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# Comparison of Static and Dynamic Balance in Healthy but Untrained Versus Frail Community-dwelling Older Adults

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**Abstract**

Falls represent a major public health issue for older adults and loss of balance ability is a primary cause of falls. However, little attention has been given to the balance ability of frail older adults. The objective of this study was to determine differences in static (SB) and dynamic (DB) balance between healthy but untrained older adults and frail community-dwelling older adults. Balance parameters were evaluated in healthy but untrained (HO: n=15) and frail older adults (FO: n=19). A force platform was used to determine indices of SB and DB. Sway Velocity (SV) was used to measure SB standing on a firm surface with eyes open and closed. DB was evaluated using Limits of Stability that measured endpoint excursion (EPE) and maximum excursion (MXE) of the body's center of pressure while leaning in 8 directions. Reaction time (RT), movement velocity (MV) and directional control (DL) were also used to characterize DB. SB in the HO group was significantly better than the FO group ($P< 0.05$). For DB measures, EPE and MV in the forward direction was significantly less in the FO group compared to the HO group ($P< 0.05$). Frail older adults have lower SB and DB when compared to healthy but untrained older adults. Therefore, balance-training interventions that target these deficits should be implemented with frail older adults to reduce their risk for falls.

**Keywords:** Computerized dynamic posturography; Postural control; Sway velocity; Limits of stability; Aging

## Abbreviations

ADL: Activities of Daily Living; FO: Frail Older adults (physically frail Japanese older adults who needed assistance performing ADL according to long term care insurance regulations in Japan); HO: Healthy but untrained Older adults (independent Japanese older adults); CDP: Computerized Dynamic Posturography; LOS: Limits Of Stability; COP: Center Of Pressure; EPE: End Point Excursion (initial extent of the movement); MXE: Maximum Excursion (actual extent of the movement); MV: Movement Velocity (speed of movement); DCL: Directional Control (amount of movement in the intended direction toward the target and extraneous movement away from the targets); RT: Reaction Time (amount of time from the auditory signal until movement).

## Introduction

Falling is the leading cause of physical disability, functional decline, and injury-related death in older adults [1]. Yang et al. reported that between 25% and 35% of persons aged 65 and over reported one or more falls each year [2]. Annually, 81% to 98% of hip fractures are caused by falls and these fractures require surgical intervention and extensive postsurgical management at great cost both to patients and the social security system [3]. Therefore, there is a growing international problem with significant fall-related health care costs [4].

A loss of balance is often the precursor to a fall. In fact, approximately 10% to 25% of all falls have been attributed to poor balance [5]. Takeshima et al. reported that age-related deficits in both static and dynamic balance exist in independently living older women aged 60 to 89 years [6]. In addition, physical frailty, defined as a clinical syndrome in which three or more of the following criteria are present: unintentional weight loss (4.5 kg in past year), self-reported exhaustion, weakness, slow walking speed, and low levels of physical activity [7], is associated with an increased risk of a fall [8]. However, little attention has been given to balance ability in physically frail older adults.

A variety of assessment tools focusing on balance ability have been developed. Assessments of balance ability tend to have two forms: (1) qualitative ratings of performance based on observation of the participant performing an activity, and (2) quantitative measures that are equipment-based such as computerized dynamic posturography (CDP) [8]. The CDP can quantify an individual's change in body position and movement control while they maintain static and dynamic balance [8]. Assessments using CDP have shown a high level of reproducibility for both static and dynamic balance ability [6].

The purpose of the present study was to compare static and dynamic balance ability using CDP in frail community-dwelling older adults versus healthy but untrained older adults.




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**Table 1:** Physical characteristics of groups.

| | Frail older (FO) group (n=19) | Healthy older (HO) group (n=15) | Comparison between both groups |
|---|---|---|---|
| **Age (year)** | 80.8±8.1 | 80.4±6.8 | N.S. |
| **Height (cm)** | 152.1±8.7 | 151.8±7.7 | N.S. |
| **Body Mass (kg)** | 52.0±8.7 | 52.2±8.5 | N.S. |
| **BMI (kg/m$^2$)** | 22.4±3.6 | 22.6±3.0 | N.S. |
| **Walking mean velocity (m/sec)** | 0.59±0.2 | 0.98±0.2 | $P$<0.05 |

**Note:** BMI: body mass index (BMI) was computed as body weight (kg) divided by the square of height (cm).

## Methods

### Participants

Nineteen physically frail older adults (frail older adults: FO) and 15 independently living Japanese older adults (healthy but untrained older adults: HO) were recruited for this study via advertisements in local newsletters and public information magazines. FO were beneficiaries of long-term care insurance and needed assistance performing ADL according to long term care insurance regulations in Japan. All participants lived in their own home but each member of the FO group received day-care service in the home from a nurse that was subsidized by long term care insurance. They also reported weakness and low levels of physical activity. Participants had no conditions that could have affected their balance such as ataxia, stroke, or osteoarthritis of the knee. The means and SDs for age, height, body mass, BMI, and maximum walking velocity are shown in Table 1. The maximum walking velocity was assessed using an 8-m walk test.

The study was approved by the ethical committee of National Institute of Fitness and Sports in Kanoya. All participants received written and oral instructions for the study and each gave their written informed consent prior to participation.

### Method for static and dynamic balance measurement

The Balance Master Platform System (Neuro Com International, Oregon, and USA) was used to measure static and dynamic balance [8]. In this study, the Clinical Test of Sensory Interaction for balance was used as a test of postural sway velocity that is designed to measure the influence of sensory input on balance [9]. Greater sway velocity indicates less postural control. The force platform was marked to maintain consistency in foot placement. For each trial, the participant stood with their eyes at the horizon and their arms at the sides in a neutral position for 10 s. Three trials were performed with the eyes open and three with the eyes closed. A trial was considered unsuccessful if the participant took a step or was unable to balance for the required time period without aid from a spotter.

Dynamic balance ability was determined using the limits of stability (LOS) assessment. During the assessment, the individual stood on a force platform facing a computer monitor. The monitor displayed a central box with eight targets in an elliptical pattern surrounding the central box. These targets represented the individual's estimated LOS (based on their height). The eight targets were displayed on the computer screen at 0 (forward), 45, 90 (right), 135, 180 (back), 225, 270 (left), and 315 degrees. The participant's center of pressure (COP) appeared as a human-shaped cursor on the computer screen that moved freely with the participants as they shifted their weight. To initiate each trial, the participant was instructed to adjust and then maintain the human-shaped cursor in the central box. Upon hearing an auditory signal from the computer, the participant moved toward the highlighted target in a straight line, as fast as possible, and held the position for 5s. Targets were highlighted sequentially in a clockwise manner. The test provided information regarding the individual's postural control as indicated by the initial shift toward the target (end point excursion: EPE) and the actual extent of the movement (maximum excursion: MXE) [10]. Information was also provided regarding the quality of the movement as indicated by the speed of movement (movement velocity: MV) and a comparison of the amount of movement in the intended direction toward the target and extraneous movement away from the target (directional control: DCL). The amount of time from the auditory signal until movement was initiated was also calculated (reaction time: RT). Lower time values and straighter path movement are indicators of better performance and control of balance. Four scores (forward, backward, right, left) were calculated based on the mean of three targets (e.g., forward score was based on average value of 0, 45, 315 degrees direction scores).

### Statistical analysis

Descriptive data are expressed as means and standard deviations. FO and HO group comparisons were performed using unpaired t-tests. A probability value of less than 0.05 was considered statistically significant. All data were analyzed using SPSS ver. 15.0 for Windows statistical software (SPSS Inc., Tokyo, Japan).

## Results

Walking speed for the 8-m walk test in the FO group was significantly less ($P < 0.05$) than and nearly half of, the HO group. Given those participants in the FO group suffered from three of the defining characteristics (i.e., weakness, low levels of physical activity, slow walking speed) they can be classified as physically frail [7].

Sway velocity of static balance with eyes open and closed was significantly greater ($P< 0.05$) in the FO group (EO: 0.39 ± 0.13 deg/sec, EC: 3.10 ± 1.40) than the HO group (EO: 0.27 ± 0.11 deg/sec (44% lower), EC: 2.90 ± 1.40 deg/sec (7% lower)) (Table 2). Also, EPE and MV of LOS in the forward direction were significantly lower ($P < 0.05$) in the FO group (EPE: 46.7 ± 11.4%) than the HO group (EPE: 62.9 ± 21.4% (34% lower). There were no significant differences for backward, right, and left directions between FO and HO groups. Lastly, there were no significant differences between FO and HO groups for MXE, RT, and DCL in all directions.

## Discussion

It is well known that static and dynamic balance ability typically decreases with age in older adults [6, 11-13]. Poor balance ability has been identified as one of the major risks for falls [6]. Moreover,

**Table 2:** Comparison of static and dynamic balance parameters between groups.

| Parameters | Frail older (FO) group (n=19) | Healthy older (HO) group (n=15) | Comparison between both groups |
|---|---|---|---|
| ***Static balance*** | | | |
| Sway velocity Firm-EO (deg/sec) | 0.39±0.13 | 0.27±0.11 | *P*<0.05 |
| Sway velocity Firm-EC (deg/sec) | 3.10±1.40 | 2.90±1.40 | *P*<0.05 |
| ***Dynamic balance*** | | | |
| **Reaction Time (sec)** | | | |
| Forward | 1.23±0.40 | 1.01±0.40 | N.S. |
| Back | 0.92±0.33 | 0.87±0.44 | N.S. |
| Right | 1.17±0.41 | 1.05±0.44 | N.S. |
| Left | 0.94±0.43 | 0.97±0.35 | N.S. |
| composite | 1.06±0.27 | 0.98±0.35 | N.S. |
| **Movement Velocity (deg/sec)** | | | |
| Forward | 2.20±0.98 | 3.30±1.62 | *P*<0.05 |
| Back | 1.57±0.72 | 1.89±1.05 | N.S. |
| Right | 2.63±1.34 | 3.71±2.43 | N.S. |
| Left | 3.04±1.43 | 3.94±1.92 | N.S. |
| composite | 2.36±1.00 | 3.21±1.64 | *P*<0.10 |
| **Endpoint Excursion (%)** | | | |
| Forward | 46.7±11.4 | 62.9±21.4 | *P*<0.05 |
| Back | 42.0±14.0 | 38.4±15.1 | N.S. |
| Right | 61.9±27.3 | 69.7±22.1 | N.S. |
| Left | 72.2±16.9 | 82.8±16.4 | *P*<0.10 |
| composite | 56.1±13.6 | 63.9±14.5 | N.S. |
| **Maximum Excursion (%)** | | | |
| Forward | 63.2±14.5 | 78.5±18.4 | N.S. |
| Back | 56.0±20.0 | 52.1±18.3 | N.S. |
| Right | 80.9±21.3 | 89.3±16.9 | N.S. |
| Left | 91.5±14.3 | 99.3±12.2 | N.S. |
| composite | 72.7±12.3 | 79.9±12.3 | N.S. |
| **Directional Control (%)** | | | |
| Forward | 79.5±11.6 | 80.4±7.9 | N.S. |
| Back | 59.9±19.3 | 58.5±12.8 | N.S. |
| Right | 76.2±9.1 | 76.5±7.5 | N.S. |
| Left | 78.0±9.6 | 75.4±6.4 | N.S. |
| composite | 72.9±9.6 | 72.7±6.0 | N.S. |

**Note:** Composite: composite scores were calculated based on movments toward all 8 targets appeared around a center square at 0, 45, 90, 135, 180, 225, 270, and 315 degrees; N.S., not significant.

it has been reported that decreased daily physical activity has a high correlation with increased risk of falls [13]. However, little is known about the balance abilities of physically frail older adults. In the current study, results showed that the static balance ability of physically frail older adults is approximately 40% lower than that of independent older adults. Furthermore, dynamic balance ability in the forward direction is also lower in frail older adults.

Assessments of static balance that use CDP are designed to quantify an individual's ability to maintain balance in a variety of complex conditions [14]. Increased postural sway in static conditions is moderately to strongly correlated with the risk of falls [8]. We have previously shown that static balance in independent older adults decreases by approximately 1.6% per year [6]. The results of the current study show that static balance in physically frail older adults is approximately 40% less than independent older adults of the same age, thus physically frail older adults would be at greater risk of falls.

Approximately a third of community-dwelling independent older adults over age 65 fall each year, whereas approximately half of older adults living in nursing homes fall each year [15]. Until now, the most recognized factor of falls related to physical frailty was

lower-extremity muscle strength [16]; however, our results show that decreased static balance ability is an additional factor to consider for fall risk in physically frail older adults.

The LOS assessment of dynamic balance ability was used in this study to quantify the ability to volitionally control the COP [14]. The range in which the COP can be moved in an anterior or posterior direction decreases with age. This decrease is particularly large in the posterior direction [17] and older adults often fall backwards as a result of this deficit [18]. Therefore, emphasis has been placed on improving posterior balance ability in older adults. However, the physically frail older adults in this study were found to have lower anterior dynamic balance ability than independent older adults of the same age. Reduced balance in the anterior direction is an important finding for intervention programs designed to prevent falls in physically frail older adults as exercises can be performed to improve this ability [13].

The exercise guidelines for older adults released by the American College of Sports Medicine and American Heart Association provide an index for balance exercises and many reports have stated that improving balance ability in community-dwelling independent older adults is not only important, but also possible [19]. We have previously shown that customized balance training allows older adults with poor balance to improve dynamic balance ability and potentially reduce the risk for falls [13, 20]. However, the extent to which physically frail older adults can improve balance via exercise training is largely unknown and warrants further research.

## Conclusion

The present study showed that balance ability was impaired in physically frail older adults compared to independent older adults. Further research is needed to determine the effects of balance exercises in this population.

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