# Reliability and Minimal Detectable Change of Center of Pressure During Quiet Stance in Older Adults with Mild Cognitive Impairment

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## Abstract

The objectives of this study were to determine the within- and between-session reliabilities as well as minimal detectable change (MDC) of the center of pressure (COP) parameters during standing with various conditions in older adults with mild cognitive impairment (MCI). Eleven participants diagnosed with MCI (age; 64.90 ± 2.98) were tested to evaluate postural control in 4 conditions, including standing with eyes open on a firm/foam surface and standing with eyes closed on a firm/foam. Excellent within-section reliability (ICC = 0.796) was found in COP velocity in the mediolateral (ML) direction, only during standing with eyes open on a firm surface condition. Moreover, excellent between-session reliability (ICC = 0.800 - 0.906) was found in COP displacement in the mediolateral (ML) direction in all conditions except during standing with eyes open on a foam surface. The study showed promise that the use of COP parameters for assessing postural control in older adults with MCI should be considered more. Only some parameters are applicable in some conditions.

**Keywords:** Reliability, Minimal Detectable Change (MDC), The Center of Pressure (COP), Mild Cognitive Impairment (MCI), Postural Control

## Introduction

Postural control is the ability to organize the body's position in various conditions and consists of multiple networks of the body system (Shumway-Cook & Woollacott, 2017). The postural sway can be qualified by the moving distance of the center of pressure (COP), which is defined as the position of the center of gravity in relation to the center of pressure. The COP is where pressure is applied to the ground by the feet due to the body segments creating the pendulum movement and representing the body's sway during stance (Winter, Patla, & Frank, 1990). Normally, measures of postural sway are used in posturographic data. The force platform is the common instrument and generalizes the COP signal in anteroposterior, mediolateral, or both directions. It assesses the COP amplitude and magnitude as well as its time-varying coordinates. In addition, the COP can be analyzed into various parameters which can represent the stability of a person where the less variable demonstrates the more stable stage while the increasing variable demonstrates the unstable stage (Goldie, Bach, & Evans, 1989; Palmieri, Ingersoll, Stone, & Krause, 2002). Furthermore, maintaining a quiet posture is necessary for performing regular tasks. The central nervous, musculoskeletal, and sensory systems are the three major systems of body components required for movement (Shumway-Cook & Woollacott, 2017). If one of them is lost or declined, postural control may not be functional or effective, especially in older adults. In the fact that older adults have experienced system aging (WHO, 2020). However, the brain is the essential body part that could also be affected by the deterioration. The decline of the brain may result in the ability of the body's organization in various systems. There are numerous brain-related conditions. One of them is called mild cognitive impairment (MCI), which is a transitional stage of cognitive decline that is more than that seen with normal aging (Petersen, 2016). Previous studies revealed that among older Thai adults, the prevalence of MCI was greater than expected, ranging from 16.7 to 71.4%. (Deetong-on et al., 2013; Griffiths, Thaikruea, Wongpakaran, & Munkhetvit, 2020) while worldwide affects between 6.7% to 25.2% of adults over 60, and prevalence rises with advanced age (Petersen et al., 2018). Although several studies measure postural control in MCI, the results still conflict. The MCI might experience postural sway more than those without MCI, but the result has not been concluded about the direction of sway. However, the outcomes of the studies are still questioned. The variety of study approaches may be the reason for this. In order to have proper reliability, the method of measurement needs to be established. Due to this, the researchers studied the reliability of measuring postural control in older adults with MCI during quiet stance and calculated COP in AP and ML directions.

**Objective of study**

To determine the within- and between-session reliabilities as well as minimal detectable change (MDC) of the COP parameters during the standing with various conditions in older adults with MCI

## Literature review

Postural control integrates different kinds of information. The movement is composed of the following three components: task, environment, and individual. Postural control is one of the task components required for 2 proposed which are stability and orientation (Shumway-Cook & Woollacott, 2017). Both are the main features of all the movements. The state of maintaining the body in an upright position is called stability which needs the interaction of body components to maintain the center of mass (COM) to be within the base of support (BOS). The quiet stance is an essential part of our everyday lives, requiring the sensory, central nervous, and musculoskeletal systems to collaborate to maintain posture. The sensory system collects information from different body parts; somatosensory, visual, and vestibular inputs, and sends those pieces of information to the central nervous system in order to direct a response to adjust the body's position by activating the muscles (Horak, 2006; Maki & McIlroy, 1996; Massion, 1992; Shumway-Cook & Woollacott, 2017). However, the ability to maintain a steady posture and an upright position may decline with age and also be affected by several medical conditions.

Mild cognitive impairment (MCI) is an early stage of dementia that affects the neurocognitive domains which has 2 subtypes of MCI: amnestic and non-amnestic MCI. (Petersen et al., 2010). Executive function, perceptual-motor function, learning and memory, and complex attention related to information processing are included in the neurocognitive domains (Sachdev et al., 2014). The neurocognitive domains are important for a lot of different parts of the movement, and they may also be involved in controlling posture. (Blümle et al., 2006; Muir-Hunter et al., 2014; Redfern, Jennings, Martin, & Furman, 2001). Static balance is a motor skill that deteriorates with age and appears to be related to cognitive function in older people (Tell, Lefkowitz, Diehr, & Elster, 1998). Although it might be difficult to recognize a motor function impairment in the early stages of cognitive impairment. A decline in cognition has been associated with stability (Hauer et al., 2003). According to the theory, older adults, and those with pathology in involved systems who experience deterioration or abnormal of physiological function are more likely to decrease their abilities to maintain postural control (Al-Momani, Al-Momani, Alghadir, Alharethy, & Gabr, 2016; Davie, 2008; Pu et al., 2015; Tyson, Hanley, Chillala, Selley, & Tallis, 2006).

As mentioned previously, the central nervous system is one of the components of postural control and performs any movement. Mignardot, Beauchet, Annweiler, Cornu, and Deschamps (2014) found an association between declining cognitive function and declining balance performance, which can provide an indicator of changes in sensory integration processing in older adults. However, postural control in older adults with MCI remains unclear in the literature. Previous studies showed that processing visual information is impaired in MCI, and this visual deficit could be useful to detect subtle changes in postural control (Borges, Carneiro, Zaia, Carneiro, & Takayanagui, 2016). However, the systematic review included four studies that demonstrated that static balance seems to be affected in those with MCI in both AP and ML sway directions during eye open but not while eye closed (Bahureksa et al., 2017). It was also suggested that more studies should be considered for the analysis. Deschamps, Beauchet, Annweiler, Cornu, and Mignardot et al. (2014) and Leandri et al. (2009) found older adults with MCI had more AP direction sway than healthy adults. According to Mignardot et al. (2014), found that the AP direction had more sway in MCI, though there was some caution regarding the history of falls that affected this sway. In contrast, Merlo et al. (2012) reported that older adults with MCI had ML direction sway different from healthy on the unstable surface condition while eyes open and suggested this condition should be evaluated in this population. However, another systematic review by Cieslik, Jaworska, and Szczepanska (2019) could not be concluded due to the small number of studies examining various methodologies of postural control in MCI.

All the findings indicated that more investigation into postural control in MCI, as well as the investigation of appropriate methodologies, was required. Measuring quiet stance under various conditions may be beneficial because no study has demonstrated the reliability of measuring COP in MCI.

## Methodology

### Participant

The sample size of participants was calculated using a website calculator (Walter, Eliasziw, & Donner, 1998) with the minimum acceptable reliability value set as 0.5, the expected reliability value set as 0.9, the alpha level set as 0.05, and the power level set as 80 percent. According to the calculation, there were 11 people required. The inclusion criteria included older adults aged 60 or older genders met the MCI criteria that had The Montreal Cognitive Assessment (MoCA) scores below 25 (Julayanont et al., 2015), no dementia (screening with TMSE), and independent activities in daily life (screening with brothel index), able to walk without an assistant. The exclusion criteria excluded those who had severe musculoskeletal pathologies, neurological disorders, taking medication affects posture control, alcoholism, vision problems, vestibular disorder, dizziness or vertigo, and depression. No heavy exercise and alcohol 24 hours before the appointment.

### Procedure

The assessment consisted of four conditions included 1) standing with eyes open on a firm surface, 2) standing with eyes closed on a firm surface, 3) standing with eyes open on the foam surface, and 4) standing with eyes closed on the foam surface. The condition measures 3 trials, 35 seconds for each condition. The participants were instructed to stand still as possible facing forward and concentrating with a mark at eye level at 2 meters in front of them. The feet' position was shoulder-wide range while the arms were at their side. The rest period of 1 minute between trials and 2 minutes between conditions. The sequent was randomized.

**Data processing**

The force platform, designed by Bertec (Bertec Crop., Columbus, OH) was used with 1200 Hz sample rate. Before calculating the COP, the force was filtered using a fourth-order Butterworth filter with a 6 Hz cutoff frequency. The 2.5-second pre- and post-data were eliminated. Four traditional sway measures were calculated to the displacement and velocity in both AP and ML directions. The first session's data from each trial resulted in a calculation of the within-session reliability. In addition, in order to determine the between-session reliability, the average values of the three trials in both the first and second sessions were also evaluated.

**Data analysis**

The Windows version of SPSS 28.0 was used for all statistical analyses (SPSS Inc, 233 S Wacker Dr, 11th Fl, and Chicago, IL 60606). Relative reliability using the intraclass correlation coefficient (ICC). Within-session (ICC3,1) and between-session (ICC3,3) reliability of the ICC, standard error of measurement (SEM), and minimal detectable change values (MDC) were presented. The significance level was set at $P < 0.05$. The levels of ICC were assessed as follows: > 0.75 was excellent, 0.4-0.75 was fair to good, and 0.4 was poor (Fleiss, 2011).

## Results

In the present study, 11 older adults with MCI participated. The demographic data and characteristics of the participants are shown in Table 1. For the reliability of COP in each condition are presented in Table 2.

**Table 1:** Demographic and characteristics of participants (n = 11)

| Participant | Mean ± SD |
|---|---|
| Gender | 3 males 8 females |
| Age (years) | 64.90 ± 2.98 |
| Height (cm) | 160.73 ± 7.79 |
| Weight (kg) | 63.08 ± 12.08 |
| BMI ($m^2$/kg) | 24.27± 3.56 |
| MoCA scores | 21.64 ± 1.82 |

**Table 1:** (Cont.)

| Medical conditions; n (%) | |
|---|---|
| - Cardiac arrhythmia | 2 (18.18) |
| - Diabetes | 4 (36.36) |
| - Hypertension | 6 (54.45) |
| - Hyperlipoidemia | 7 (63.63) |
| **History of falls; n (%)** | |
| Falls; 1 (9.10) | No falls; 10 (90.90) |
| **Exercise; n (%)** | |
| Exercise; 8 (72.72) | No Exercise; 3 (27.27) |

*BMI ; Body Mass Index*
*MoCA scores ; The Montreal Cognitive Assessment scores*

As shown in Table 2, the result was reported in each condition following:

1. Standing with eyes open on a firm surface

The ICC values of all variables are shown within session ranged from -0.093 to 0.796 and SEM values ranged from 0.088 to 0.522. While between sessions is shown the values ranged from 0.533 to 0.906, SEM values ranged from 0.048 to 0.226, and MDC values ranged from 0.134 to 0.628.

2. Standing with eyes open on the foam surface

The ICC values of all variables are shown within session ranged from 0.005 to 0.270 and SEM values ranged from 0.242 to 0.580. While between sessions is shown the values ranged from -0.246 to 0.774, SEM values ranged from 0.084 to 0.425, and MDC values ranged from 0.232 to 1.179.

3. Standing with eyes closed on a firm surface

The ICC values of all variables are shown within session ranged from 0.023 to 0.657 and SEM values ranged from 0.067 to 0.289. While between sessions is shown the values ranged from -0.540 to 0.827, SEM values ranged from 0.059 to 0.327, and MDC values ranged from 0.165 to 0.907.

4. Standing with eyes closed on the foam surface.

The ICC values of all variables are shown within session ranged from -0.069 to 0.523 and SEM values ranged from 0.200 to 0.598. While between sessions is shown the values ranged from -0.535 to 0.800, SEM values ranged from 0.113 to 0.301, and MDC values ranged from 0.312 to 0.835.

**Table 2:** The reliability of COP, SEM, and MDC values in 4 conditions

| Condition/Parameter | Within-session | | Between-session | | |
|---|---|---|---|---|---|
| | ICC (95% CI) | SEM | ICC (95% CI) | SEM | MDC |
| 1. standing with eyes open on a firm surface (n=11) | | | | | |
| *COP displacement (ML)* | 0.526 (0.158-0.822) | 0.308 | 0.906 (0.651-0.975) | 0.098 | 0.271 |
| *COP displacement (AP)* | -0.093 (-0.322-0.340) | 0.522 | 0.533 (-0.736-0.874) | 0.226 | 0.628 |
| *COP velocity (ML)* | 0.796 (0.545-0.934) | 0.088 | 0.905 (0.646-0.974) | 0.067 | 0.186 |
| *COP velocity (AP)* | 0.146 (-0.179-0.581) | 0.172 | 0.817 (0.320-0.951) | 0.048 | 0.134 |
| 2. standing with eyes open on a foam surface (n=11) | | | | | |
| *COP displacement (ML)* | 0.036 (-0.250-0.483) | 0.494 | -0.246 (-3.630-0.665) | 0.425 | 1.179 |
| *COP displacement (AP)* | 0.181 (-0.154-0.610) | 0.580 | 0.774 (0.160-0.939) | 0.178 | 0.495 |
| *COP velocity (ML)* | 0.005 (-0.268-0.452) | 0.244 | 0.739 (0.030-0.930) | 0.084 | 0.232 |
| *COP velocity (AP)* | 0.270 (-0.087-0.674) | 0.242 | -0.242 (-3.618-0.666) | 0.151 | 0.418 |
| 3. standing with eyes closed on the firm surface (n=11) | | | | | |
| *COP displacement (ML)* | 0.335 (-0.032-0.717) | 0.166 | 0.827 (0.357-0.953) | 0.093 | 0.258 |
| *COP displacement (AP)* | 0.023 (-0.258-0.470) | 0.289 | -0.540 (-4.723-0.586) | 0.327 | 0.907 |
| *COP velocity (ML)* | 0.657 (0.323-0.880) | 0.067 | 0.691 (-0.149-0.971) | 0.059 | 0.165 |
| *COP velocity (AP)* | 0.026 (-0.256-0.473) | 0.227 | 0.653 (-0.291-0.907) | 0.069 | 0.190 |
| 4. standing with eyes closed on the foam surface (n=11) | | | | | |
| *COP displacement (ML)* | 0.523 (0.154-0.820) | 0.409 | 0.800 (0.257-0.946) | 0.180 | 0.500 |
| *COP displacement (AP)* | 0.236 (-0.113-0.651) | 0.598 | 0.491 (-0.892-0.863) | 0.301 | 0.835 |
| *COP velocity (ML)* | 0.046 (-0.244-0.492) | 0.200 | 0.051 (-2.526-0.745) | 0.113 | 0.312 |
| *COP velocity (AP)* | -0.069 (-0.309-0.370) | 0.325 | -0.535 (-4.704-0.587) | 0.116 | 0.322 |

*COP displacement (AP and ML); Center of Pressure displacement in the mediolateral or anteroposterior direction*
*COP velocity (AP and ML) ; Center of Pressure velocity in the mediolateral or anteroposterior direction*

## Discussion and conclusion

To our knowledge, this study was the first to illustrate the between- and within-section reliability of COP parameters in older adults with MCI during quiet stance. The reliability of the within section showed poor to excellent reliability, mostly poor reliability. There are substantial differences in the reliability of each COP parameter. The result indicated that only a trial of all COP parameters might not be suitable to quantify the postural sway in this group except the COP velocity in the ML direction which can be measured in standing with eyes open on a firm surface condition, was only a parameter that showed excellent reliability. The others condition in this parameter showed poor reliability which does not recommend measuring in older adults with MCI. However, COP velocity in the ML direction had fair to good reliability in standing with eyes closed on a firm surface condition as well. Another parameter that should be used with some caution was COP displacement in ML direction that showed fair to good in standing with eyes open on a firm surface and standing with eyes closed on a foam surface. However, most parameters showed that one trial is not appropriate for data processing, these parameters should be considered to measure postural control in this population if used on average over 3 trials because they demonstrated excellent reliability in all parameters but just in some conditions. Although, researchers controlled every part of the methodology between 2 sections of this study. However, only some parameters can be used. The study can demonstrate that the COP displacement in the ML direction seems to be the most suitable parameter to measure postural control in quiet stance which represents the consistency of their balance performance and methodology in both sections. It can be used in all conditions except standing with eyes open on a foam surface condition. Next, COP displacement in the AP direction can be measured only in standing with eyes open on a foam surface condition. In addition, both COP velocity ML and AP directions showed that can be measured in standing with eyes open on a firm surface condition in this population.

As the results, this can demonstrate that there is a limitation of COP parameters to evaluate in older adults with MCI. Although, the COP has been used as a traditional parameter to measure postural control in numerous populations but lacks in MCI. However, this might be the limitation of these parameters which cannot generate and explain the structure of their performance. Either way, in each trial of standing conditions calculating COP displacement and velocity in AP and ML directions that are inconsistent in older adults with MCI. This might be due to the brain function related to postural control in this group is still questioned. During measurement, the mechanism and responsiveness of the performance might not be able to function properly and consistently. This investigation can show that the MCI approach currently lacks sufficient data for measurement. This could be the cause of the ongoing uncertainty around postural control in MCI and previous studies which measured the COP trajectory to assess postural control in MCI still showed a variety of results.

In conclusion, the COP velocity in the ML direction showed only consistently excellent value of within-section reliability, and the COP displacement in ML showed consistently excellent values of between-section reliability in most conditions. The number of trials must be taken into account in measurement. Only a trial is not recommended to measure in these COP parameters except COP velocity in ML direction in standing with eyes open on a firm surface condition only. At least 3 trials of measurement should be measured. Thus, these COP parameters must be considered before being used in older adults with MCI.

## Suggestions

The findings suggested that researchers should be more concerned to study the methodology in older adults with MCI. The variety and nature of this population can show the different strategies of postural control. Although the COP trajectory is the common analysis method to measure in various populations using the force platform to generate the signal, researchers need to consider the COP parameters. Due to the complexity of posturographic data, it requires a suitable technique for processing the data and interpreting the results. Other COP parameters such as COP frequency domain parameters should be considered. However, nowadays many experts have found that there are other parameters that are more suitable for detecting a subtle change in postural control. The processing data of the nonlinear analysis method should be considered to measure postural control in older adults with MCI as well. Further study of postural control in MCI will be useful for healthcare professionals working with people with MCI and their caregivers to promote health and prevent falls.

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