Reliability and clinical applicability of lower limp strength using an enhanced paper grip strength

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Abstract

The enhanced paper grip test (EGPT) quantitatively assesses lower limb strength. EGPT assesses the hallux grip force by reacting a pulling force derived from a card, being positioned underneath the participant's hallux. This study aimed to investigate the repeatability and clinical applicability of the EPGT for assessing foot muscle strength. EPGT force was measured using a dynamometer. The reliability of the measurement of EPGT force was assessed by having two examiners performing the test on the same group of healthy adults. Clinical applicability was assessed in community-dwelling adults of both genders. EPGT force was recorded for both feet using the same standardised protocol for all participants. Regarding reliability, 20 healthy adults aged 23.04±5.5 years participated in the present study. The EGPT demonstrated good to excellent test-retest (ICC1,2 0.8 to 0.86) and interrater reliability (ICC1,2 0.82 to 0.88). A convenience sample of 15 community-dwelling adults (71.6±7.8 years, 68.5% women) was recruited for clinical applicability testing. All participants performed the test with mean score 15±5.7 N. EPGT is a reliable measurement of the hallux grip force strength and can be used for clinical and research purposes.

Key Words: lower limp strength; enhanced paper grip strength; reliability; clinical applicability.

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It is well-established that an inevitable consequence of aging is a decline in muscle strength,[1] accompanied with a decrease in muscle quality.[2,3] Low muscle strength in older adults is associated with poor physical function.[4] It could indicate reduced functional capacity and risks of depression, hospitalization, fractures and mortality.[3-6] Muscle weakness is used to identify geriatric syndromes such as dynapenia,[7] frailty,[8] and sarcopenia.[9] Numerous studies have demonstrated that foot and ankle muscle strength measurements can be useful for the prediction of falls.[10-12] The toes play an essential stabilizing role in weight-bearing activities and walking.[13] Foot muscles are vital in maintaining physical capability, and toe muscle weakness is an independent predictor of falls in older people.[1] The evaluation of foot muscle strength is important in various clinical applications. However the evaluation of the strength of small foot muscles is challenging. Toe flexor strength methodology has relied on hand held dynamometry,[14,15] or paper grip test (PGT).[12-16] However none of these methods are widely adopted as part of standard clinical practice.[12]

The paper grip test is a simple, clinically applicable test to detect muscle weakness in the foot.[12] Theuvenet and Roche developed the PGT in the 1990s as a screening tool for muscle paralysis in the intrinsic foot muscles of people with leprosy.[12,16,17] During the PGT the examiner places a piece of cardboard at the size of a business card under the patient's hallux and ask them to grip it with their hallux. The participant passes the test if they can successfully grip the card. The enhanced paper grip test (EPGT) was developed by Chatzistergos et al., in the 2020s.[12] The participant sits in a sturdy chair without shoes and socks. The examiner asks the patient to start gripping the card and then starts pulling the dynamometer until the card is fully removed from underneath the hallux. Unlike the conventional PGT, in the EPGT, the card is linked to a dynamometer.[12] Researchers from Staffordshire University suggest that EPGT force is a reliable and accurate measurement of the hallux grip force.

They also highlighted the clinical value of this measurement in prevention of falls in people with

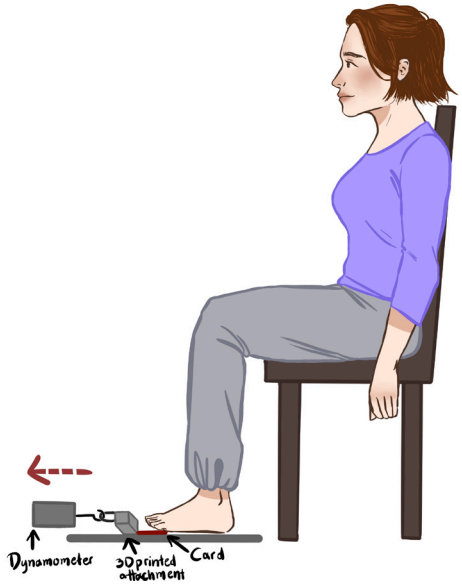

Fig 1. *Enhanced paper grip test (EGPT).*

Fig 2. *Card and participant's foot.*

diabetes.[12] Accurately assessing foot strength can help doctors and researchers identify weaknesses and monitor rehabilitation progress.[16,17] Thus, the aim of this study was to test the repeatability of the EPGT for assessing foot muscle strength and its clinical applicability in community-dwelling older adults.

Materials and Methods

This cross-sectional survey study was conducted at the University of Patras, Greece between February 2023 and May 2023. All participants were informed about the study objective and procedures and signed an informed consent form prior to their testing. They were assured that information obtained would be anonymous and confidential. The study was approved by the Ethics Committee of the University of Patras (N. 15213 27/2/2013).

Procedure

The procedure has been divided into 2 phases: reliability and clinical applicability testing. For the EGPT testing all participants were seated in a sturdy chair without arm rests. They took shoes and socks off, and each hallux's plantar surface was wiped clean using a wet wipe. The card was placed underneath the participant's foot (Figure 1 and Figure 2). The examiner asked the patient to start gripping the card and then started pulling the dynamometer until the card was fully removed from underneath.[12] The test was repeated three times per foot, alternating between feet to allow at least 30 seconds of rest for each foot between tests. The highest value was recorded as the participant's strength and the average of provided a single value for each foot. The card was connected to a 100 N hand-held dynamometer (Omega engineering, UK) using a 3D-printed attachment. The developers at Staffordshire University gave the dynamometer and the 3D-printed attachment to the Greek researchers.

Reliability

Measurements from the EPGT were evaluated for reliability in healthy participants. A convenience sample of twenty-two healthy participants was recruited at the Department of Physiotherapy, University of Patras to test the inter- and intra-rater reliability of the proposed EPGT. Eligible participants had to be above 18 years-old. Exclusion criteria were surgeries or other musculoskeletal problems that could affect the ability to complete objective assessments. Before recruitment, each participant was screened for eligibility whether she/he met the inclusion criteria. An interview survey was performed including physical activity. For test-retest testing, each participant attended two separate testing sessions within 48 hours.

For inter-tester reliability testing, each participant was tested by two independent examiners in random order. The two examiners were physiotherapists with different educational backgrounds and different years of clinical practice. Examiner 1 had a PhD qualification, >15 years of clinical practice and was trained by the developers of the EPGT. Examiner 2 was an MSc student with 4 years of clinical experience and had never before performed the test. Both examiners were given a detailed step-by-step protocol to follow which included the exact instructions to participants. Both foot were tested for all participants.

Clinical applicability

A convenient sample of 15 community dwelling adults of both genders agreed to participate in this study. Participants were recruited via invitations to social media

Table 1. *Young participants' characteristics.*

Characteristics	
	Mean (SD)
Age (years)	23.04 (5.5)
Weight (kg)	67.2 (11.4)
Height (m)	1.7 (0.08)
BMI	23.04 (2.9)
Drugs (n)	4 (1.1)
	Number (percentage)
Gender Female Male	 13 (65%) 7 (25%)
Involved in physical activity	17 (85%)

BMI: Body mass Index; SD: Standard Deviation.

and University. Eligible participants had to be above 65 years. Exclusion criteria included a) inability to walk independently for at least 10 m, b) active foot ulcer, c) active infection, d) active/history of Charcot osteoarthropathy, (b) surgeries or other musculoskeletal problems that could affect ability to complete objective assessments. Each participant was interviewed face-to-face to assess her/his medication use (number of drugs) and comorbidities. EPGT force was recorded for both feet using the same protocol as outlined above. A highly experienced physiotherapist performed the test for all participants. After the testing all participants answered 3 questions: i) Do you have any complain; ii) Did you find the procedure easy?; iii) Do you feel safe during the assessment procedure?

Statistical analyses

All the statistical analyses were conducted using IMB SPPS Statistics 28.0. The descriptive characteristics were presented with means and standard deviations for numeric variables and as percentages for nominal/categorical variables. The normality of recorded data was tested using the Shapiro Wilk test. Comparisons between examiners, as well as between the two measurements were made via t-test. Reliability (both interrater and test-retest) was tested by the intraclass correlation coefficient (ICC) and its 95% confidence intervals (CIs). ICCs were calculated based on a single measurement, absolute agreement, and two-way mixed-effects model. Reliability assessed by ICC estimates was defined as follows: ICC estimate (0.90: excellent reliability, between 0.75 and 0.9: good reliability, 0.5-0.75: moderate reliability, >0.5: poor reliability).[18,19] Statistical results were considered significant at the 5% critical level ($p< 0.05$).

Table 2. *Test–retest reliability of the test (n = 20).*

	Test retest results $ICC_{2,1}$ 95% CI
Examiner 1 Right foot	0.86. 0.76 - 0.92
Examiner 1 Left foot	0.80 0.68 - 0.89
Examiner 2 Right foot	0.88 0.79-0.94
Examiner 2 Left foot	0.82 0.77-0.92

Results

Reliability

Twenty two participants for both testing sessions and both examiners were included in the study. Two participants had to be excluded because their EPGT force exceeded the dynamometer's capacity (i.e. > 100 N). Young participants' characteristics are presented in Table 1.

Intra-rater reliability was excellent for both feet. Test-retest reliability results for the first examiner were excellent for the right foot with ICC = 0.86 and 95 %

Table 3. *Comparison between examiners and test retest measurements.*

	EGPT values		Mean difference	P value
	Examiner 1	Examiner 2		
Right foot	40.45±12.44	42.12±14.43	-1.67±8	0.18
Left Foot	41.8±16.2	41.78±14.76	0.02±11.3	0.49
	Test day 1	Test day 2		
Right foot	40.45±12.44	42.22±12.3	-1.77±80	0.18
Left foot	41.24±16.27	42.31±14.83	-1.07±9	0.22

Table 4. *Older adults' characteristics.*

Characteristics	
	Mean (SD)
Age (years)	74.03 (2.7)
Weight (kg)	66.5 (10.1)
Height (m)	1.64 (0.08)
BMI	25.7 (3.7)
Drugs	3.9 (3.7)
Comorbidities	4 (1.1)
	Number (percentage)
Gender	
Female	11 (73.4%)
Male	4 (26.7%)

BMI: Body mass Index; SD: Standard Deviation.

confidence intervals between 0.76 and 0.92 and very good for the left foot (ICC = 0.8, 95 % CI:0.68 and 0.89). Inter-rater reliability was excellent for the right foot ICC = 0.88 and 95 % confidence intervals between 0.79 and 0.94 and excellent for the left foot with ICC = 0.82 and 95 % confidence intervals between 0.77 and 0.92 (Table 2). Comparisons between examiners and days of testing are presented in Table 3.

Clinical applicability testing

Fifteen community dwelling older adults participated for clinical applicability testing. Older adults' characteristics are presented in Table 4. All participants performed the test with no complaints. Mean score on EGPT was 15±5.7 N.

Discussion

This is the first study to investigate the reliability and clinical applicability of the EGPT in Greek population. Results show that the EPGT test is reliable, easy to use and has clinical applicability. The test had excellent reliability (ICC 0.80 to 0.88) results in Greek participants. Comparisons between examiners and days of testing, showed that participants performed similarly since all p values were well above 0.05 (Table 3). Regarding reliability and clinical applicability, results are in agreement with the study of Chatzistergos et al., (2020).[12] This indicates that this repeatability can be expected from any raters, however novice they are, in performing this test.[21] One of the main advantages of this test is that it is easy to perform and has low cost. The only device that is needed is a hand-held dynamometer which is substantially less expensive than plantar pressure assessment systems.

In the present study all participants, both health adults and older adults > 65 years of age performed the test easily and without complains. Results of the present study are clinically meaningful and applicable assisting clinicians regarding muscle strength assessment.[21] The test and the data obtained was performed in less than 5 minutes, indicating that it may be used as part of standard clinical practice among health professionals.[12] Clinical applicability is defined as the extent to which the users can apply a recommendation in practice securing the correct use of the test.[22] Researchers applied this method on a specific age group (community dwelling older adults) in order to identify potential sources of error. All participants performed the test easily and safely. However future studies should be designed in order to assess clinical responsivess and the ability of the test to detect changes after an intervention.[23]

Considering the global aging population and their complex needs a primary health priority should be to maintain the independence and physical function of older adults.[1] Early detection of lower limb muscle strength may help design effective interventions. The literature currently shows that increasing lower limb muscle strength is effective for reducing the number of falls.[24] Research shows that hallux grip force can assess the strength of the foot-ankle muscles and could be used to identify people at risk of falling.[25] Lower levels of lower-limb muscle strength are associated with greater signs of frailty and sarcopenia. According to the revised European consensus on sarcopenia, muscle strength is the primary parameter of sarcopenia and is associated with adverse outcomes or physical limitation.[3,8]

Recent studies have also shown that the most effective interventions for preventing falls are based on balance training and lower limb muscle strengthening.[26-29] Lower limb muscle strengthening seems to be an effective intervention for preventing falls;[1] however, before intervention proper assessment of strength seems important. Gauging the effectiveness and value of interventions from hallux training in clinics and research requires valid metrics for the repeated quantification of strength.[28] Constant testing surface conditions are crucial for acquiring reliable and valid results.[12] Apart from securing a flat and rigid surface, a sheet of paper was taped on the floor to secure a stable friction coefficient. This is fundamental, since this method is developed to be applied in any place, as it is the case in the current study, where older participants were assessed in their home environment. It is obvious that different slippery conditions would affect the testing results. The maximal value reflects the moment, toe pressure on the floor fails to create adequate friction between itself and the testing card. The present study has important clinical implications. Firstly, it is the first study to perform this test in Greek population. In addition, it is simple and quick test, thus making it feasible for clinical and research purposes among health professionals. This test may help health professionals to assess and detect muscle weakness in the foot in order to design an exercise

program to improve strength, balance and to prevent falls.[12,30]

One limitation is that the study participants constitute a convenience sample, which may not fully represent the whole Greek elderly population or patient samples. Further studies of the EGPT will need to be verified in more diverse and larger populations. For instance, patients with diabetes may benefit because they have weak big toe muscles,[31] or patients with sarcopenia because of low muscle strength.[9] The second limitation was that, the sensitivity to change (i.e. the ability to detect clinical changes) was not assessed.[32] This would require a treatment intervention on a sample. Future studies should evaluate patient prognosis and the responsiveness of the test. One hypothesis is that hallux strength may capture disease progression, or a response to therapeutic intervention.[29]

Future studies should test validity of the test. In additions it would be of great interest to investigate individual with foot deformities and to test EPGT for it's prognostic value on falls and other conditions.

In conclusion, EPGT is a reliable and clinically applicable measurement of strength of the hallux grip. It is recommended to be used in research and clinical practice. Further research is required to assess the clinical value of this measurement for the prevention of falls in the older population.

List of acronyms

BMI - body mass index
EGPT - enhanced paper grip test
ICC - intraclass correlation coefficient
N - newton
PGT - paper grip test
SD - standard deviation

Contributions of Author

All authors equally participated in developing this study and in writing the typescript.
All authors read and approved the final edited typescript.

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Conflict of Interest

The authors declare they have no financial, personal, or other conflicts of interest.

Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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