Manuscript Title

Relationship between walking speed, respiratory muscle strength, and dynamic balance in older people requiring long-term care or support

Takumi Jiroumaru[1], Yutaro Hyodo[2], Michio Wachi[1], Nobuko Shichiri[3], Junko Ochi[1], Takamitsu Fujikawa[1]

[1] Department of Physical Therapy, School of Health Sciences, Bukkyo University, Kyoto Nakagyo-ku, Kyoto, Japan

[2] Department of Rehabilitation, Kanazawa Orthopaedic and Sports Medicine Clinic, Ritto, Shiga, Japan

[3] Department of Occupational Therapy, School of Health Sciences, Bukkyo University, Kyoto Nakagyo-ku, Kyoto, Japan

Corresponding Author:

Takumi Jiroumaru[1]

7 Nishinokyohigashitoganocho, Kyoto Nakagyo-ku, Kyoto, 604-8418, Japan

Email address: t-jiromaru@bukkyo-u.ac.jp

Introduction

Japan is currently considered to have a hyper-aged society, and the number of older people who have disabilities, need assistance, or require long-term care has increased rapidly, with a corresponding increase in the economic burden[1,2]. Japan's long-term care insurance system, which began in 2000, is estimated to cost more than $100 billion, more than three times the cost of 20 years ago[1]. Thus, the increasing cost of Japan's long-term care insurance system is an essential issue in an aging society.

One way to ensure financial sustainability is to provide preventive services to maintain the physical function of older people and minimize the need for long-term care or support. However, in a study examining the efficacy of preventive services in Japan's long-term care insurance system, the group aged ≥ 85 years with a low level of disability showed significantly less deterioration in the level of long-term care or support. In contrast, the study reported no efficacy in the other groups[3]. These results indicate that preventive services provided by the Japanese long-term care insurance system may be effective only for some older people. Therefore, it is necessary to reexamine the physical function interventions that are effective for most older people.

Comentado [IG1]: This paragraph was too large, I suggest to divided as I did.

A decline in physical function is a common feature of older age and has significant consequences in terms of quality of life, falls, health care utilization, hospitalization, and mortality [4,5]. Previous studies have examined activities of daily living (ADL) limitations in the last months or years before death [6,7,8]. Landré et al. [9] found that older people with a faster gait, higher muscular grip strength, and greater ability to stand up from a chair and who maintain the motor skills to perform daily activities, such as bathing and dressing, may have a lower risk of death compared with older people with reduced motor function. The authors also found that the decline in motor functions begins 4–10 years before death, and that basic/instrumental ADL limitations appear later in life. Regarding gait speed, previous studies have reported a decrease in gait speed as early as 10 years before death [10]. Therefore, focusing on the relationship between frail older people and walking speed is essential to minimize the need for long-term care or support.

Recently, the importance of respiratory muscle strength regarding the physical function of older people has gained attention. Respiratory muscle strength in older people is associated with sarcopenia and frailty[11,12], and respiratory muscle strength in older people may be related to grip strength and walking speed, which are indicators of total body muscle mass [13,14]. Additionally, inspiratory muscle strength is a possible cause of limitations in ADL [15]. Furthermore, a decrease in walking speed in older people is associated with falls [16] and an increased risk of needing long-term care or support [17]. However, one study reported no correlation between walking speed and respiratory muscle strength in older people [18]. The participants in the study were healthy older people with high physical function.

In contrast, a previous study that reported a relationship between walking speed and respiratory muscle strength in older people [13] included participants with sarcopenia and healthy older people. Considering these studies, an association between walking speed and respiratory muscle strength in older people is likely in frail older people. However, studies examining the relationship between walking speed and respiratory muscle strength only in frail older people, such as those requiring long-term care or support, are lacking.

Comentado [IG2]: This paragraph was too large, I suggest to divided as I did.

Walking speed is associated with dynamic stability, and instability increases gradually at slower walking speeds in older people compared with younger people [19]. Additionally, a decrease in dynamic stability in older people may lead to falls [20,21]. In Japan, the maximal double-step length test (MDST) has been used as a dynamic balance index to evaluate locomotive syndrome [22] (a condition in which mobility in daily activities is impaired owing to reduced balance and mobility, muscle weakness, and pain caused by musculoskeletal disorders). However, no studies have examined the relationship between the MDST, respiratory muscle strength, and walking speed exclusively in older people requiring long-term care or support.

~~Therefore, ~~W~~w~~e hypothesized that walking speed, respiratory muscle strength, and dynamic balance are interrelated in older people who require long-term care or support. ~~It is essential to clarify the relationship between gait speed, respiratory muscle strength, and dynamic balance in health management and prevention for older people who need long-term care or support. ~~A better understanding of this relationship may improve the quality of care services in the long-term care insurance system and reduce the risk of the requirement for long-term care or support. Therefore, this study aimed to ~~provide new knowledge by ~~investigate~~ing~~ the relationship between walking speed, respiratory muscle strength, and dynamic balance among older people living in the community who required long-term care or support.

Comentado [IG3]: This is already justified before.

Materials and Methods

Study Design

This was a cross-sectional study performed at two daycare centers from April 2023 to June 2023. All participants were informed of the study details verbally and in writing, and their consent was obtained in writing. This study was performed in accordance with the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the Kanazawa Orthopedic Sports Medicine Clinic (kanazawa-OSMC-2023-003).

Study Participants

This study included 50 community-dwelling older people (21 men and 29 women) aged ≥ 65 years who used daycare services in Japan. Participants were certified as requiring long-term care or support under the Japanese system [23]. The daycare service for older people at the target facilities provided rehabilitation services, including exercise and transportation options. The participants in this study were those with no cognitive difficulties and whose walking function was unaided or who used walking aids for ADLs. Patients diagnosed with dementia or aphasia, those who had difficulty performing spirometry, and those who were receiving home oxygen therapy or had a respiratory disease with a forced expiratory volume in 1 second of < 70% were excluded in accordance with previous studies on the effects of airway obstruction on respiratory function [24]. Potential participants with prominent pain, contractures, or postural abnormalities that would interfere with the gait speed test or MDST were also excluded. Additionally, the order in which each test (respiratory muscle strength, gait speed, and MDST) was performed was randomized to avoid bias due to the measurement order.

Respiratory muscle strength

The respiratory muscle strength parameters used in this study were maximal inspiratory pressure (PImax) and maximal expiratory pressure (PEmax). Respiratory muscle strength was measured using a spirometer (Autospiro AS-507; Minato, Japan). All measurements were performed by a physical therapist in accordance with the American Thoracic Society/European Respiratory Society guidelines [25]. PImax and PEmax were used to indicate respiratory muscle strength, and the maximal values after two measurements were considered representative.

Walking speed

Walking speed was assessed using a 5 m walking test on a flat floor. The same physical therapist performed all tests, under safe conditions. The test was practiced 3–5 times in advance, and participants were asked to wear their usual shoes during the test. Participants were instructed to start from a standing position and walk for 5 m without slowing down in front of the 5 m line. The time from when the first foot passed the starting line until the first foot passed the 5 m line was measured using a handheld stopwatch. This measurement was divided by the distance walked to obtain the average speed (m/s). Participants were asked to perform two walking speed tasks, one at their habitual daily pace (normal walking speed) and the other at their maximal speed (maximal walking speed). Walking at normal and maximal speeds was performed twice each, and the maximal measurement was adopted. The tests were performed under the close supervision of a physical therapist to avoid problems such as falls, but no physical assistance was provided in any of the tests. However, participants were allowed to use personal aids (e.g., canes, walkers).

Dynamic Balance (MDST)

The MDST was performed by the same physical therapist as for the walking speed evaluations, on a flat floor in the daycare facilities under safe conditions. The MDST was practiced 3–5 times in advance, and the patients were asked to wear their usual shoes when performing the MDST. The MDST was measured twice in the standing position in accordance with the original method, without losing balance, and the maximal measurement was recorded. The MDST was measured from the starting

Comentado [IG4]: In which unit was it recorded?

line (toe) to the heel of the second foot, based on the method of Demura et al. [26]. The order of the preceding swinging lower limb was arbitrary. It was assumed that the participants in this study would have lower movement ability than those in the previous study. Therefore, the 5 cm measurement used in the previous study was judged to be problematic for capturing differences in ability among our participants, and a more detailed measurement unit of 0.5 cm was used. Each value for the MDST results was divided by the participant’s height (cm), considering the influence of body composition. The tests were performed under the strict supervision of a physical therapist to avoid problems, such as falls, but no physical assistance was provided in any of the tests. However, participants were allowed to use personal assistive devices (e.g., canes, walkers).

Comentado [IG5]: Does it mean that there is no unit for MDST, since it was measured in cm, then divided for the height, also in centimeter?

Statistical Analyses

Comentado [IG6]: I suggest to add a sentence about the descriptive analyses of the data and the normality of that.

The relationships between walking speed, respiratory muscle strength, and MDST~~,~~ were examined using Pearson's correlation coefficient and multiple regression analysis. In the m~~M~~ultiple regression analysis using a stepwise method, walking speed (normal and maximal walking speed) was defined as the dependent variable, and PImax, PEmax, MDST, sex, height, and weight were defined as independent variables, considering multicollinearity. Moreover, MDST was defined as the dependent variable, and PImax, PEmax, normal walking speed, maximal walking speed, sex, height, and weight were defined as independent variables.

A stepwise method was used for the multiple regression analysis. We calculated the effect size needed for Pearson’s correlation coefficient (sample size = 50, significance level [α] error = 0.05, power [1−β error probability (err prob)] = 0.80) and multiple regression analysis (sample size = 50, αerr prob = 0.05, power [1 − β err prob] = 0.80, number of predictors = 1 or 2) using G Power software (version 3.1; Heinrich Heine University of Düsseldorf, Düsseldorf, Germany). We obtained a result of 26 for Pearson's correlation coefficient and 36 for the multiple regression analysis. Statistical analysis was performed using SPSS version 26 (IBM Japan, Tokyo, Japan), and p-values < 0.05 were considered statistically significant.

Results

Figure 1 is a study flowchart showing the selection of the study participants. Sixty participants (30 men and 30 women) were recruited, of whom, 10 were excluded (seven with difficulty walking independently in daily life, two with knee joint pain, and one with low back pain). The final sample comprised 50 study participants (21 men and 29 women) (Table 1).

Pearson's correlation coefficient reveled correlations between maximal walking speed and PImax ($r=0.607$, $p<0.001$), normal walking speed and PImax ($r=0.497$, $p<0.001$), and MDST and PImax ($r=0.429$, $p=0.02$). Correlations were also observed between maximal walking speed and PEmax ($r=0.518$, $p<0.001$), normal walking speed and PEmax ($r=0.479$, $p<0.001$), and MDST and PEmax ($r=0.330$, $p=0.033$). Moreover, a correlation was found between maximal walking speed and MDST ($r=0.682$, $p<0.001$) and normal walking speed and MDST ($r=0.645$, $p<0.001$). The effect size was 0.375.

Multiple regression analysis using a stepwise method with maximal walking speed as the dependent variable showed that PEmax, sex, height, and weight were excluded, and maximal walking speed was significantly associated with MDST ($p<0.001$) and PImax ($p<0.001$), with an effect size of 0.210. The model's adjusted coefficient of determination was 0.569 (p<0.001). Multiple regression analysis using a stepwise method with normal walking speed as the dependent variable showed that PImax, sex, height, and weight were excluded, and normal walking speed was significantly associated with MDST (p<0.001) and PEmax (p=0.006), with an effect size of 0.210. The model's adjusted coefficient of determination was 0.505 (p<0.001). Furthermore, multiple regression analysis using a stepwise method with MDST as the dependent variable showed that PImax, PEmax, normal walking speed, sex, height, and weight were excluded, and MDST was significantly associated with maximal walking speed (p<0.001), with an effect size of 0.165. The adjusted coefficient of determination for this model was 0.466(p<0.001) (Table 2).

Discussion

To our knowledge, this is the first study to examine the relationship between walking speed, respiratory muscle strength, and MDST, a dynamic balance index, in community-dwelling older people requiring long-term care or support. This study showed a significant correlation between PImax and maximal walking speed, normal walking speed, and MDST in older people requiring long-term care or support. Additionally, significant correlations were found between PEmax and maximal walking speed, normal walking speed, and MDST and between MDST and maximal walking speed and normal walking speed. ~~Additionally~~

Moreover, multiple regression analysis showed that MDST and PImax affected the maximal walking speed of older people requiring long-term care or support, and MDST and PEmax affected the participants' normal walking speed. Furthermore, maximal walking speed was identified as a factor affecting MDST in older people requiring long-

Comentado [IG7]: I suggest to diminish the size of the paragraphs, thus, I had changed some of them, creating new paragraphs.

I general, I found it was a good discussion. However, I suggest to diminish the size of it, leaving the ideas a little more objective.

I also suggest to add the strength of the study before the limitations.

term care or support. The results of this study reflect our hypothesis, and the authors consider that the fact that walking speed, respiratory muscle strength, and dynamic balance in older people requiring long-term care or support were associated is important for improving the quality of care services in the long-term care insurance system in Japan.

The reason why maximal walking speed was associated with MDST and PImax and normal walking speed with MDST and PEmax may involve a breakdown in the postural control system. The postural control system has two main functions: first, to create a posture against gravity and to ensure balance, and second, to fix the orientation and position of the body segments that serve as the reference frame for perception and action concerning the external world [27]. In other words, the postural control system is the process of maintaining posture through the coordination of muscles and the nervous system, and this system plays an essential role in maintaining posture and movement stability during walking.

It is widely known that respiratory muscles, which are also trunk muscles, are involved in this postural control system. The diaphragm and transversus abdominis are the primary respiratory muscles involved in the postural control system [28,29]; the diaphragm is the major inspiratory muscle [30]. The diaphragm is thought to have both an indirect role in supporting the spine by increasing intra-abdominal pressure and a direct role in contributing to postural stabilization through sustained co-contraction [28,31]. In comparison, the transversus abdominis muscle, one of the expiratory muscles [32], is also thought to contribute to postural stabilization by increasing the tension of the thoracolumbar fascia [33] or by increasing intra-abdominal pressure [34], thereby stabilizing the spine [29,35].

Comentado [IG8]: I suggest to add a reference here

The strength of the diaphragm and transversus abdominis muscles is likely related to inspiratory and expiratory muscle strength [36,37,38,39]. Therefore, a decrease in PImax and PEmax causes a breakdown in the postural control system, affecting the maximal and normal walking speeds. ~~Therefore, i~~ICorroborating with this idea, ~~n~~ the results of this study~~, we considered~~ suggested that a decrease in PImax and PEmax caused a breakdown in the postural control system, which affected the maximal and normal walking speeds. Although instability increases with increasing walking speed [19], the results of the present study showed that PImax was associated with the maximal walking speed at which instability increased. This result suggests that PImax, rather than PEmax, is involved in situations in which instability increases. In other words, the diaphragm may be more critical than the transversus abdominis muscle under increased instability, such as during maximal walking speed.

Özkal et al. [40] noted that the diaphragm is thicker in older people than that in younger people to compensate for atrophied lower limbs and to maintain balance. The results of this previous study also support the importance of postural control by the diaphragm in situations of increased instability. In contrast, the results of the present study showed that normal walking speed was associated with PEmax, suggesting that the function of the transversus abdominis muscle may be more important than that of the diaphragm under conditions such as normal walking speed, where instability is not increased as much as it is with maximal walking speed.

In this study, maximal walking speed was associated with MDST, a dynamic balance index. Therefore, MDST is an essential factor in improving maximal walking speed. MDST was correlated with both PImax and PEmax; however, PImax was more strongly correlated with MDST compared with PEmax. As the MDST is performed at the

Comentado [IG9]: Reference?

Formatado: Realce

maximal effort, it is a task that increases instability more than that with other dynamic balance tests. Therefore, the MDST is considered to have higher reliability regarding ADLs and falls than that with other dynamic balance tests [41]. Furthermore, the MDST and walking at maximal walking speed may be related more to the diaphragm than the transversus abdominis muscle.

In summary, the relationships between walking speed, respiratory muscle strength, and dynamic balance in older people requiring long-term care or support can be explained through a breakdown of the postural control system due to a decline in respiratory muscle strength. Disruption of the postural control system due to decreased respiratory muscle strength may adversely affect dynamic balance and cause a decrease in walking speed. Walking speed declines approximately 10 years before death, leading to basic/instrumental ADL limitations later in life [10]. Because of the decline in walking speed, older people who need long-term care or support may be reluctant to leave home and engage in social activities. This leads to social isolation and physical activity limitations, decreasing quality of life and increasing the likelihood of premature death.

Comentado [IG10]: This needs a reference

This study has several limitations. The participants in this study were older people who needed long-term care or support, and the participants may have been affected by various medical conditions. However, it was difficult to determine whether the effects on gait speed, respiratory muscle strength, and dynamic balance ability were due to disease. Therefore, to generalize the results of this study, additional studies are needed, including comparisons between sarcopenia and non-sarcopenia groups and between frail and non-frail groups, and including healthy older people as a control group. Furthermore, this study was observational, and future interventional studies should be performed. Moreover, as the participants in this study were recruited from only two facilities, it is necessary to continue the study by recruiting participants from multiple sources. In this study, only the MDST, a dynamic balance index, was measured as a balance index, and the relationship between the MDST and other balance indices must be clarified. Future studies measuring balance indices other than the MDST and investigating the relationship between walking speed and respiratory muscle strength are necessary. This is expected to prove that the MDST is a valuable balance index for older people requiring long-term care or support. As another limitation, because this study focused on only respiratory muscle strength, which involves the trunk muscles, the relationship with lower limb muscle strength must be clarified. Therefore, further investigation of the relationships between respiratory muscle strength, gait speed, and balance indices, as well as lower limb muscle strength, will enable a more detailed understanding of the physical functions of older people requiring long-term care or support.

Conclusions

This study revealed that respiratory muscle strength and dynamic balance are associated with walking speed in older people requiring long-term care or support. These associations may have an important impact on basic/instrumental ADL limitations and death among older people requiring long-term care or support. Therefore, preventive services to minimize the need for long-term care or support must incorporate programs and interventions that improve walking speed and dynamic balance by improving respiratory muscle strength. The development of such programs

Comentado [IG11]: This can not be concluded, once it is an observational study. This means there is no effect-cause.

You can say that preventive services are recommended, but not that respiratory muscle strength will improve walking speed, because the relationship found is not of effect-cause.

and interventions is urgently needed; however, this study was observational, and the development of these programs requires interventional studies.

Acknowledgments

The authors thank all people who contributed to this study. We thank Jane Charbonneau, DVM, from Edanz (https://jp.edanz.com/ac) for editing a draft of this manuscript. This work was not funded.

References

[1] Ministry of Health, Labour and Welfare, Japan. Long-term care insurance system of Japan. 2016. https://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf. [accessed 26 June 2023].

[2] United Nations. World population ageing. 2017. https://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2017_Highlights.pdf. pdf. [accessed 26 June 2023].

[3] T Ito, T Mori, H Takahashi, et al., Prevention services via public long-term care insurance can be effective among a specific group of older adults in Japan. BMC Health Serv Res. 2021 May 30;21(1):531. doi: 10.1186/s12913-021-06495-0.

[4] V. A Freedman, L. G Martin, R. F Schoeni, Recent trends in disability and functioning among older adults in the United States: a systematic review. JAMA. 2002 Dec 25;288(24):3137-46. doi: 10.1001/jama.288.24.3137.

[5] T. M Gill, B Kurland, The burden and patterns of disability in activities of daily living among community-living older persons. J Gerontol A Biol Sci Med Sci. 2003 Jan;58(1):70-5. doi: 10.1093/gerona/58.1.m70.

[6] J. R Lunney, J Lynn, D. J Foley, et al., Patterns of functional decline at the end of life. JAMA. 2003 May 14;289(18):2387-92. doi: 10.1001/jama.289.18.2387.

[7] J. R Lunney, S. M Albert, R Boudreau, et al., Three Year Functional Trajectories Among Old Age Survivors and Decedents: Dying Eliminates a Racial Disparity. J Gen Intern Med. 2018 Feb;33(2):177-181. doi: 10.1007/s11606-017-4232-6. Epub 2017 Dec 4.

[8] J. R Lunney, S. M Albert, R Boudreau, et al., Mobility Trajectories at the End of Life: Comparing Clinical Condition and Latent Class Approaches. J Am Geriatr Soc. 2018 Mar;66(3):503-508. doi: 10.1111/jgs.15224. Epub 2018 Jan 18.

[9] B Landré, A Fayosse, C. B Hassen, et al., Terminal decline in objective and self-reported measures of motor function before death: 10 year follow-up of Whitehall II cohort study. BMJ. 2021 Aug 4;374:n1743. doi: 10.1136/bmj.n1743.

[10] S Sabia, J Dumurgier, B Tavernier, et al., Change in fast walking speed preceding death: results from a prospective longitudinal cohort study. J Gerontol A Biol Sci Med Sci. 2014 Mar;69(3):354-62. doi: 10.1093/gerona/glt114. Epub 2013 Aug 2.

[11] M. B Vidal, M. S Pegorari, E. C Santos, et al., Respiratory muscle strength for discriminating frailty in community-dwelling elderly: a cross-sectional study. Arch Gerontol Geriatr. 2020 Jul-Aug;89:104082. doi: 10.1016/j.archger.2020.104082. Epub 2020 Apr 20.

[12] A Nagano, H Wakabayashi, K Maeda, et al., Respiratory Sarcopenia and Sarcopenic Respiratory Disability: Concepts, Diagnosis, and Treatment. J Nutr Health Aging. 2021;25(4):507-515. doi: 10.1007/s12603-021-1587-5.

[13] D. G Ohara, M. S Pegorari, N. L.O. D Santos, et al., Respiratory Muscle Strength as a Discriminator of Sarcopenia in Community-Dwelling Elderly: A Cross-

Sectional Study. J Nutr Health Aging. 2018;22(8):952-958. doi: 10.1007/s12603-018-1079-4.

[14] A. N Parentoni, V. A Mendonça, K. D. D Santos, et al., Gait Speed as a Predictor of Respiratory Muscle Function, Strength, and Frailty Syndrome in Community-Dwelling Elderly People. J Frailty Aging. 2015;4(2):64-8. doi: 10.14283/jfa.2015.41.

[15] A. Roldán, P. Monteagudo, A Cordellat, et al., Inspiratory Muscle Strength and Cardiorespiratory Fitness Association With Health-Related Quality of Life in Healthy Older Adults. Front Sports Act Living. 2021 Mar 18;3:624947. doi: 10.3389/fspor.2021.624947. eCollection 2021.

[16] I. L Kyrdalen, P Thingstad, L Sandvik, et al., Associations between gait speed and well-known fall risk factors among community-dwelling older adults. Physiother Res Int. 2019 Jan;24(1):e1743. doi: 10.1002/pri.1743. Epub 2018 Sep 10.

[17] Ministry of Health, Labour and Welfare, Japan. Summary Report of Comprehensive Survey of Living Conditions 2019. https://www.mhlw.go.jp/english/database/db-hss/dl/report_gaikyo_2019.pdf. [accessed 5 May 2023].

[18] H. I Shin, Don-Kyu Kim, K. M Seo, et al., Relation Between Respiratory Muscle Strength and Skeletal Muscle Mass and Hand Grip Strength in the Healthy Elderly. Ann Rehabil Med. 2017 Aug;41(4):686-692. doi: 10.5535/arm.2017.41.4.686. Epub 2017 Aug 31.

[19] J Kongsuk, D. A Brown, C. P Hurt, Dynamic stability during increased walking speeds is related to balance confidence of older adults: a pilot study. Gait Posture. 2019 Sep;73:86-92. doi: 10.1016/j.gaitpost.2019.06.018. Epub 2019 Jul 4.

[20] L Bizovska, Z Svoboda, M Janura, et al., Local dynamic stability during gait for predicting falls in elderly people: A one-year prospective study. PLoS One. 2018 May 10;13(5):e0197091. doi: 10.1371/journal.pone.0197091. eCollection 2018.

[21] S Bohm, M Mandla-Liebsch, F Mersmann, et al., Exercise of Dynamic Stability in the Presence of Perturbations Elicit Fast Improvements of Simulated Fall Recovery and Strength in Older Adults: A Randomized Controlled Trial. Front Sports Act Living. 2020 May 27;2:52. doi: 10.3389/fspor.2020.00052. eCollection 2020.

[22] Locomotive syndrome. In: Locomotive Challenge! Council. Tokyo: Japanese Orthopaedic Association; 2015. Locomotive syndrome pamphlet 2015, https://locomo-joa.jp/assets/pdf/index_english.pdf. [accessed 26 June 2023].

[23] M Yamada, H Arai, Long-Term Care System in Japan. Ann Geriatr Med Res. 2020 Sep;24(3):174-180. doi: 10.4235/agmr.20.0037. Epub 2020 Aug 24.

[24] T Kera, H Kawai, H Hirano, et al., Definition of Respiratory Sarcopenia With Peak Expiratory Flow Rate. J Am Med Dir Assoc. 2019 Aug;20(8):1021-1025. doi: 10.1016/j.jamda.2018.12.013. Epub 2019 Feb 6.

[25] American Thoracic Society/European Respiratory Society, ATS/ERS Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002 Aug 15;166(4):518-624. doi: 10.1164/rccm.166.4.518.

[26] S Demura, T Yamada, Relationships of maximal single- and double-step length tests with sex and the dominant and non-dominant legs. Eur J Sport Sci. 2008 Feb 6; 8(1): 47-53. doi: 10.1080/17461390701871973.

[27] J Massion, Postural control system. Curr Opin Neurobiol. 1994 December; 4(6): 877-887. Doi: 10.1016/0959-4388(94)90137-6.

[28] P. W Hodges, S.C Gandevia, Activation of the human diaphragm during a repetitive postural task. J Physiol. 2000 Jan 1;522 Pt 1(Pt 1):165-75. doi: 10.1111/j.1469-7793.2000.t01-1-00165.xm.

[29] P. W Hodges, C. A Richardson, Transversus abdominis and the superficial abdominal muscles are controlled independently in a postural task. Neurosci Lett. 1999 Apr 16;265(2):91-4. doi: 10.1016/s0304-3940(99)00216-5.

[30] S. J Enright, V. B Unnithan, C Heward, Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. Phys Ther. 2006 Mar;86(3):345-54.

[31] J Kocjan, B Gzik-Zroska, K Nowakowska, et al., Impact of diaphragm function parameters on balance maintenance. PLoS One. 2018 Dec 28;13(12):e0208697. doi: 10.1371/journal.pone.0208697. eCollection 2018.

[32] G Tagliabue, M Ji, J. V Jagers, et al., Expiratory and inspiratory action of transversus abdominis during eupnea and hypercapnic ventilation. Respir Physiol Neurobiol. 2022 Dec;306:103951. doi: 10.1016/j.resp.2022.103951. Epub 2022 Jul 30.

[33] P.W Hodges, C.A Richardson, Feedforward contraction of transversus abdominis is not influenced by the direction of arm movement. Exp Brain Res. 1997 Apr;114(2):362-70. doi: 10.1007/pl00005644.

[34] A. G Cresswell, L Oddsson, A Thorstensson, The influence of sudden perturbations on trunk muscle activity and intra-abdominal pressure while standing. Exp Brain Res. 1994;98(2):336-41. doi: 10.1007/BF00228421.

[35] Jung-Seok Lee, Tae-Ho Kim, Da-Yeon Kim, et al., Effects of selective exercise for the deep abdominal muscles and lumbar stabilization exercise on the thickness of

the transversus abdominis and postural maintenance. J Phys Ther Sci. 2015 Feb;27(2):367-70. doi: 10.1589/jpts.27.367. Epub 2015 Feb 17.

[36] H Souza, T Rocha, M Pessoa, et al., Effects of inspiratory muscle training in elderly women on respiratory muscle strength, diaphragm thickness and mobility. J Gerontol A Biol Sci Med Sci. 2014 Dec;69(12):1545-53. doi: 10.1093/gerona/glu182.

[37] F. V Ferraro, J. P Gavin, T. W Wainwright, et al., Comparison of balance changes after inspiratory muscle or Otago exercise training. PLoS One. 2020 Jan 24;15(1):e0227379. doi: 10.1371/journal.pone.0227379. eCollection 2020.

[38] J. M McMeeken, I. D Beith, D. J Newham, et al., The relationship between EMG and change in thickness of transversus abdominis. Clin Biomech (Bristol, Avon). 2004 May;19(4):337-42. doi: 10.1016/j.clinbiomech.2004.01.007.

[39] G Misuri, S Colagrande, M Gorini, et al., In vivo ultrasound assessment of respiratory function of abdominal muscles in normal subjects. Eur Respir J. 1997 Dec;10(12):2861-7. doi: 10.1183/09031936.97.10122861.

[40] Ö Özkal, M Kara, S Topuz, et al., Assessment of core and lower limb muscles for static/dynamic balance in the older people: An ultrasonographic study. Age Ageing. 2019 Nov 1;48(6):881-887. doi: 10.1093/ageing/afz079.

[41] S Demura, T Yamada, The maximal double step length test can evaluate more adequately the decrease of physical function with age, than the maximal single step length test. Arch Gerontol Geriatr. 2011 Jul-Aug;53(1):e21-4. doi: 10.1016/j.archger.2010.09.009. Epub 2010 Oct 8.

Formatado: Normal, Sem marcadores ou numeração

	n = 50（Men = 21, Women =29）
Age（years）	82.6 ± 5.7
Height（cm）	153.8 ± 9.7
Weight（kg）	54.8 ± 10.6
BMI（kg/m^2）	23.1 ± 3.2
Care level（1-7）	lev1=15, lev2=10, lev3=16, lev4=9, lev5=0, lev6=0, le
Respiratory muscle strength	
PEmax（cmH_2O）	50.4 ± 21.6
PImax（cmH_2O）	36.2 ± 16.7
Walking speed	
Normal (m/s)	0.9 ± 0.3
Maximal (m/s)	1.1 ± 0.4
Dynamic balance	
MDST	0.9 ± 0.2

Comentado [IG12]: This table needs a title.

I suggest to add the subtitle describing BMI, cm, kg, BMI, Pemax… etc

Which unit is used for the MDST?

	Maximal walking speed			Normal walking speed			MDST		
	SE	β	P-value	SE	β	P-value	SE	β	
PImax	0.02	0.385	<0.001***	—	—	—	—	—	
PEmax	—	—	—	0.001	0.512	<0.001***	—	—	—
Maximal walking speed	—	—	—	—	—	—	0.068	0.682	<0.001***
Normal walking speed	—	—	—	—	—	—	—	—	—
MDST	0.161	0.517	<0.001***	1.34	0.312	0.006**	—	—	—

Comentado [IG13]: This table needs a title.

Additionally, I suggest to add the subtitle describing BMI = **body mass index**, cm, kg, BMI, Pemax… etc