go test (5.28%) and smallest for jumping mechanography (3.60%) (Table 1), but the coefficient of variation for intersubject variability (45.4%) was highest for jumping mechanography and lowest for freely chosen gait speed (24.0%).

Table 1. Short-Term Error (E_{ST}), Coefficient of Variation (CV), and Correlation Coefficient (*r*) for the Repeated Measurements in Study 1 (26 Subjects Aged 24 to 88)

Test	Mean	Range	E _{ST}	CV	<i>r</i>
			%	%	
Timed up and go, s ⁻¹	0.131	0.073–0.177	5.28	25.5	0.90
Free gait speed, s ⁻¹	0.141	0.077–0.203	4.20	24.0	0.93
Maximum gait speed, s ⁻¹	0.204	0.108–0.328	3.69	30.6	0.97
Chair-rising test, s ⁻¹	0.143	0.072–0.226	5.10	30.9	0.91
Jumping mechanography, W kg ⁻¹	31.5	8.0–55	3.60	45.4	0.99

Note: CV was assessed using test (not retest) data.

Table 2. Correlation Matrix for the Five Neuromuscular Tests in Study 1*

	Timed Up and Go	Free Gait Speed	Maximum Gait Speed	Chair-Rise Test
Free gait speed	0.93			
Maximum gait speed	0.84	0.83		
Chair-rising test	0.76	0.71	0.81	
Jumping mechanography	0.82	0.78	0.92	0.86

*26 subjects aged 24 to 88.

Given is Pearson correlation coefficient. All correlations were significant, $P < .01$.

All test-retest correlations were found to be significant (Table 1). The highest correlation coefficient for test-retest values was for jumping mechanography ($r = 0.99$) (Table 1) and the lowest for timed up and go ($r = 0.81$).

Significant correlations were also found between different tests (Table 2). Correlation coefficients were particularly high for the correlation between timed up and go values and the freely chosen gait speed (0.93) and between jumping mechanography and maximum gait speed (0.92). The lowest coefficient was observed between the chair-rise test and freely chosen gait speed (0.71).



Figure 1. Eighty-eight-year-old woman performing jumping mechanography.

Study 2

A significant, positive learning error was found for the timed up and go test on all repetition days (Figure 2). Averaged errors as high as 7.8% were observed. Significant errors of the same magnitude were found for repetition Days 3 through 5 for the chair-rise test. Although not significant, a consistent trend for errors in the range of 5% seemed to exist after repetition Day 3 for the freely chosen gait speed. No significant learning errors were found for maximum gait speed or jumping mechanography. For these tests, errors were confined to the 1% range.

DISCUSSION

These data show that, in a mixed population of young adults to older physically competent subjects, the timed up and go test, the chair-rise test, freely chosen gait speed, and maximum gait speed yield a good test-retest reliability, with

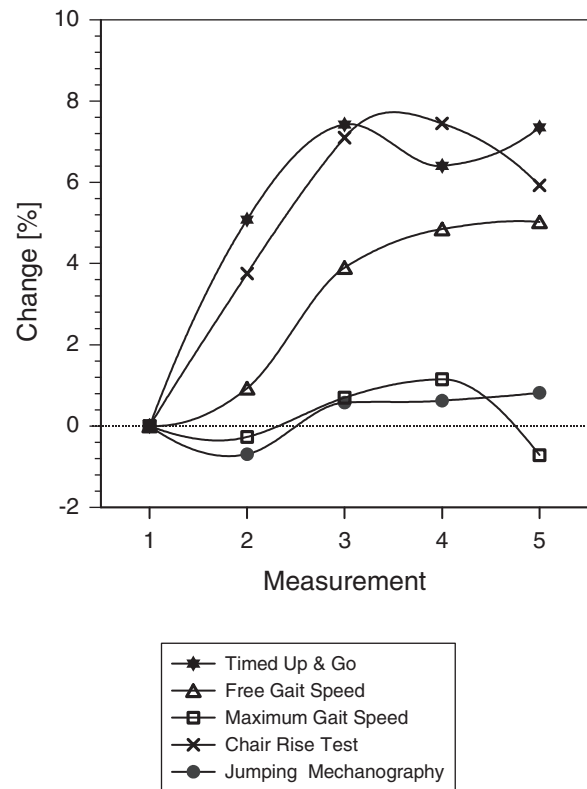


Figure 2. Averaged learning error in percentages for the five neuromuscular tests, given for measurements on 5 consecutive days of Study 2 (22 subjects aged 19 to 86).

short-term errors less than 5% and test-retest correlation coefficients greater than 0.90. Although this was expected for the former four tests,^{10,18} the information is new for the jumping mechanography.

A closer look reveals smaller short-term repetition errors and stronger test-retest correlations for jumping mechanography and maximum gait speed than for the other tests. Moreover, these two tests, which are both mainly directed at mechanical power output, showed practically no learning effect in Study 2.

Correlation coefficients between different test methods ranged from 0.71 to 0.93 and were in all cases smaller than the test-retest correlation coefficients. The latter suggests that the different tests, at least to a certain extent, assess different functions.

In conclusion, these data show that jumping mechanography is applicable in physically competent older subjects with good reproducibility. Maximum gait speed was almost as reliable as jumping mechanography. Moreover, the latter two tests were highly correlated, which may add to the clinical validity of jumping mechanography, but maximum gait speed resulted in a considerably smaller variation coefficient and will thus discriminate between a smaller range of performance levels. It seems as if jumping mechanography is representative of impairment level and may thus be a useful extension for planning and evaluating locomotor therapy.

Jumping tests have been applied to discern sprinting and endurance capacity¹⁹ and to assess degree of mechanical efficiency.²⁰ Other applications are possible. Given that jumping mechanography is applicable in older physically competent subjects with good reproducibility, it is hoped that there will be research into the mechanical power output of the locomotor system, applying this technique with different paradigms.

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