


Standard Error of the Mean and Minimal Detectable Change of Gait Speed in Older Adults Using Japanese Long-Term Care Insurance System

Gerontology & Geriatric Medicine
Volume 7: 1–7
© The Author(s) 2021
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/23337214211048955
journals.sagepub.com/home/ggm


Yui Takada, RPT¹  and Shigeharu Tanaka, PhD²

Abstract

Evaluation of motor function, such as gait ability, can accurately predict the subsequent occurrence of disability in older adults. There are no reports of standard error of the mean (SEM) or minimal detectable change (MDC) with respect to gait in Japanese long-term care insurance-certified individuals. The purpose of this study was to investigate the values of preferred gait, fast gait, and the timed up and go (TUG) test. This study included 46 participants using the Japanese long-term care insurance system. (age 86.5 ± 6.6 years, 12 men, 34 women). The duration of three gait were measured twice using a stopwatch. The SEM was 0.07 for preferred gait, 0.09 for fast gait and 2.59 for TUG. The MDC was 0.19 for preferred gait, 0.26 for fast gait, and 7.17 for TUG. The SEM and MDC values of preferred gait, fast gait, and TUG in this study corroborated with those of previous studies, whereas others were different. Considering that gait speed differs with the country, it may be difficult to compare it among different population groups. We obtained the results of gait speed of Japanese long-term care insurance-certified individuals, which is a new finding

Keywords

gait speed, standard error of the mean, minimal detectable change, Japanese older adults

Manuscript received: June 4, 2021; final revision received: August 13, 2021; accepted: August 25, 2021.

Introduction

The aging rate in Japan (Cabinet Office Japan, 2020) is 28.1%, and the average life expectancy is steadily increasing, reaching 81.14 years for men and 87.45 years for women. Healthy life expectancy is a new health indicator proposed by the World Health Organization (WHO). This is the average period of time one is healthy without being impeded by illnesses/injuries in their daily life. In 2016, the difference between average life expectancy and healthy life expectancy (Cabinet Office Japan, 2020) was 8.84 years for men and 12.35 years for women and each municipality in Japan is working to close the gap. A comparison of healthy life expectancy between 2001 and 2016 (Cabinet Office Japan, 2020) shows a slight stretch of 0.17 years for males and 0.07 years for females.

Older adults have decreased motor function due to aging, and gait speed in their 70 s is 17–20% lower than that in their 20s (Elble et al., 1991). The evaluation of motor function, such as gait ability, can, reportedly, accurately predict the subsequent occurrence of disability in older adults (Guralnik et al., 1995, 2000). Previous studies have indicated that normal gait speed in older adults is related to disability,

¹Social Welfare Corporation Kowakai, Miyazaki, Japan

²Faculty of Health and Social Services, Kanagawa University of Human Services, Yokosuka, Japan

Corresponding Author:

Yui Takada, RPT, Social welfare corporation Kowakai, 3-9-10, Miyazaki-eki Higashi, Miyazaki 880-0879, Japan.
Email: yuitakada55@gmail.com



Creative Commons Non Commercial CC BY-NC: This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 License (<https://creativecommons.org/licenses/by-nc/4.0/>) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed as specified on the SAGE

and Open Access pages (<https://us.sagepub.com/en-us/nam/open-access-at-sage>).

cognitive impairment, institutionalization, falls, and death (Graham et al., 2008; van Kan et al., 2009). Gait speed is a screening tool that needs to be evaluated to provide insights into the functional capacity and safety of older adults and is treated as a “sixth vital sign” for daily life (Fritz & Lusardi, 2009). Furthermore, increased gait variability has been suggested to be associated with an increased risk of future falls and predicts clinical outcomes, such as fall incidence and admission to nursing homes (Hausdorff et al., 2001). Stephanie et al., (2003) clarified that walking speeds below 1.0 m/s increased the risk of death. From these studies, it is hypothesized that measurement of gait speed may identify the pre-stages of disability in older adults.

Quantitative measurement is objective and indispensable for the evaluation of gait ability. Gait analysis using various devices, such as a three-dimensional motion analysis device, an accelerometer, a floor reaction force meter, and a treadmill, has been put into practical use. However, these devices are costly, complex to operate, and take too long to analyze, restricting them to only laboratory use, and making them difficult to implement in routine clinical practice (Toro et al., 2003). Measuring gait ability using a stopwatch, however, is simple and inexpensive compared to using mechanical devices. Furthermore, because the results obtained are universal in terms of speed, it is easy for patients to understand them. Test methods for examining gait speed in older adults include not only mean and standard deviation but also mean standard error (SEM) and minimum detectable change (MDC) (Shimoi & Tani, 2010). Currently, there are few articles that have reported SEM and MDC of gait in older adults (Fiser et al., 2010; Goldberg & Schepens, 2011; Kwon et al., 2009). Furthermore, there are no reports on SEM or MDC of gait in Japanese older adults using a long-term care insurance system, and the understanding of the accurate gait ability in older adults is limited.

In Japan, there is a system called the long-term care insurance that mainly covers adults aged >65 years. The level of disability is divided into seven categories: those requiring support 1 and 2, and those requiring nursing care 1–5, with support 1 being the mildest. Those who require support 1 are able to perform basic daily life activities (eating, using the toilet, bathing, and cleaning) at home by themselves. However, this program is for people who need to be looked after or assisted in any one or some of the instrumental activities of daily living (shopping, money management, medication management, and telephone use). Those who need support 2 are those who in addition to needing support 1 and have unstable walking conditions due to lower limb muscle weakness. These people may need nursing care in their daily lives in the future. Nursing care 1 also applies to people who need help with some of the activities of daily living because they are unsteady walking or have reduced strength in their lower limbs. Nursing care 2 is for people who need daily assistance with some or all activities of daily living. People who are able to perform activities of daily living but show

symptoms of dementia and may have trouble in their daily lives are also eligible. Nursing care 3 is for people who have difficulty walking independently and use a cane, walker, or wheelchair. This category includes people who need help with all parts of their daily life, including manual handling. Nursing care 4 is for those who require a wheelchair for mobility and are unable to lead their daily lives without constant nursing care. This category is for people who need full nursing care, but are still able to talk. Nursing care 5 is for those who, mostly bedridden, have difficulty communicating, and are unable to eat on their own. Individuals can receive the services they need according to these conditions (The Longevity Science Foundation, 2018).

In the care environment, it is important to determine whether physical capabilities are improving or declining, as this is relevant for predicting future disability and health span. However, it is difficult to measure physical functions for the same using sophisticated equipment, such as treadmills; hence, it is more useful to measure easy-to-perform physical functions. At our facility, we measured the gait speed of those who were able to walk, including those who needed nursing care, once every 2–3 months. By using the measurement error shown in this study, it is possible to clearly determine the state of physical function, and thus determine whether the exercise currently being performed is sufficient.

The purpose of this study was to measure the speeds of preferred gait, fast gait, and timed up and go test (TUG) in Japanese older adults using the long-term care insurance system, and to clarify the SEM and MDC of gait speed.

Methods

Participants

This cross-sectional study included 46 participants using the Japanese long-term care insurance system (age 86.5 ± 6.6 years, 12 men, 34 women). The mean values and percentages for all variables are presented in Table 1. This study was conducted between January and February of 2020. The inclusion criteria were that the patient could walk 11 m or more without a cane or support and that they had the cognitive ability to understand the measurement. G-power 3.1.9.4 was used to calculate the sample size, with an effect size of 0.8, α of 0.05, β of 0.8, and the mean and standard deviation of preferred gait as inputs. The results showed that the sample size required was 21 participants. Similarly, the same sizes of fast gait and TUG were calculated, but the results remained the same. Because of the possibility of changes in physical condition, we included that is 46 participants as mentioned above.

Ethics

This study was approved by an appropriate review board (2019-1). The purpose and content of the study were fully

Table 1. Characteristics of the study population ($n = 46$).

Age (yrs)	86.5 ± 6.6
Sex, female	34 (73.9)
Body mass index (BMI) (kg/m^2)	23.4 ± 4.2
Cane support	13 (28.3)
Heart disease	7 (15.2)
Diabetes	5 (10.9)
Hypertension	15 (32.6)
History of cancer	2 (4.3)
History of cerebrovascular accident	6 (13.0)
History of fracture of lower limb	7 (15.2)

Values are mean ± standard deviation or n (%).
BMI, body mass index.

explained to the participants in writing, and informed consent was obtained.

Procedure

One physical therapist (PT) measured the times of (1) preferred gait, (2) fast gait, and (3) TUG using a stopwatch. Each measurement was performed twice, and the retest was performed 1–7 days after the first measurement. The measurements were taken in a quiet, straight, level hallway of the welfare facility. Care was taken to avoid distractions, by evaluating one person at a time.

Preferred Gait. The participants walked a total of 11 m on pedestrian paths with 3 m of reserve roads in front and behind. Markers were placed at the start and end positions of the 5 m walkway. The gait speed at which the foot passed the marker at the start position and the speed at which both feet passed the end position was measured over an auxiliary path of 3 m. Before the participants started walking, one PT instructed them to walk at their usual pace. The time required for a 5 m walk was measured once.

Fast Gait. As with preferred gait, the participants walked a total of 11 m on the promenade, and the gait speed was measured. Before the participants started walking, one PT instructed them to walk as fast as possible. The time required for a 5 m gait was measured once.

Timed Up and Go Test. A marker cone was placed 3 m from a chair. The participants got up from the chair, walked 3 m at a preferred and safe pace, walked back to the chair, and sat down. The time taken for the gait was measured once.

Statistical Analyses

The standard deviation (SD) was calculated using two measured values obtained from the measurements. The intraclass correlation coefficient (ICC) was calculated to

examine the reliability of all participants at each speed. SEM and MDC were calculated using the following formulas: $SEM = SD\sqrt{(1-ICC)}$, $MDC = SEM \times \sqrt{2} \times 1.96$. The classification of Landis and Koch (1977) was used to evaluate the ICC result. The R commander version R-2.8.1 was used for the statistical analyses in this study. Statistical significance was set at $p < .05$.

Results

The Japanese long-term care insurance system is classified into seven categories based on the need for support and the level of care: support 1 and 2 and Nursing care 1–5. Eight participants required support 1, 6 required support 2, 29 required care 1, 2 required care 2, and 1 required care 3. Thirteen participants needed a cane and 33 participants did not. No physical changes were observed between the first and second measurements. Table 2 shows the measurement results for all participants. The average preferred gait speed for 5 m was 0.78 ± 0.26 m/s. The ICC was 0.93, which was considered excellent. The SEM was 0.07, and the MDC was 0.19. The average fast gait speed for 5 m was 0.98 ± 0.37 m/s. The ICC was excellent (0.94). The SEM was 0.09, and the MDC was 0.26. The mean TUG score was 16.97 ± 6.95 s, ICC was 0.86, SEM was 2.59, and MDC was 7.17. (Table 3)

Discussion

In Japan, the difference between average life expectancy and healthy life expectancy is 8.84 years for men and 12.35 years for women (Cabinet Office Japan, 2020). The classification of the long-term care insurance is divided around motor function (The Longevity Science Foundation, 2018), and it is necessary to maintain proper motor function in order to lead a healthy life. In addition, since there are several reports that gait speed predicts falls, longevity, and living range, it is important to evaluate gait speed (Fritz & Lusardi, 2009; Graham et al., 2008; Guralnik et al., 1995, 2000; Hausdorff et al., 2001; Studenski et al., 2011; van Kan et al., 2009). However, although there are some previous studies on the gait ability of older adults in Japan (Fiser et al., 2010; Goldberg & Schepens, 2011; Kristensen et al., 2019; Kwon et al., 2009), there are no studies showing the SEM or MDC of gait speed in older adults using the long-term care insurance system. By clarifying these issues, changes in gait speed can be easily understood and may enable the assessment of motor content and predict the progression in the degree of disability. It may also help healthcare professionals understand the functioning of older adults and build better intervention methods. The results of this study were 0.07 m/s for SEM of preferred gait, 0.19 for MDC , 0.09 for SEM of fast gait, and 0.26 for MDC . The SEM of the TUG was 2.59 and the MDC was 7.17. We believe that this quantification of SEM and MDC will enable appropriate evaluation of treatment programs.

Table 2. Results of gait speed ($n = 46$).

	Preferred gait first	Preferred gait second	Fast gait first	Fast gait second	TUG first	TUG second
1	0.86	0.91	0.98	0.98	17.56	15.22
2	1.24	1.27	1.87	1.72	7.56	8.4
3	0.99	1.07	1.27	1.39	12.03	11.9
4	1.26	1.18	1.70	1.75	9.72	8.53
5	1.43	1.40	1.95	1.69	7.46	8.12
6	0.31	0.32	0.32	0.35	31.53	26.78
7	0.85	1.10	1.08	1.47	11.9	11.56
8	0.80	0.93	0.97	1.05	12.6	12.25
9	0.70	0.82	0.93	0.87	16.84	16.32
10	0.74	0.77	0.81	0.93	21.28	16.12
11	0.64	0.66	0.80	0.97	14.59	13.63
12	0.65	0.62	0.66	0.64	24	21.09
13	1.22	1.17	1.74	1.85	11.59	10.06
14	0.67	0.39	0.67	0.55	14.47	32.25
15	0.49	0.50	0.58	0.50	25.41	26.13
16	0.79	0.79	1.01	1.01	12.5	13.94
17	1.16	1.00	1.21	1.23	13.5	13.44
18	0.75	0.71	0.99	0.77	12.55	15.5
19	0.94	1.05	0.96	1.29	9.35	10.56
20	0.67	0.70	0.93	0.87	11.4	12.75
21	0.93	0.93	1.11	1.11	13.07	14.94
22	0.53	0.43	0.60	0.53	21.41	24.59
23	0.62	0.64	0.81	0.73	16.43	19.69
24	0.71	0.83	1.11	0.92	14.09	13.81
25	0.50	0.73	0.95	1.10	24.75	18.19
26	0.59	0.59	0.67	0.70	23.16	20.22
27	0.35	0.36	0.45	0.45	24.47	25.59
28	0.56	0.54	0.64	0.61	19.34	20.54
29	1.07	0.84	1.36	1.18	11.97	10.31
30	0.91	0.87	1.03	1.17	11.32	12.71
31	0.44	0.63	0.77	0.90	25.72	23.07
32	0.83	1.01	1.22	1.49	12.22	13.37
33	0.60	0.62	0.95	0.68	18.12	18.59
34	0.98	1.07	1.07	1.18	12.72	11.81
35	0.64	0.67	0.79	0.80	16.79	17.47
36	1.10	1.06	1.47	1.27	10.25	12.19
37	0.73	0.86	0.91	0.89	15.88	12.9
38	0.98	0.94	0.99	1.02	14.69	15.75
39	0.63	0.70	0.86	0.87	21.5	23.13
40	0.99	1.10	1.29	1.23	8.97	10
41	0.96	0.91	1.05	1.05	13.72	13.4
42	0.21	0.19	0.22	0.23	43.19	39.63
43	0.81	0.71	1.38	1.27	18.53	16.69
44	0.80	0.84	0.97	1.01	15.91	12.88
45	0.46	0.42	0.56	0.56	26.18	35.32
46	0.56	0.55	0.65	0.67	25.47	22.56

Preferred gait, Fast gait (m/s), TUG (s).

Goldberg and Schepens (2011) evaluated the 4 m gait speed of 30 community-dwelling older adults aged 60 years and older. According to their study, the average gait speed was 1.077 m/s, the SEM was 0.049, and the MDC was 0.136.

Fiser et al. (2010) reported a 10 min treadmill habitual gait speed SEM of 0.04. In addition, Kwon et al. (2009) compared the 4 m gait speed of 424 people aged 70–89 years, and reported that the SEM was 0.03–0.05, and the MDC was 0.08.

Table 3. Inspection value.

	Average	ICC	SEM	MDC
Preferred gait	0.78 ± 0.26 m/s	0.93	0.07	0.19
Fast gait	0.98 ± 0.37 m/s	0.94	0.09	0.26
TUG	16.97 ± 6.97 s	0.86	2.59	7.17

Note. TUG = timed up and go test; ICC = intraclass correlation coefficient; SEM = standard error of the mean; MDC = minimal detectable change.

On the other hand, the TUG results of this study averaged 16.97 ± 6.95 s. In a previous report by Kristensen et al. (2019), the SEM of the TUG was 1.7, and the MDC was 4.6. Some of these results are similar in SEM and MDC values to those in this study, whereas others are different. According to a meta-analysis by Bohannon and Williams Andrews (2011), gait speed using a stopwatch varies from country to country. For example, the average values measured in women aged 70–79 years are 1.21 m/s in the United States, 1.29 m/s in Germany, 1.12 m/s in Australia, 1.05 m/s in Japan, and 1.13 m/s in Sweden. Based on these facts, it may be difficult to compare the results among countries, even if the participants are of the same age. This study obtained the results of gait speed and TUG tests for Japanese older adults. This is a novel finding of this study, which can lead to a better understanding of older adults in Japan.

The participants of this study were older adults; therefore, it is necessary to avoid measurement bias due to fatigue. The three types of gait, such as preferred gait, fast gait, and TUG, were measured once, and the same measurement was repeated 1–7 days later. Almarwani et al. (2016) measured these parameters twice with an interval of 1 week, which is a method similar to that in the current study. Other methods have also been reported, and in a report that measured the gait speed of patients with hip fractures, a rest time was set when measuring the gait speed for 10 m, and it was performed twice a day (Hollman et al., 2008). In a previous study, measurements were performed six times in total. Measurements were taken twice a day at different intervals of time, within 1–4 days (Verghese & Xue, 2011). In another report (Lewek & Robert, 2019), measurements were recorded twice in 19 ± 13 days, and preferred gait and fast gait were measured thrice at a time. In yet another study (Steffen et al., 2002), measurement was performed twice in succession and the average value of the two measurements was used. The ICC in this study was 0.93 for preferred gait, 0.94 for fast gait, and 0.86 for TUG, which are considered to be perfect according to the classification by Landis and Koch (1977). The ICC for gait speed were 0.94–0.95 by Unver et al. (2017); 0.97 by Bohannon and Wang (2018) and Nair et al. (2012); 0.93 by Kristensen et al. (2019); 0.97 by Steffen et al. (2002); and 0.99 by Podsiadlo and Richardson. (1991) However, as per the report by Rockwood et al. (2000), ICC was 0.56, which was inferior to that of this study. From the above findings, it can be deduced that the method used in this study is useful for

evaluating gait speed in Japanese older adults using the long-term care insurance system, and it is a useful method for measuring motor function in clinical practice.

This study has some limitations. The only inclusion criterion was that the individual should have been certified by the long-term care insurance system, should be able to walk 11 m or more without a cane or support, and could cognitively understand the measurement. Under these conditions, all participants were grouped and evaluated using a stopwatch. However, it has been reported that older adults are less stable than young adults and have greater time fluctuations (Almarwani et al., 2016). In addition, gait speeds measured by using an accelerometer or a stopwatch are different (Maggio et al., 2016). A study with a high proportion of female participants also reported that gait speed slowed by 0.003 m/s for every 1% increase in female participants (Peel et al., 2013). Furthermore, it has been reported that inter-individual variation is likely to occur because of cognitive impairment (Dixon et al., 2007). Lewek and Robert (2019) reported the importance of grouping by baseline gait speed to accurately quantify MDC. Therefore, in the future, it will be necessary to increase the number of cases, clarify the background of cases, such as blood pressure and pulse, and quantify SEM and MDC grouped by sex, cognitive aspect, and gait speed.

Conclusion

The normative reference values in this study may be useful in interpreting measurements of gait speed in older adults using the Japanese long-term care insurance system. However, the reliability of gait speed measurements is limited, in turn their usefulness in making decisions about changes in treatment.

Acknowledgments

The authors would like to thank the institution's physical therapists and caregivers for their help in conducting this study. We would like to thank Editage (www.editage.com) for English language editing.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Yui Takada  <https://orcid.org/0000-0002-2550-143X>

References

- Almarwani, M., Perera, S., VanSwearingen, J. M., Sparto, P. J., & Brach, J. S. (2016). The test-retest reliability and minimal

- detectable change of spatial and temporal gait variability during usual over-ground walking for younger and older adults. *Gait & Posture*, 44, 94-99. <https://doi.org/10.1016/j.gaitpost.2019.09.015>.
- Bohannon, R. W., & Wang, Y. C. (2018). Four-meter gait speed: Normative values and reliability determined for adults participating in the NIH toolbox study. *Archives of Physical Medicine and Rehabilitation*, 100(3), 509-513. <https://doi.org/10.1016/j.apmr.2018.06.031>.
- Bohannon, R. W., & Williams Andrews, A. (2011). Normal walking speed: A descriptive meta-analysis. *Physiotherapy*, 97(3), 182-189. <https://doi.org/10.1016/j.physio.2010.12.004>.
- Cabinet Office Japan (2020). *Annual report on the aging society*. <https://www8.cao.go.jp/kourei/english/annualreport/index-wh.html>.
- Dixon, R. A., Garrett, D. D., Lentz, T. L., MacDonald, S. W. S., Strauss, E., & Hulstsch, D. F. (2007). Neurocognitive markers of cognitive impairment: Exploring the roles of speed and inconsistency. *Neuropsychology*, 21(3), 381-399. <https://doi.org/10.1037/0894-4105.21.3.381>.
- Elble, R. J., Thomas, S. S., Higgins, C., & Colliver, J. (1991). Stride-dependent changes in gait of older people. *Journal of Neurology*, 238(1), 1-5. <https://doi.org/10.1007/BF00319700>.
- Fiser, W. M., Hays, N. P., Rogers, S. C., Kajkenova, O., Williams, A. E., Evans, C. M., & Evans, W. J. (2010). Energetics of walking in elderly people: Factors related to gait speed. *The Journals of Gerontology Series A*, 65(12), 1332-1337. <https://doi.org/10.1093/gerona/gdq137>.
- Fritz, S., & Lusardi, M. (2009). White paper: "walking speed: the sixth vital sign". *Journal of geriatric physical therapy*, 32(2), 46-9. <https://doi.org/10.1519/00139143-200932020-00002>.
- Goldberg, A., & Schepens, S. (2011). Measurement error and minimum detectable change in 4-meter gait speed in older adults. *Aging Clinical and Experimental Research*, 23(5-6), 406-412. <https://doi.org/10.1007/BF03325236>.
- Graham, J. E., Ostir, G. V., Fisher, S. R., & Ottenbacher, K. J. (2008). Assessing walking speed in clinical research: A systematic review. *Journal of Evaluation in Clinical Practice*, 14(4), 552-562. <https://doi.org/10.1111/j.1365-2753.2007.00917.x>.
- Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., Studenski, S., Berkman, L. F., & Wallace, R. B. (2000). Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *The Journals of Gerontology Series A*, 55(4), M221-M231. [10.1093/gerona/55.4.m221](https://doi.org/10.1093/gerona/55.4.m221).
- Guralnik, J. M., Ferrucci, L., Simonsick, E. M., Salive, M. E., & Wallace, R. B. (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *New England Journal of Medicine*, 332(9), 556-562. <https://doi.org/10.1056/NEJM199503023320902>.
- Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: A 1-year prospective study. *Archives of Physical Medicine and Rehabilitation*, 82(8), 1050-1056. <https://doi.org/10.1053/apmr.2001.24893>.
- Hollman, J. H., Beckman, B. A., Brandt, R. A., Merriwether, E. N., Williams, R. T., & Nordrum, J. T. (2008). Minimum detectable change in gait velocity during acute rehabilitation following hip fracture. *Journal of Geriatric Physical Therapy*, 31(2), 53-56. [10.1519/00139143-200831020-00003](https://doi.org/10.1519/00139143-200831020-00003).
- Kristensen, M. T., Bloch, M. L., Jønsson, L. R., & Jakobsen, T. L. (2019). Interrater reliability of the standardized timed up and go test when used in hospitalized and community-dwelling older individuals. *Physiotherapy Research International*, 24(2), e1769. <https://doi.org/10.1002/pri.1769>.
- Kwon, S., Perera, S., Pahor, M., Katula, J. A., King, A. C., Groessl, E. J., & Studenski, S. A. (2009). What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P study). *The Journal of Nutrition, Health and Aging*, 13(6), 538-544. <https://doi.org/10.1007/s12603-009-0104-z>.
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159-174. <https://doi.org/10.2307/2529310>.
- Lewek, M. D., & Sykes, R. (2019). Minimal detectable change for gait speed depends on baseline speed in individuals with chronic stroke. *Journal of Neurologic Physical Therapy*, 43(2), 122-127. <https://doi.org/10.1097/NPT.0000000000000257>.
- Maggio, M., Ceda, G. P., Ticinesi, A., De Vita, F., Gelmini, G., Costantino, C., Meschi, T., Kressig, R. W., Cesari, M., Fabi, M., & Lauretani, F. (2016). Instrumental and non-instrumental evaluation of 4-meter walking speed in older individuals. *PLoS One*, 11(4), e0153583. <https://doi.org/10.1371/journal.pone.0153583>.
- Nair, P. M., Hornby, T. G., & Behrman, A. L. (2012). Minimal detectable change for spatial and temporal measurements of gait after incomplete spinal cord injury. *Topics in Spinal Cord Injury Rehabilitation*, 18(3), 273-281. <https://doi.org/10.1310/sci1803-273>.
- Peel, N. M., Kuys, S. S., & Klein, K. (2013). Gait speed as a measure in geriatric assessment in clinical settings: A systematic review. *The Journals of Gerontology: Series A*, 68(1), 39-46. <https://doi.org/10.1093/gerona/gls174>.
- Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*, 39(2), 142-148. <https://doi.org/10.1111/j.1532-5415.1991.tb01616.x>.
- Rockwood, K., Awalt, E., Carver, D., & MacKnight, C. (2000). Feasibility and measurement properties of the functional reach and the timed up and go tests in the Canadian study of health and aging. *The Journals of Gerontology Series A*, 55(2), M70-M73. <https://doi.org/10.1093/gerona/55.2.m70>.
- Shimoi, T., & Tani, H. (2010). The absolute reliability of two different tandem gait tests with minimal detectable change. *Rigakuryoho Kagaku*, 25(1), 49-53. <https://doi.org/10.1589/rika.25.49>.
- Steffen, T. M., Hacker, T. A., & Mollinger, L. (2002). Age- and gender-related test performance in community-dwelling elderly

- people: Six-minute walk test, berg balance scale, timed up & go test, and gait speeds. *Physical Therapy*, 82(2), 128-137. <https://doi.org/10.1093/ptj/82.2.128>.
- Stephanie, S., Subashan, P., Dennis, W., et al. (2003). Physical performance measures in clinical settings. *J Am Geriatr Soc*, 51, 314-322. <https://doi.org/10.1046/j.1532-5415.2003.51104.x>. 12588574.
- Studenski, S., Perera, S., & Patel, K. (2011). Gait speed and survival in older adults. *JAMA*, 305(1), 50-58. <https://doi.org/10.1001/jama.2010.1923>.
- The Longevity Science Foundation. (2018). <https://www.tyojyu.or.jp/net/kaigo-seido/kaigo-hoken/kaigodo.html>.
- Toro, B., Nester, C., & Farren, P. (2003). A review of observational gait assessment in clinical practice. *Physiotherapy Theory and Practice*, 19(3), 137-149. <https://doi.org/10.1080/09593980307964>.
- Unver, B., Baris, R. H., Yuksel, E., Cekmece, S., Kalkan, S., & Karatosun, V. (2017). Reliability of 4-meter and 10-meter walk tests after lower extremity surgery. *Disability and Rehabilitation*, 39(25), 2572-2576. <https://doi.org/10.1080/09638288.2016.1236153>.
- van Kan, G. A., Rolland, Y., Andrieu, S., Bauer, J., Beauchet, O., Bonnefoy, M., Cesari, M., Donini, L. M., Gillette-Guyonnet, S., Inzitari, M., Nourhashemi, F., Onder, G., Ritz, P., Salva, A., Visser, M., & Vellas, B. (2009). Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people: An international academy on nutrition and aging (IANA) task force. *The Journal of Nutrition, Health & Aging*, 13(10), 881-889. <https://doi.org/10.1007/s12603-009-0246-z>.
- Verghese, J., & Xue, X. (2011). Predisability and gait patterns in older adults. *Gait & Posture*, 33(1), 98-101. <https://doi.org/10.1016/j.gaitpost.2010.10.004>.