Chapter 2

Comprehensive Physical Function Assessment in Elderly People

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http://dx.doi.org/10.5772/67528

Abstract

In elderly people with mobility limitations, abnormalities in posture and gait contribute to the greater decline of physical motor function. The aim of the review article was to determine the comprehensive physical motor function assessment. Muscle function was assessed with the grip strength. Gait function was assessed with walking time tests conducted at a normal pace. Balance function was assessed with one-legged standing time. The 6-min walking distance test (6MD) was performed in a 10-m, straight corridor. Walking efficiency during the 6MD trials was measured using the Cosmed K4b2 (Rome, Italy), an indirect calorimetry system specifically designed to measure energy expenditure in nonlaboratory settings. The center of pressure was recorded using a balance board (Wii; Nintendo Co., Ltd., Kyoto, Japan). A vibratory stimulus was applied alternately to two muscles by fixing two vibrators from the vibration device onto the participant's gastrocnemius and lumbar multifidus muscle. These findings show that an assessment affecting postural control under proprioceptive stimulation might be a good indicator of elderly people. Also, the objective assessment of walking efficiency might be important for identifying the risk of external activity limitation or functional limitations among the late elderly.

Keywords: elderly people, physical function assessment, walking efficiency, proprioceptive system

1. Introduction

The ability to walk safely and postural control stabilization are vital for elderly people to decrease their risk of falling and to maintain their independence. A function of walking that accompanies aging is a higher energy cost of movement, often referred to as a lower economy of walking [1, 2]. In addition, a defect or slowing of this mechanism has been suggested to explain the difficulties experienced by older persons when trying to control their posture [3, 4]. Moreover, both muscle strength and lower postural stability decline with aging [5, 6]. Therefore, aging is characterized by changes in the neuromuscular system that decreases muscle strength, balance, and proprioception.

Meanwhile, this progressive decline in physical capacities reduces the ability of elderly people to perform complex motor tasks and is associated with impaired mobility and a reduction in the ability [7]. Assessment of motor function contributes to the identification of factors that generate impairments to the performance of daily activities and an increase in the risk of falls for elderly people. Moreover, assessment of motor function by physical therapist provides important information about age-related progressive reduction in muscle strength, ability to walk, and postural control.

This chapter provides an overview of the assessment method on motor function in elderly people.

2. The relationship between walking efficiency and life-space assessment in elderly people

2.1. Life-space assessment

The increased metabolic cost of walking can detract from the activity and quality of life of elderly people as a decline in physical activity rapidly degrades physical and psychological functions [8, 9]. Life space has been reported to have good construct and criterion validity for measuring the severity of mobility limitations, and achieving efficient walking plays a crucial role in the extension of life space. Life-space assessment (LSA) is a tool that measures mobility and reflects participation in society based on the distance through which a person reports moving during the 4 weeks prior to the assessment [10, 11]. Life space, a relatively understudied concept in gerontology, can be defined as the size of the spatial area a person intentionally moves through in daily life, as well as the frequency of travel within a specific time frame [10]. Also, a reduced frequency of going outdoors could represent reduced life space, which has been hypothesized to be a risk factor in future physical disability. Murata et al. reported that life space was related not only to age or health status but also to environmental or psychosocial factors [12]. Shimada et al.'s reports confirm that LSA was more strongly associated with gait speed than the other gait variables [13] and also show that these declines in physical performances were apparent at age 80 years and over in women and at age 90 years and over in men [13].

LSA may reflect the physical activity status indirectly in elderly people because the LSA score is associated with physical performance, Activities of Daily Living (ADL), and sociodemographic factors [11].

Life-space mobility was measured using a Japanese translation of the LSA [14]. The LSA provided a score based on the distance a person reported moving during the 4 weeks before the assessment [10, 13].

The LSA scores range from 0 (“completely room-bound”) to 120 (“travel out of town every day without assistance”) [13].

2.2. Walking efficiency in elderly people

It may be that the decline in walking efficiency is a common result of the decrease of many bodily functions that capture the overall impact of life space and is an important indicator of life space. However, the mechanism by which older people’s life space and walking efficiency decline is not well investigated and remains poorly understood. Also, the specific mechanisms that explain the difference between the decline in walking efficiency and life space in early elderly and late elderly are not yet clear. Additionally, little is known about the relationship between the walking efficiency decline and confined life space to influence on aging.

In older adults with mobility limitations, abnormalities in posture and gait contribute to the greater energy cost of inefficient gait, with adjustments for age and gait speed [15]. Limitations in life space, as measured by the University of Alabama at Birmingham (UAB) life-space assessment, reflect lifestyle as well as walking efficiency and may be a valuable measure of functional decrease for community-dwelling elderly people, especially since life space specifically relates to mobility and a person’s participation in society.

2.2.1. Walking efficiency assessment

Walking efficiency during the 6MD trials was measured using the Cosmed K4b2 (Rome, Italy), an indirect calorimetry system specifically designed to measure energy expenditure in nonlaboratory settings (**Figure 1**).

In brief, it uses a breath-by-breath measurement of gas exchange through a rubberized facemask and a turbine for gas collection, secured by a head harness. A flexible facemask that the participants keep in place by a head harness covers the participants’ mouth and nose. Flexible facemask is attached to a digital turbine flowmeter to measure the volume of expired air and inspired. Sampling line from the turbine to analyzer unit system delivers expired air for the measurement (O_2, CO_2 content). Before test, the K4b2 was calibrated according to the manufacturer’s guidelines. After warming up the unit for 60 min, the CO_2 and O_2 analyzers were calibrated against room air as well as a reference gas of known composition (4.94% CO_2, 16.07% O_2). Before walking efficiency assessment, each participant was required to sit quietly for 10 min as a rest period. The speed and distance of the 6-min walking distance test (6MD) was recorded using standardized procedures.

Figure 1. Expiration gas analyser.

Walking efficiency was calculated based on net efficiency as follows: Walking efficiency = (walking VO_2 ml/kg - resting VO_2 ml/kg)/6MD average walking speed (m/s) (**Figure 2**) [16]. The Cosmed K4b2 system uses the increased VO_2/kg ratio after noise processing to predict walking efficiency from O_2 consumption.

Breath-by-breath values from the Excel spreadsheet were calculated from the increased ratio over 1-breath intervals. Outliers from the increased ratio were calculated from exploratory data analysis of participants. We defined outliers (noise) as values beyond an increased ratio of 100%. Data that were more than 100% of the increased ratio were removed, and a below-100% value was calculated from the remaining test data. This method contributes to noise processing of the VO_2/kg signal. For each subject, walking efficiency was calculated by recording the noise-processed VO_2/kg values.

2.3. Relationship between walking efficiency and life-space assessment

Ito et al. reported the significant relationship between walking efficiency and LSA in late elderly [16]. Moreover, the data from this study suggest that as walking efficiency declines with age, life space increasingly declines (**Figure 3**). This suggests that the age-related decline of walking efficiency is caused by physiological changes of the late elderly. Other studies have suggested that as aerobic capacity declines with age, walking at a habitual speed becomes an increasingly more intense and therefore difficult activity, resulting in a slowing of walking speed in an effort to reduce fatigue [17]. Also, the previous study has shown that the walking energy cost for a comparable speed is generally higher for healthy

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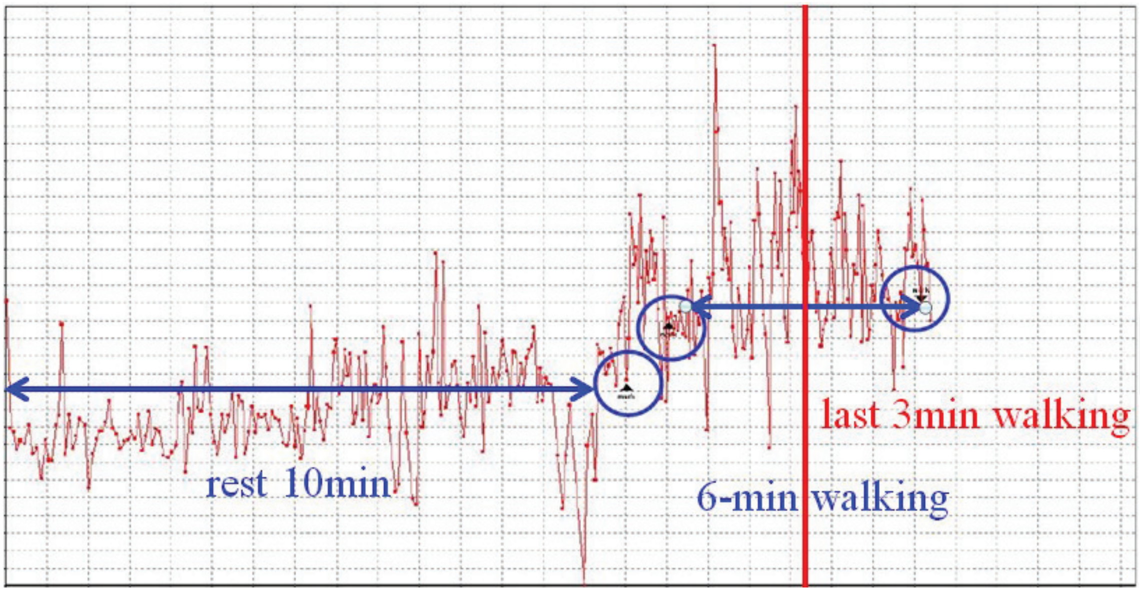

Figure 2. Walking efficiency = (walking VO_2 ml/kg - resting VO_2 ml/kg)/6MD average walking speed (m/s). Horizontal axis of blue shows the meaning of 10 min of the rest period and 6-min walking trial. Vertical axis of red shows the meaning of last 3 min of the 6-min walking trial. Following the transfer of data from the instrument, an Excel spreadsheet was used to calculate steady-state VO_2/kg and mean counts per minute during the last 3 min of the 6MD trial and 10 min of the rest period.

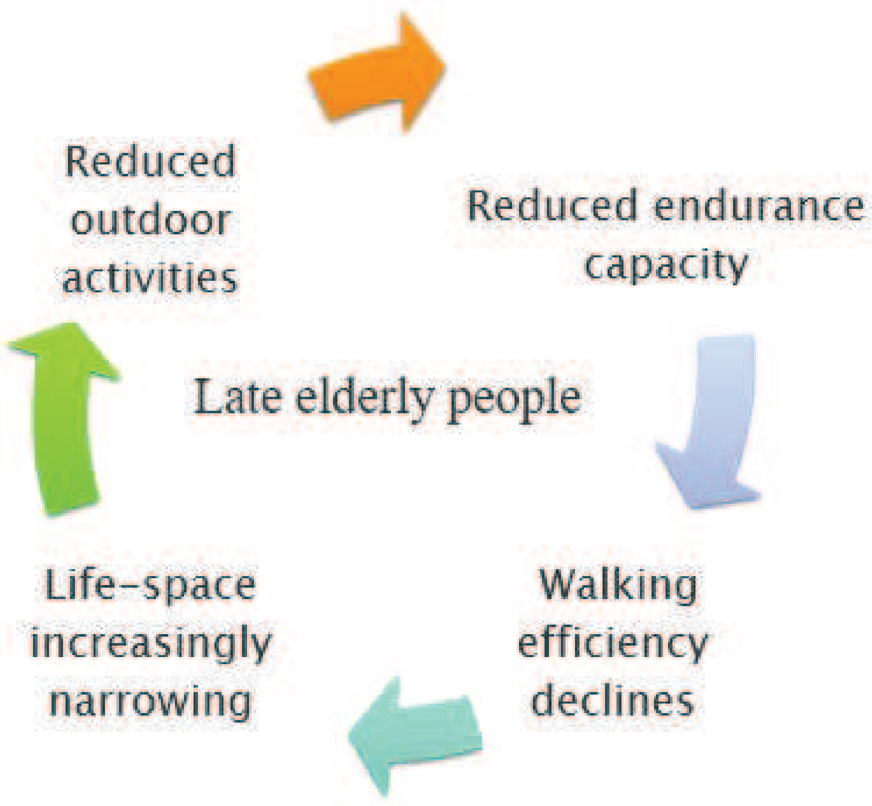

Figure 3. Schematic diagram of the incidence of walking efficiency decline in late elderly people.

elderly people, particularly those above 65 years, compared with younger people [18, 19]. Mechanisms related to the initiation and stepping patterns of gait, such as hip extension, step width, and cadence, have previously been reported to be related to the energy cost of walking in older adults with slow and variable gait [15]. Abe et al. reported that women of advanced age (75 years or older) have diminished pulmonary function, physical function, and mobility, and that diminished pulmonary function is associated with declining physical function [20]. Malatesta et al. reported that healthy octogenarians exhibited higher walking cost and greater stride time variability [21] and also reported that these declines in physical performances were apparent at age 80 years and over in women and at age 90 years and over in men [13]. Shimada reported that increased VO_2 in older adults manifests as walking becomes inefficient and reduced endurance capacity occurs [22].

This suggests that going activity to extension of LSA may better impact walking efficiency than efforts to improve gait speed and muscle strength.

3. Physical function assessments in elderly people

3.1. Performance assessment

The assessment measures are taken by well-trained staff who had nursing, physiotherapy, occupational therapy, or similar qualifications.

3.1.1. Grip strength assessment

Muscle function is assessed by the grip strength (GS) (**Figure 4**). GS is measured in kilograms in the participant's dominant hand using a Smedley-type handheld dynamometer (GRIP-D; Takei Ltd, Niigata, Japan).

3.1.2. Five-meter walk test

Five-meter walk test is assessed with walking conducted at a normal pace (usual walking speed; UWS). Two marks are used to indicate the path (start and end) of a 5-m walk path space. UWS is measured using a stopwatch system. Examiner tells the subjects to walk on a straight and flat surface at UWS. Moreover, examiner tells the subjects to maintain gait past the end of the walk path for a further 2.5 m.

3.1.3. One-legged standing time test

Balance function is assessed with one-legged standing time (**Figure 5**). One-legged standing time is used to measure how long a subject remains standing on one leg (eyes open). Subjects are allowed to decide which leg to use as support leg. Next, examiner tells the subjects to lift the converse foot from flat floor. Moreover, examiner tells the subjects to confirm sure not to press the lifted leg against support leg. The test ended when lifted leg touched the support leg, the lifted leg touched the floor, or after 60 s of successful balance.

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Figure 4. Grip strength assessment.

Figure 5. One-legged standing time test.

3.1.4. The 6-min walking distance test

6MD is performed in a 10-m, straight corridor. In the 6MD, participants are instructed to walk as quickly as possible to cover the longest distance possible within 6 min. This test measures the distance that a participant could quickly walk on a flat, hard surface in a period of 6 min.

3.1.5. Appendicular skeletal muscle mass assessment

In the elderly, muscle weakness is associated with the muscle atrophy aging (sarcopenia) progressive loss. Skeletal muscle mass loss may also have the potential to impact quality of life and ultimately the need for long-term care in elderly people [23]. Several studies developed equations for estimating skeletal muscle mass [24–26].

3.1.6. Prediction models

Sanada K, et al., 2010: Prediction models of sarcopenia [24]

Men: appendicular skeletal muscle mass = 0.326 × body mass index (BMI) − 0.047 × waist circumference - 0.011 × Age + 5.135 ($R^2 = 0.68$).

Women: appendicular skeletal muscle mass = 0.156 × BMI + 0.044 × hand grip strength − 0.010 × waist circumference + 2.747 ($R^2 = 0.57$).

Yoshida D, et al., 2014: Bioelectrical impedance analysis [25]

Men: appendicular skeletal muscle mass = 0.197 × (impedance index) + 0.179 × (weight) 0.019 ($R^2 = 0.87$).

Women: appendicular skeletal muscle mass = 0.221 × (impedance index) + 0.117 × (weight) + 0.881 ($R^2 = 0.89$).

Ito T, et al., 2016: Simple estimation of appendicular muscle mass [26]

Appendicular skeletal muscle mass = 5.051 × (gender: men = 1, women = 0) + 0.364 × (BMI) + 0.168 × (maximum calf circumference) − 0.815 ($R^2 = 0.80$).

3.2. Reduced physical activity

Past studies have provided the first evidence that slightly constricted life space may serve as an important marker and/or risk factor for the development of frailty, whereas severely constricted life space may indicate a high risk of mortality [27]. Webber et al. reported how mobility impairments can lead to limitations in accessing different life spaces and stressed the associations among determinants that influence mobility [28]. Previous study reported falls and reduced life space closely related to physical performance [29, 30].

4. Assessment of relative proprioceptive weighting ratio in elderly people with lumbar spondylosis

4.1. Sensory proprioceptive inputs in postural control

In daily life, an upright postural control task is essential for the activities of elderly people. After processing of the sensory inputs, individuals must integrate the respective contributions of the various sources of sensory information for regulating posture. Hay et al. reported

http://dx.doi.org/10.5772/67528

that older persons have difficulties in taking advantage of sensory redundancy in postural control [31]. In addition, a defect or slowing of this mechanism has been suggested to explain the difficulties experienced by older persons when trying to control their posture [32, 33]. Proprioceptive input from the muscles of the legs and trunk plays an important role in maintaining postural stability [34]. Previous studies have reported that proprioception and vibration sensation in the lower limbs decrease during normal aging [3, 4] and also reported that postural instability has been observed in elderly people [35]. Therefore, a vibratory stimulus that matches the response frequency of the receptors present in skeletal muscle may influence body sway (**Figure 6**).

Previous studies have reported that patients with recurrent low back pain (LBP) have impaired motor control [36] and altered lumbosacral proprioceptive acuity [37, 38]. LBP is a widespread pathological condition that is often related to impaired or degenerated trunk mobility, which becomes evident during common activities [39, 40]. Taimela et al. reported that lumbar muscle fatigue impaired lumbar positional sense in both patients with LBP and healthy subjects [41]. These impairments lead to pain and declines in postural strategy, muscle function, and proprioception [42, 43].

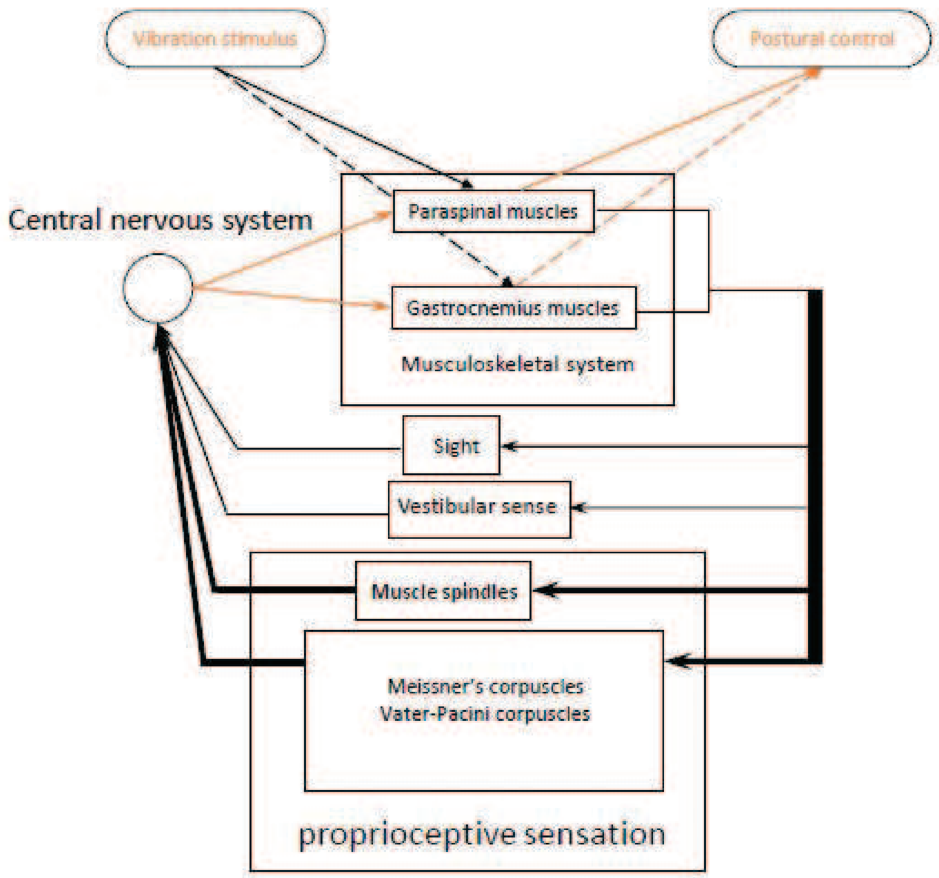

Figure 6. The representative receptor and response frequencies are 30 Hz in Meissner's corpuscles, 60 Hz in muscle spindles, and 240 Hz in Vater-Pacini corpuscles.

Muscle vibration, known to be a strong stimulus for muscle spindles and Vater-Pacini corpuscles, has been used to assess the role of proprioception [44, 45]. Both of these studies suggest that pain is a possible cause of decreased variability in postural strategy. These impairments lead to pain and declines in postural strategy, muscle function, and proprioception.

4.2. Assessment of relative proprioceptive weighting ratio

The center of pressure (COP) was recorded using a balance board (Wii; Nintendo Co., Ltd., Kyoto, Japan) (**Figure 7**) [46–48]. A vibratory stimulus is applied alternately to each muscle by fixing vibrators from the vibration device onto the subjects' lumbar multifidus (LM) muscle and gastrocnemius (GS). The device consists of an amplifier, laptop computer, and four vibrators (**Figure 8**). This mechanical vibration test has been used to analyze the role of proprioception in the postural control strategy [49–53].

The subjects stood barefoot on the Wii Balance Board with their feet together and their eyes closed. They were instructed to remain still and relax in the standing posture with their arms hanging loosely at their sides (**Figure 9**).

To provide information regarding relative proprioceptive sensation dominance, the relative proprioceptive weighting (RPW) ratio was calculated using following computation expression.

$$RPW = (Abs\ GS)/(Abs\ LM + Abs\ GS) \times 100[\%]$$

RPW of near to 0 conform to 100 [%] dependence on trunk strategy, whereas RPW of near to 100 conform to 100 [%] dependence on lower limb strategy [54–56].

Figure 7. Recently, the Wii Balance Board has been much used in the field of medical research, and it has been reported that results from the Wii Balance Board correlate closely with those of commercially available force plates.

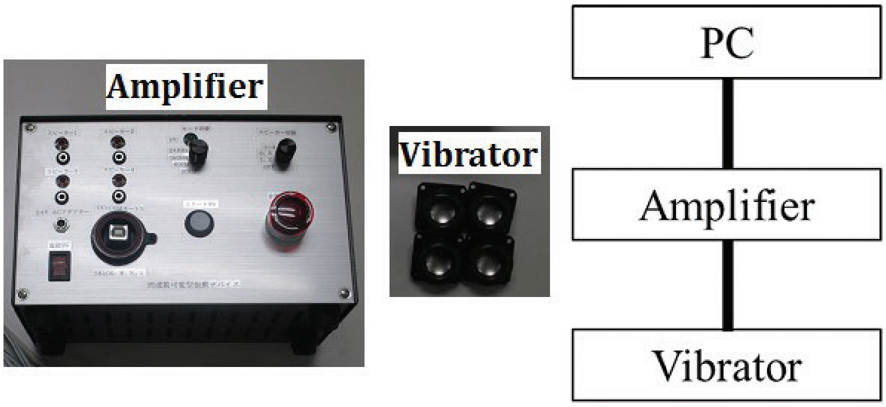

Figure 8. Photograph and block diagram of variable-frequency vibratory stimulation device.

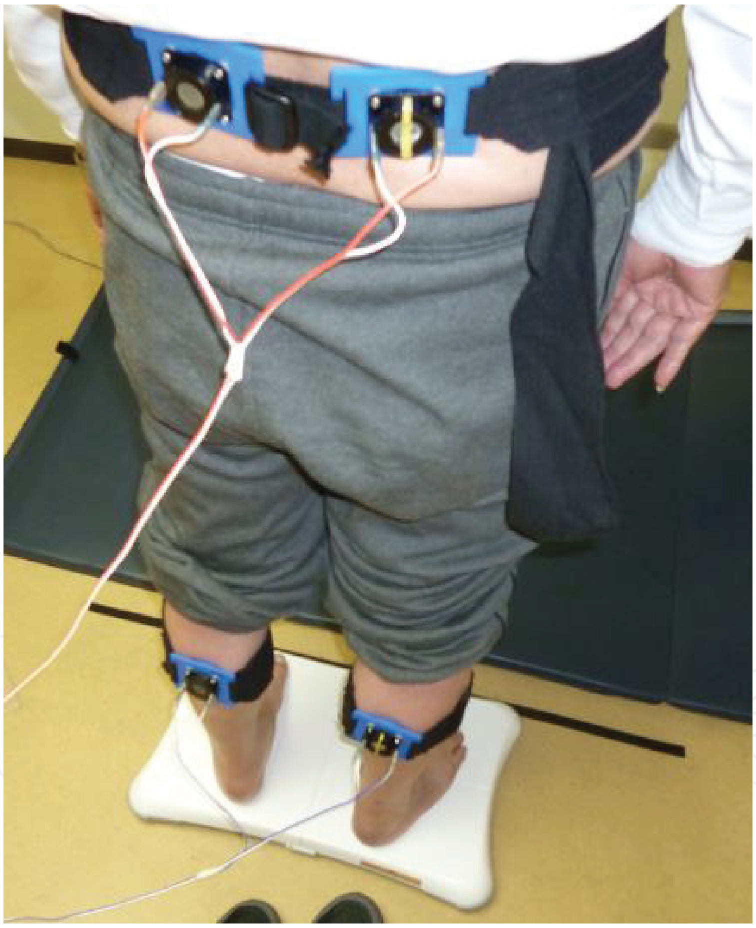

Figure 9. Experimental setup: paraspinal muscles and gastrocnemius muscles in vibration trial.

4.3. Proprioceptive input decline from the muscles of the legs or trunk

Recent studies in which a vibratory stimulation of 60 Hz was used have suggested that people with LBP adopt a lower leg-derived postural control strategy [57]. A possible explanation is that these participants were exploiting this strategy to its maximum effect during vibratory stimulation of 60 Hz. Also, according to other study, the impairment of back muscle strength leads to the motor function and sensory deficit that affects balance performance [58]. Moreover, according to another study, the lower leg's response to balance control under 30 Hz proprioceptive stimulation might be a good indicator of declining gait function [59].

These differences may result from differences between the measurement conditions and physical status of the participants.

5. Conclusions

Comprehensive physical function assessment has been proved useful for understanding the ability of elderly people. Walking efficiency is closely correlated with life space, and it can be used for comparing physical function. Performance assessment, such as the grip strength, skeletal muscle mass, and postural control stabilization, may help slow the events that ultimately can lead to motor function disorder and disability. This chapter suggests that comprehensive physical function assessment is a useful method to evaluate the physical function and therefore aids rehabilitation programs.

Acknowledgements

We also thank Yoshihito Sakai, Yoshifumi Morita, Noritaka Sato, and Kazunori Yamazaki for their help in this chapter.

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