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ARE THE TIMED UP AND GO TEST AND FUNCTIONAL REACH TEST USEFUL PREDICTORS OF TEMPORAL AND SPATIAL GAIT PARAMETERS IN ELDERLY PEOPLE?

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ABSTRACT
Purpose. The study aim was to analyse the relationships between the results of the Timed Up and Go (TUG) test and the Functional Reach Test (FRT), and the temporal and spatial gait parameters determined with the GAITRite system. **Methods.** The study included 60 healthy, physically active elderly people aged 70.4 ± 5.1 years. The participants' functional fitness was evaluated with the TUG and FRT, and their temporal and spatial gait parameters – with the GAITRite system. **Results.** The TUG results correlated inversely with the step length ($r = -0.70$ and $r = -0.61$ for the preferred and fast speed, respectively), stride length ($r = -0.71$ and $r = -0.61$, respectively), and velocity ($r = -0.69$ and $r = -0.38$, respectively). The regression model with these variables explained 43% of variance in the TUG results ($p \leq 0.0001$). The FRT results correlated positively with the step length ($r = 0.61$ and $r = 0.54$, for the preferred and fast speed, respectively), stride length ($r = 0.60$ and $r = 0.56$, respectively), and velocity ($r = 0.37$ and $r = 0.38$). The regression model with these variables explained 26% of variance in the FRT outcomes. **Conclusions.** Basic temporal and spatial parameters of gait at the preferred speed, i.e. velocity, step length, stance time, single support time, swing time, and double support time, explain up to 43% of the TUG outcome variance and 26% of the FRT results variance.

Key words: Timed Up and Go test, Functional Reach Test, gait analysis, aging

Introduction

The analysis of gait based on observation, measurement, and description of its parameters is an inevitable component of elderly people assessment for cognitive impairment, functional independence, physical performance, and the risk of fall [1–4]. Age-related deficits in the central nervous system control [5], physiological and biomechanical changes within the muscular system [6], and functional impairment of sensory organs [7] disrupt walking mechanics and movements of individual body parts in relation to each other (e.g. [2, 8]). Goutier et al. [8] observed that elderly people showed greater trunk sways than young individuals while walking. These differences, particularly evident at a faster pace, imply that the gait of older subjects is less stable than in the young. In a study conducted by Fan et al. [9], young participants differed from older subjects in terms of all analysed basic gait parameters. Irrespective of the gait speed (normal, fast, slow), elderly people presented with significantly slower velocity, shorter step length, and relative shortening of the swing phase in relation to the stance phase. Thaler-Kall et al. [10] analysed temporal and spatial parameters of gait in 890 older persons aged 65–90 years. It was stride length which turned out to be the best predictor of falls, distinguishing between the subjects with and without a history of falling most accurately of all the 23 analysed parameters. Moreover, the results of many previous studies point to gait velocity as a useful component of complex geriatric evaluation, marker of mobility limitations [11], and predictor of falls [12]. According to Woo et al. [13], walking speed of people older than 70 years tends to decrease with age, by 0.1–0.7% annually. This decline is postulated to be primarily linked to a shortening of step length [14, 15].

Comprehensive gait analysis with the state-of-the-art systems available in biomechanical laboratories is costly and time-consuming [16]. Therefore, simple and easy to apply functional tests and scales, such as the Timed Up and Go (TUG) test, Tinetti Balance Test, Berg Balance Scale, and Functional Reach Test (FRT), are commonly used in physiotherapy practices, hospitals, and nursing homes to assess patient mobility and to identify subjects at increased risk of falls [17].

According to Mathias et al. [18], the TUG is the shortest and simplest clinical balance test. Yelnik and Bonan [19] emphasized a principal advantage of the test, namely the fact that in contrast to commonly used subjective rating scales, its results are expressed in seconds. Previous studies showed that the TUG accurately predicted the risk of fall in the elderly [20], and its results correlated strongly with Parkinson's disease of moderate-to-severe stage [21].

The FRT was developed to evaluate the maximum limits of stability in stance [22]. The maximal distance one can reach forward during the test is considered an accurate predictor for fall risk [23]. However, an experiment performed by Jonsson et al. [24] demonstrated that the FRT was a weak measure of stability limits in healthy elderly people. Probably, the trunk and shoulder movement during reaching forward has a greater

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influence on the outcome of the test than the centre of pressure (COP) displacement [24].

The maximum voluntary lean (MVE) test is another instrument used increasingly to assess the risk of fall [25]. During the test, the COP displacement with a maximum voluntary lean forward is determined with the help of a posturographic platform.

The aim of the study was to verify if various objective temporal and spatial parameters of gait determined with the GAITRite system correlated with the results of simple functional tests, TUG and FRT. Specifically, the authors wanted to find out which of the objective temporal and spatial parameters of gait indicated with the complex GAITRite system most accurately reflected the results of the two functional tests.

Material and methods

Participants

The study included 60 healthy, functionally independent and physically active persons (44 women and 16 men) with mean age of 70.4 ± 5.1 years. All the subjects participated in the Third Age University program at the Medical University of Berlin, and were systematically involved in physical activity within the framework of supervised programs. Only the volunteers who provided their written informed consent to participate in the project were enrolled in the study. The protocol of the study was approved by the Ethics Committee at the Medical University of Berlin, Campus Mitte Berlin (decision No. EA1/089/14).

Procedures

The proper study was preceded by the determination of basic somatic characteristics (body height and body weight) that were used to calculate the body mass index (BMI). Then, the study participants were subjected to 2 functional tests commonly performed in the elderly.

Timed Up and Go test procedure

The subjects were asked to stand up from a chair (seat height, 45 cm), walk for 3 m, return and sit down again. The time required to complete the task was recorded. The purpose of the test was to evaluate the subjects' balance during sitting and standing up, their stability during walking, and the ability to change the direction of walking without any compensation strategy. Physically independent individuals with normal balancing skills can complete this task in 10 seconds or less [26].

Functional Reach Test procedure

The subjects were asked to stand next to a wall, with the right arm being closer to the wall, at 90° of shoulder flexion, and both the fingers and thumbs flexed. The starting position of the right upper limb was marked on the ruler. Then, the participants were instructed to reach forward as far as possible without taking a step. The difference between the start and end position of the right upper limb was measured [22].

Gait analysis

The temporal and spatial gait parameters were determined with the GAITRite instrumented walkway system (CIR Systems, Inc., Havertown, PA, USA). The GAITRite consists of a pressure-sensitive mat (61 × 366 cm) with the active area forming a grid of 48 × 288 sensors placed on 1.27 cm centres. The sampling frequency was 60 Hz. The GAITRite was connected to a personal computer via a serial interface cable, and the data were processed with the GAITRite software, version 3.8g.

During data collection, the subjects were instructed to stand up from a chair placed 3.5 m from the border of the GAITRite mat and to assume the starting position. Starting before the GAITRite mat and continuing past its border, the subjects could accelerate and obtain a steady self-selected walking speed (SSWS) before they reached the instrumented portion of the GAITRite mat. Moreover, they were instructed to continue walking for another 3.5 m past the border of the GAITRite to minimize the possibility of deceleration before stepping off the instrumented portion of the mat. Prior to the proper measurement, the participants were allowed to practice up to 3 times if needed. During each SSWS trial, the subjects were instructed to walk over the mat at their 'normal' speed. Then they rested for 3 minutes in a seated position, while their data were processed to minimize the potential effect of fatigue on the result. After completing the 3 SSWS trials, the subjects were allowed to rest for 5 minutes before the fast walking speed (FWS) trials began. The protocol of the FWS trials was the same as for the SSWS trials, but the participants were instructed to walk as fast as they felt comfortable going. The subjects wore a gait belt during each walking trial and were guarded by an assistant walking beside the electronic walkway. For reliability purposes, all walking data were collected by the same researcher.

The following temporal and spatial parameters, described in detail in the GAITRite manual [27], were analysed: step length (cm), stride length (cm), velocity (cm/s), cadence (steps/min), swing time (s), stance time (s), single support time (s), double support time (s), swing (% of cycle), stance (% of cycle), single support time (% of cycle) and double support time (% of cycle).

Statistical analyses

The statistical analyses were conducted with the Statistica 12.0 software (StatSoft Inc., Tulsa, OK, USA). The statistical significance of all the tests was set at the value of $p \leq 0.05$. The normal distribution of the study variables was verified with the Shapiro-Wilk test. The power of relationships between the TUG/FRT results and the gait parameters determined with the GAITRite system was determined on the basis of Pearson's linear correlation coefficients (*r*) (for normally distributed variables) and Spearman's rank correlation coefficients (*R*) (for variables with non-normal distributions). Multiple stepwise regression analysis with forward selection was used to create the models explaining the variance in the functional tests results. Prior to the analysis, the data were tested for their consistency with the multiple regression assumptions.

Results

The basic somatic characteristics of the study subjects and the results of the functional tests are presented in Table 1.

The correlations between the TUG results and the gait parameters determined with the GAITRite system are presented in Table 2. The result of the test showed strong inverse correlations with the step length and stride length at both SSWS ($r = -0.70$ and $r = -0.71$, respectively) and FWS ($r = -0.61$ for both). Moreover, the test results correlated inversely with velocity ($r = -0.69$ and $r = -0.38$ for SSWS and FWS, respectively) and single support time ($r = -0.27$ and $r = -0.26$ for SSWS and FWS, respectively). They showed positive correlations with the stance time at SSWS ($r = 0.37$) and double support time at both SSWS ($r = 0.11$) and FWS ($r = 0.27$).

The step length, stride length, and velocity were the only gait parameters that correlated significantly with the FRT results (Table 3). The correlation coefficients at SSWS and FWS equalled $r = 0.61$ and $r = 0.54$ for step length, $r = 0.60$ and $r = 0.56$ for stride length, and $r = 0.37$ and $r = 0.38$ for velocity, respectively.

As the next stage, multiple stepwise regression analysis with forward selection was conducted with the TUG test result during walking at SSWS as a dependent variable and the gait parameters determined with the GAITRite system as explanatory variables (Table 4). The model was fitted well with the data, as shown by $F_{(4,55)} = 12.2$ ($p \leq 0.0001$) and adjusted $R^2 = 0.43$. Velocity ($p \leq 0.0001$) turned out to be the only significant predictor of the TUG results from among the 4 parameters included in the model (velocity, single support time, swing time, and double support time). The following regression equation to predict the value of the dependent variable was derived from the model:

TUG = 19.58 – 0.05 velocity – 2.19 single support time – 8.49 swing time + 5.98 double support time

Table 1. Descriptive statistics for somatic characteristics of the study subjects and the results of the TUG and FRT tests

Parameter	*Mean* ± *SD*	Min.–Max.
BMI (kg/m²)	27.1 ± 4.9	18.9–45.3
Age (years)	70.4 ± 5.1	60.0–84.0
TUG test (s)	9.7 ± 1.6	6.8–13.7
FRT test (cm)	30.4 ± 6.5	11.4–42.3

SD – standard deviation, BMI – body mass index, TUG – Timed Up and Go, FRT – Functional Reach Test

Table 2. Coefficients of correlation between the gait parameters determined with the GAITRite system and the TUG test results

Gait parameters	SSWS *r*/*R*	FWS *r*/*R*
Step length (cm)	–0.70***	–0.61***
Stride length (cm)	–0.71***	–0.61***
Velocity (m/s)	–0.69***	–0.38**
Cadence (steps/min)	–0.26	0.08
Swing time (s)	–0.02	–0.22
Stance time (s)	0.37*	0.00
Single support time (s)	–0.27*	–0.26*
Double support time (s)	0.11*	0.27*
Swing (% of cycle)	–0.45**	–0.35*
Stance (% of cycle)	0.44**	0.33*
Single support time (% of cycle)	–0.41**	–0.35*
Double support time (% of cycle)	0.41**	0.31*

Statistical significance: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

TUG – Timed Up and Go, SSWS – self-selected walking speed, FWS – fast walking speed, *r* – Pearson correlation coefficient, *R* – Spearman correlation coefficient

Table 3. Coefficients of correlation between the gait parameters determined with the GAITRite system and the FRT results

Gait parameters	SSWS *r*/*R*	FWS *r*/*R*
Step length (cm)	0.61***	0.54**
Stride length (cm)	0.60***	0.56**
Velocity (m/s)	0.37*	0.38*
Cadence (steps/min)	–0.12	–0.14
Swing time (s)	0.11	0.16
Stance time (s)	0.08	0.12
Single support time (s)	0.20	0.20
Double support time (s)	0.08	–0.13
Swing (% of cycle)	–0.01	0.02
Stance (% of cycle)	0.01	–0.01
Single support time (% of cycle)	0.10	0.12
Double support time (% of cycle)	–0.05	–0.14

Statistical significance: * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

FRT – Functional Reach Test, SSWS – self-selected walking speed, FWS – fast walking speed, *r* – Pearson correlation coefficient, *R* – Spearman correlation coefficient

The results of multiple stepwise regression analysis with forward selection for the FRT result as a dependent variable are presented in Table 5. The regression model was statistically significant ($F_{(4,55)} = 6.06$, $p \leq 0.001$), with the adjusted R^2 equal 0.26. Stance time ($p \leq 0.05$) turned out to be the only significant predictor of the the FRT result from among the 4 explanatory variables included in the model (step length, stance time, velocity, and single support time). The following regression equation to predict the value of the dependent variable was derived from the model:

FRT = –47.79 – 0.23 step length + 70.78 stance time + 0.33 velocity + 14.80 single support time

Discussion

The aim of the study was to analyse the relationships between the results of commonly used functional tests for gait performance, balance, and risk of falls in elderly people – the TUG and FRT – and the gait parameters determined with the complex laboratory system, GAITRite. The results of the TUG test turned out to correlate significantly with the majority of temporal and spatial parameters used for biomechanical analysis of gait. The strongest correlations ($r = -0.70$) were observed for 2 basic and most often analysed parameters: stride length and step length. The values of the correlation coefficients were similar, irrespective of the walking speed (SSWS or FWS). Similar relationships between the step length, stride length, and the TUG results were previously reported by Thomas et al. [28]. Although the correlations reported by these authors were somehow weaker than those presented in this paper ($r = -0.47$ for step length and $r = -0.51$ for stride length), it should be remembered that their study included a group of relatively young and physically fit persons.

The coefficient of correlation between velocity and the TUG result was $r = -0.69$ for SSWS and $r = -0.38$ for FWS. A slightly stronger correlation ($r = -0.61$) between the TUG test outcome and the gait velocity determined with the GAITRite system was previously reported by Muratori [29] in patients with Huntington's disease. According to this author, this implies that the standardized TUG test can be used for clinical decision making in Huntington's disease.

In the hereby tested regression model, gait velocity turned out to be the only statistically significant predictor of the TUG test result. The values of standardized regression coefficients (β) for explanatory variables included in the model imply that velocity contributed most to variance in the TUG outcome. This suggests that the individuals whose SSWS was faster achieved better results during the TUG test (i.e. completed the task in a shorter time). Importantly, the model did not include the 2 variables that correlated strongly with the TUG result, namely step length and stride length. These 2 variables turned out to be collinear, which means that their values were explained by the remaining variables (in particular, by velocity). The regression model constructed in this way explained 43% of variance in the TUG test results. Taking into account that the TUG test outcome reflects muscle strength, balance, and mobility [30], the adjusted R^2 coefficient for the model seems to be satisfactory.

Table 4. The results of multiple stepwise regression analysis for the TUG test outcome as a dependent variable

	β	Standard error (for β)	*B*	Standard error (for *B*)	*t*(55)	*p*	Semipartial correlation	Tolerance
Intercept			19.58	2.85	6.87	0.0000		
Velocity (m/s)	–0.56	0.13	–0.05	0.01	–4.25	0.0001	–0.42	0.55
Single support time (s)	–0.15	0.11	–2.19	1.52	–1.44	0.1556	–0.14	0.83
Swing time (s)	–0.17	0.11	–8.49	5.61	–1.51	0.1357	–0.15	0.73
Double support time (s)	0.17	0.14	5.98	5.11	1.17	0.2473	0.11	0.48

TUG – Timed Up and Go, β – standardized regression coefficients, *B* – non-standardized coefficients

Table 5. Results of multiple stepwise regression analysis for the FRT outcome as a dependent variable

	β	Standard error (for β)	*B*	Standard error (for *B*)	*t*(55)	*p*	Semipartial correlation	Tolerance
Intercept			–47.79	24.68	–1.94	0.0579		
Step length (cm)	–0.30	0.43	–0.23	0.32	–0.72	0.4772	–0.08	0.07
Stance time (s)	0.66	0.29	70.78	30.91	2.29	0.0259	0.26	0.15
Velocity (m/s)	0.92	0.48	0.33	0.17	1.93	0.0590	0.22	0.06
Single support time (s)	0.26	0.18	14.80	10.62	1.39	0.1691	0.16	0.37

FRT – Functional Reach Test, β – standardized regression coefficients, *B* – non-standardized coefficients

However, when searching the available literature, the authors found some contradictory data on the TUG test usefulness and reliability. A systematic review and meta-analysis conducted by Barry et al. [30] imply that the predictive value of this test is relatively limited. According to these authors, balance, leg muscle strength, and mobility, i.e. the principal determinants of the TUG test outcome, provide too little information and are inadequate to assess such a complex phenomenon as the risk of fall. Recently, modified TUG tests with secondary motor or cognitive tasks have been proposed [31]. In the cognitive TUG, the subjects are asked to count backward, starting with 80 or 100, while completing the test task, whereas in the manual TUG test, they need to fulfil the task carrying a cup of water [32].

Unlike for the TUG test, fewer less significant associations were found between the FRT results and the gait parameters determined with the GAITRite system. Although the FRT outcome showed significant and relatively strong correlations with step length and stride length, these relationships, in the authors' opinion, should be interpreted carefully. Supposedly, both these variables (functional reach distance and step length) are bound with the body type of a given person. This may explain why longer reach distances (determined by the length of upper and lower extremities) coexisted with higher values of step length and stride length (i.e. derivatives of lower limb length). Moreover, a positive, statistically significant correlation was observed between the FRT result and velocity. A similar relationship ($r = 0.68$) was also reported by Muratori [29] in a study of Huntington's disease patients. According to this author, patients who walked faster presented also with higher values of functional reach. The hereby presented findings are also consistent with the results of a study of community-dwelling elderly people conducted by Weiner et al. [23]. However, Thapa et al. [33] observed markedly weaker relationships between the functional reach and gait parameters of nursing home residents.

Other parameters determined with the GAITRite system did not correlate significantly with the FRT test results. Perhaps, the lower number of statistically significant correlations reflected the specific character of the test, which, in contrast to the TUG, does not require moving from one place to another (walking), but consists in reaching forward without taking a step. This hypothesis seems to be supported by the regression analysis results. The temporal and spatial parameters of gait determined with the GAITRite system during walking with SSWS explained only 26% of variance in the FRT outcome. Also, the values of semipartial correlations, reflecting the proportion of variance explained by a specific independent variable within the whole variance of the dependent variable, turned out to be low. This confirms that the analysed temporal and spatial parameters of gait explained only a very small proportion of variance in the FRT results.

Some previous studies analysed the consistency of the results obtained with various functional tests and scales assessing balance and the risk of fall. In an elderly people study conducted by Karuka et al. [34], no strong correlations (*r* values between 0.2 and 0.6) were found between the outcomes of the Performance-Oriented Mobility Assessment, TUG, FRT and Berg Balance Scale. This implies that these instruments are complementary to each other, and therefore a few various tests should be used during a complex assessment of functional fitness.

Conclusions

The results of simple functional tests, TUG and FRT, show significant albeit moderately strong correlations with basic gait parameters (step length, stride length, velocity), being established predictors of functional fitness, balance, and falls [10–12]. The lower number of statistically significant correlations between the FRT results and the parameters determined with the GAITRite system probably reflects a specific character of the former test, which does not require moving from one place to another. The multiple regression analysis outcomes suggest that the temporal and spatial parameters of walking at SSWS, i.e. velocity, step length, stance time, single support time, swing time, and double support time, may explain up to 43% of variance in the TUG test results and up to 26% of variance in the FRT results. This implies that both the TUG and FRT have limited application in the assessment of locomotor movements in the elderly. To improve the prognostic value of the TUG test and FRT as predictors of functional fitness and falls in the elderly, the results of these tests should be adjusted for lower limb and trunk strength, somatic parameters, and the fear of falling.

References

1. Fish D.J., Nielsen J.-P., Clinical assessment of human gait. *J Prosthet Orthot*, 1993, 5 (2), 39–48.
2. Maki B.E., Gait changes in older adults: predictors of falls or indicators of fear? *J Am Geriatr Soc*, 1997, 45 (3), 313–320.
3. Best J.R., Davis J.C., Liu-Ambrose T., Longitudinal analysis of physical performance, functional status, physical activity, and mood in relation to executive function in older adults who fall. *J Am Geriatr Soc*, 2015, 63 (6), 1112–1120, doi: 10.1111/jgs.13444.
4. Garcia-Pinillos F., Cozar-Barba M., Munoz-Jimenez M., Soto-Hermoso V., Latorre-Roman P., Gait speed in older people: an easy test for detecting cognitive impairment, functional independence, and health state. *Psychogeriatrics*, 2016, 16 (3), 165–171, doi: 10.1111/psyg.12133.
5. Nagamatsu L.S., Chan A., Davis J.C., Beattie L., Graf P., Voss M.V., et al., Physical activity improves verbal and spatial memory in older adults with probable mild cognitive impairment: a 6-month randomized controlled trial. *J Aging Res*, 2013, 861–893, doi: 10.1155/2013/861893.

6. Keller K., Engelhardt M., Strength and muscle mass loss with aging process. Age and strength loss. *Muscles Ligaments Tendons J*, 2014, 3 (4), 346–350, doi: 10.11138/mltj/2013.3.4.346.
7. Harwood R.H., Visual problems and falls. *Age Ageing*, 2001, 30 (Suppl. 4), 13–18.
8. Goutier K.M., Jansen S.L., Horlings C.G., Küng U.M., Allum J.H., The influence of walking speed and gender on trunk sway for the healthy young and older adults. *Age Ageing*, 2010, 39 (5), 647–650, doi: 10.1093/ageing/afq066.
9. Fan Y., Li Z., Han S., Lv C., Zhang B., The influence of gait speed on the stability of walking among the elderly. *Gait Posture*, 2016, 47, 31–36, doi: 10.1016/j.gaitpost.2016.02.018.
10. Thaler-Kall K., Peters A., Thorand B., Grill E., Autenrieth C.S., Horsch A., et al., Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study. *BMC Geriatr*, 2015, 15, 32, doi: 10.1186/s12877-015-0032-1.
11. Peel N.M., Kuys S.S., Klein K., Gait Speed as a measure in geriatric assessment in clinical settings: a systematic review. *J Gerontol A Biol Sci Med Sci*, 2013, 68 (1), 39–46, doi: 10.1093/gerona/gls174.
12. Sterke C.S., van Beeck E.F., Looman C.W., Kressing R.W., van der Cammen T.J., An electronic walkway can predict short-term fall risk in nursing home residents with dementia. *Gait Posture*, 2012, 36 (1), 95–101, doi: 10.1016/j.gaitpost.2012.01.012.
13. Woo J., Ho S.C., Lau J., Chan S.G., Yuen Y.K., Age-associated gait changes in the elderly: pathological or physiological? *Neuroepidemiology*, 1995, 14 (2), 65–71, doi: 10.1159/000109780.
14. Finley F.R., Cody K.A., Finizie R.V., Locomotion patterns in elderly women. *Arch Phys Med Rehabil*, 1969, 50 (3), 140–146.
15. Watelain E., Barbier F., Allard P., Thevenon A., Angué J.C., Gait pattern classification of healthy elderly men based on biomechanical data. *Arch Phys Med Rehabil*, 2000, 81 (5), 579–586, doi: 10.1053/mr.2000.4415.
16. Frenken T., Lohmann O., Frenken M., Steen E.E., Hein A., Performing gait analysis within the timed up & go assessment test: comparison of a TUG to a marker-based tracking system. *Inform Health Soc Care*, 2014, 39 (3–4), 232–248, doi: 10.3109/17538157.2014.931850.
17. Mancini M., Horak F.B., The relevance of clinical balance assessment tools to differentiate balance deficits. *Eur J Phys Rehabil Med*, 2010, 46 (2), 239–248.
18. Mathias S., Nayak U.S., Isaacs B., Balance in elderly patients: the "get-up and go" test. *Arch Phys Med Rehabil*, 1986, 67 (6), 387–389.
19. Yelnik A., Bonan I., Clinical tools for assessing balance disorders. *Neurophysiol Clin*, 2008, 38 (6), 439–445, doi: 10.1016/j.neucli.2008.09.008.
20. Whitney J.C., Lord S.R., Close J.C., Streamlining assessment and intervention in a falls clinic using the Timed Up and Go Test and Physiological Profile Assessments. *Age Ageing*, 2005, 34 (6), 567–571, doi: 10.1093/ageing/afi178.
21. Brusse K.J., Zimdars S., Zalewski K.R., Steffen T.M., Testing functional performance in people with Parkinson disease. *Phys Ther*, 2005, 85 (2), 134–141.
22. Duncan P.W., Weiner D.K., Chandler J., Studenski S., Functional reach: a new clinical measure of balance. *J Gerontol*, 1990, 45 (6), M192–M197.
23. Weiner D.K., Duncan P.W., Chandler J., Studenski S.A., Functional reach: a marker of physical frailty. *J Am Geriatr Soc*, 1992, 40 (3), 203–207.
24. Jonsson E., Henriksson M., Hirschfeld H., Does the functional reach test reflect stability limits in elderly people? *J Rehabil Med*, 2003, 35 (1), 26–30, doi: 10.1080/16501970306099.
25. Błaszczyk J.W., Lowe D.L., Hansen P.D., Ranges of postural stability and their changes in the elderly. *Gait Posture*, 1994, 2 (1), 11–17, doi: 10.1016/0966-6362(94)90012-4.
26. Podsiadlo D., Richardson S., The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*, 1991, 39 (2), 142–148.
27. GAITRite Electronic Walkway Technical Reference. 2016, Available from: http://www.gaitrite.com/WI-02-15_Technical_Reference_T.pdf.
28. Thomas M., Jankovic J., Suteerawattananon M., Wankadia S., Caroline K.S., Vuong K.D., et al., Clinical gait and balance scale (GABS): validation and utilization. *J Neurol Sci*, 2004, 217 (1), 89–99.
29. Muratori L.M., Clinical measures for therapeutic intervention in Huntington's disease. Huntington's Study Group Annual Meeting, St. Pete Beach, FL, USA, November 2007.
30. Barry E., Galvin R., Keogh C., Horgan F., Fahey T., Is the Timed Up and Go test a useful predictor of risk of falls in community dwelling older adults: a systematic review and meta- analysis. *BMC Geriatr*, 2014, 14, 14, doi: 10.1186/1471-2318-14-14.
31. Yamada M., Aoyama T., Nakamura M., Tanaka B., Nagai K., Tatematsu N., et al., The reliability and preliminary validity of game-based fall risk assessment in community-dwelling older adults. *Geriatr Nurs*, 2011, 32 (3), 188–194, doi: 10.1016/j.gerinurse.2011.02.002.
32. Clark S., Iltis P.W., Anthony C.J., Toews A., Comparison of older adult performance during the functional-reach and limits-of-stability tests. *J Aging Phys Act*, 2005, 13 (3), 266–275, doi: 10.1123/japa.13.3.266.
33. Thapa P.B., Gideon P., Fought R.L., Kormicki M., Ray W.A., Comparison of clinical and biomechanical measures of balance and mobility in elderly nursing home residents. *J Am Geriatr Soc*, 1994, 42 (5), 493–500.
34. Karuka A.H., Silva J.A., Navega M.T., Analysis of agreement of assessment tools of body balance in the elderly. *Rev Bras Fisioter*, 2011, 15 (6), 460–466, doi: 10.1590/S1413-35552011000600006.

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