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Original article

The assessments of body sway on the static standing using the center of pressure

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Abstract

The Center of Pressure (COP) has been used in evaluation of balance and motion analysis research. When it is measured with such a platform systems, the COP is defined as the center of the total number of active transducers for each data sample collected. Smaller magnitude of the COP movement on static standing reflects greater ability of postural control. On the contrary, bigger magnitude of the COP movement on static standing reflects poorer ability of postural control. Though this theory has been supported by some researches, there are some exceptions.
To clarify the meaning of measuring the COP movements on static standing, we focused on some parameters concerning the COP, reliability and validity of the COP, the way to use, the COP movements of static standing with balance disabled people, the effect of aging on static balance, the relationship between gender and static balance, the effect of a low alcohol dose, and the balance of the day.

Key words : COP, static balance, evaluation

1. Introduction

The evaluation of static balance is obtained in the standing subject with devices that reflect the movements of the body or its center of gravity, or mostly, the center of pressure (COP). The COP has been used in evaluation of balance and motion analysis research since Elfman (1939) first used it and has become increasingly popular with the advent of floor-mounted transducer matrix systems. When it is measured with such a platform systems, the COP is defined as the center of the total number of active transducers for each data sample collected.

As to evaluating the postural control ability using the COP, it has been assumed that magnitude of the COP movement is directly associated with the ability of postural control. Smaller magnitude of the COP movement on static standing reflects greater ability of postural control. On the contrary, bigger magnitude of the COP movement on static standing reflects poorer ability of postural control. This theory has been supported by some researches, and it has been thought that orthopedic impairment, sensory disturbance with age, fatigue, and so on make the COP movement on static standing bigger. There are some exceptions on this theory. For instance, the magnitude of COP movement on static standing with Parkinson disease is smaller than healthy people with same age. (Panzer and Hallett, 1995; Horak, 2005) On the other hand, the COP movement on static standing of a Flamenco dancer who has higher dancing skill is bigger than ordinary people with same age(Bejjani, 1988). In figure 1, the example of the COP movements of static standing with healthy adult are shown.

The purpose of this study is to confirm the meaning of evaluating the COP movement on static standing. Especially, we focused on the parameters, reliability and validity, the way to use, evaluation of static balance with balance disorders, the relation-

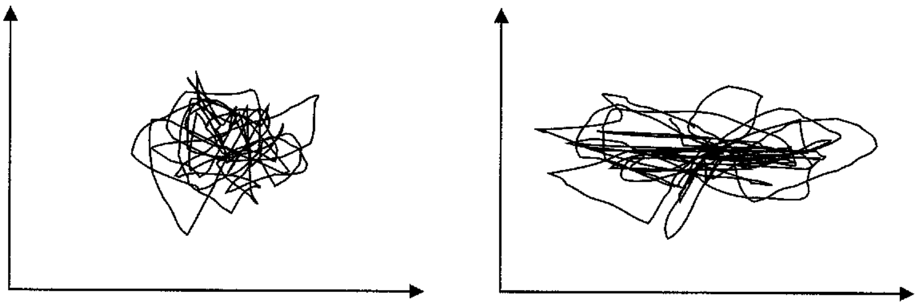

Fig. 1 The trajectory of the COP recorded with eyes open (left) and closed (right)

ship between age and static balance, and other states and factors affecting the COP movements.

2. The parameters of the COP on static standing

The COP co-ordinates are derived from ground reaction forces registered with the aid of a force platform. All the proposed parameters describe some aspect of the complicated movement pattern termed body sway and stability. Besides the length of the COP trajectory, and its equivalent, the mean velocity of the COP movements, the maximal range of the movement in perpendicular horizontal dimensions and the total area of the horizontal planar domain of the COP and statistical derivations such as the standard deviation of the displacement in both directions and combinations thereof, have been used by several authors (Lord SR, 1991; Dean EM, 1986). A dimensionless combined stability parameter derived from phase plane analysis has also been proposed.

Collins and DeLuca (1995) proposed different researches concerning body sway. They describe the data in the form of a so called diffusion stabilogram by analogy with the random movements of liquid molecules. The squared distance between randomly chosen pairs of COP is plotted against the corresponding time interval, a mean squared critical displacement and diffusion constant. The results of similar single parameters obtained with different equipment have been compared in the literature, for instance, the length of the COP trajectory and the area of movement with force platform. Still we can not tell what parameters concerning body sway provides the most useful information, i. e. is most effective in discriminating between individuals with low and those with an elevated risk of falling or morbid conditions, and which is responding most to changes of the situation in which the individual is maintaining his or her standing balance. Furthermore, it is uncertain that data derived from body sway on static standing is useful to obtain certain information about the ability of balance needed in a daily living, the falling risk on gait, and the necessity of walking devices for him/her. Common parameters of the COP and their definition were shown in table 1.

3. Reliability and validity of the COP

In previous studies, many evaluation parameters for the COP in a static standing posture have been proposed, and their reliability and interrelationships have been examined (Demura, 2006; Cornwall, 2003; Pinsault, 2008).

Cornwall and his colleagues (2003) examined the reliability and validity of the COP. As a result they showed that intraclass correlation coefficient values ranged from 0.374 to 0.889 for the lateral-medial area index and from 0.215 to 0.905 for the lateral-medial force index. They concluded that the lateral-medial are index and the lateral-medial force index may have adequate between-trial reliability. Demura and his colleagues (2006) examined trial-to-trial reliability and the interrelationships of various evaluation parameters. They used seventy-six evaluation parameters from 114 parameters proposed in previous studies. Distance, the COP, distribution of amplitude, area, velocity, power spectrum, and vector for body sway, were used as the data. They concluded that the intraclass correlation coeffi-

Table 1 Definition of COP parameters

Parameters	Dimension	Meaning
Planar deviation	cm	estimated standard deviation of x and y
Range anterior-posterior	cm	$\|ymax-ymin\|$
Range medial-lateral	cm	$\|xmax-xmin\|$
Displacement velocity	cm/s	$\frac{\sqrt{\{(xi-xi-1)2+(yi-yi-1)2\}}}{ti-ti-1}$
Mean velocity	cm/s	$\frac{\Sigma Vd}{n}$
Phase plane parameter	No dimension	the velocities in x and y-demension
Area	cm^2	surface contained within the closed curve including all record COP
Diffusion constant	mm^2/s	slope of regression line through points beyond the critical time interval in the diffusion stabilogram
Critical time interval	s	interval at which the slope of the regression of the mean squared distance between random pairs on their time interval in a diffusion stabilogram shows a significant break towards a more shallow regression than the initial one
Mean squared critical displacement	mm^2	mean squared distance between random samples of COP pairs in the diffusion stabilogram with a time difference corresponding to the critical interval

cient was 0.7 or over, except for the following parameters: the x-axis and the y-axis distribution for body sway and body sway speed, and the cross correlations for body sway and body sway speed.

4. The way to use the COP

The COP measurements are used very often in the study of static balance and gait analysis. In the gait analysis, the COP path or gait line during the stance phase of walking has been used in a variety of research studies. Another use of the COP measurement in gait analysis has been in the investigation of foot function. The rationale for such a use has been the theory that the COP path is a direct result of foot pronation and supination during walking. On the basis of this theory, Kato (2000) proposed using the COP as a means of evaluating the efficacy of foot orthoses. McPoil and his colleagues (2000) used the COP pattern to investigate three different types of foot orthoses. By integrating the medial-lateral area under the COP displacement time curve, they demonstrated that all three types of foot orthoses significantly reduced the mediolateral excursion of the COP if the individual had a forefoot valgus deformity.

Corriveau H and his colleagues (2004) criticized about the way to evaluate postural control using the COP only. One limitation of using the COP alone to evaluate postural stability is that it measures the secondary consequences of swaying movements, movements of the COM, and not the movements themselves. It has been suggested the combined analysis of the movement of the COP and COM during quiet stance and dynamic activity provides better insight into the assessment of balance than analyzing either variable alone.

Recently, the COP-the whole body center of mass (COM) distance has been proposed as a variable sensitive to changes or problem in postural stability. The COP-COM distance measured at a given time may enhance the interpretation of the COP and COM displacements and provide better insight into postural control. Static postural control as well as dynamic stability during activities such as rising from a chair, stair climbing, stepping over obstacles, and gait initiation have been evaluated using this technique (Martin M, 2002; Chang H, 1999).

5. Evaluation of static balance with balance disorders using the COP

Quantification of the movement of the COP during quiet stance has provided useful insight into postural control deficiencies in balance-challenged people. So in the previous studies, evaluation of static balance with balance disorders using the COP has been shown.

Armand S and his colleagues (2008) researched about postural stability with Parkinson disease not only when OFF, but also while being ON with levodopa-induced dyskinesia (LID) using the COP. They found a significant increase of the COP displacement in all parameters when patients were ON with dyskinesia compared to the OFF state. Patients demonstrated a tendency to sustain their weight on the foot less affected by dyskinesia, as a compensatory mechanism. They concluded that LID may compromise balance and independently contribute to postural instability in advanced Parkinson disease.

Chasten and his colleagues (2008) measured postural instability in early stage Parkinson's disease. The COP movements were recorded with open eyes and closed eye states. Under static conditions with both open eyes and closed eyes, subjects with Parkinson's disease had a larger COP sway area than the healthy subjects. They concluded that all subjects used an ankle strategy, but early stage Parkinson's disease had larger head oscillations than the healthy subjects. Early stage Parkinson's disease patients have an infraclinical postural instability which is compensated when it is more difficult to maintain good balance, suggesting that the neurological mechanisms of balance are partially still operating at this stage of the disease.

Maejima and his colleagues (2004) clarified the effect of postural deformation. They could not find significant difference among the five groups concerning postural deformation on the COP movement in quiet standing. However, the results of measured items concerning the ability to control the center of gravity (COG) during movement were significantly worse in the subjects with postural deformation compared with the normal group. They concluded that postural deformation in elderly persons effects exclusively on the ability to control the COG during movement in standing balance.

Static balance of 14 patients with diabetic polyneuropathy and 11 with sensory neuron disease (SND) were assessed. (Nardone and his colleagues; 2007) Patients with SND show unsteadiness under static condition, particularly with eye closed. They concluded that the patchy sensory loss of SND, disrupting sensation from territories vestibular nerve, could be responsible for this instability.

There are a lot of studies investigating static balance of patients with multiple sclerosis (MS). (Davide C, 2000; Karst GM, 2005) As the patients with MS have balance disorders, all studies show clear differences when comparing healthy adults with even minimally impaired adults with MS.

6. The relationship between age and static balance

The relationship between age and static balance was also reported by some researchers. Amiridis IG and his colleagues (2003) examined the effect of aging on static balance using electromyography (EMG) and the COP movement. Both young and older groups increased postural sway as a result of narrowing the base of support and older adults displayed increased hip movement accompanied by higher hip EMG activity, whereas no similar increase was noted in the younger group. It is concluded that older adults rely more on their hip muscles when responding to self induced perturbations introduced by increased task constraints during quiet standing. Same results concerning older static balance were shown by Perrin PP and his colleagues (1997).

Rival and his colleagues (2005) investigated the time course by which children aged 6 to 10 years old adapt and maintain their static balance. They reported that with age, the range of the COP decreased non-monotonically, with a maximum at 8 years from 6 to 10 years of age, and over time, both parameters decreased and stabilized, similarly for all age groups. It is concluded that the processes underlying the maintenance of an optimal postural stability are mature at least as soon as 6 years of age.

7. Other states and factors affecting the COP movements

Some researchers reported about several factors and states affecting the COP movement on static standing besides balance disorders.

Kitabayashi and his colleagues (2004) examined gender differences in 4 factors of the COP, unit time sway, anterior-posterior sway, medial-lateral sway, and high frequency band power, during static upright posture. They found significant gender differences in medial-lateral sway and high frequency band power. Female showed the greater COP movement and higher frequency band power on static standing than Male.

Mangold S and his colleagues (1996) researched about the effects of a low alcohol dose on static balance and mental performance. It was demonstrated that a low alcohol dose (men 0.54g and women 0.44g alcohol per kg body weight) has enough effects on static balance and mental performance. The static balance test proved to be a sensitive, fast, and atraumatic method to identify slight neurotoxic disturbance.

There are some studies investigating time-of day influences on static postural control. Gribble and his colleagues (2007) determined the influence of time of day with 30 healthy college-aged students. For static postural control, velocity scores in both directions were lower at 10: 00 than at 15: 00 and 20: 00 on day. They concluded that postural control may be better in the morning than in the afternoon or evening. Forsmann and his colleagues (2007) investigated the effect of daytime on balance, on posturographic measurements, and on their repeatability in 30 healthy volunteers. The daytime effect was assessed by measuring balance at 8: 30 am, 10: 30 am, and 1: 30 pm. As results, the balance of the day was worse than that of in the morning.

8. Conclusion

We reviewed the studies written about the COP movements on static standing.

1) The COP co-ordinates are derived from ground reaction forces registered with the aid of a force platform. We can not tell what parameters concerning body sway provides the most useful information.
2) The intraclass correlation coefficient of the COP was 0.7 or over. We can tell that the evaluation of static balance using the COP is almost reliable method.
3) The COP-COM distance measured at a given time may enhance the interpretation of the COP and COM displacements and provide better insight into postural control.
4) The patients with Parkinson's disease, sensory neuron disease, and multiple sclerosis showed a larger COP sway area than the healthy subjects.
5) Both young and older groups increased postural sway as a result of narrowing the base of support and older adults displayed increased hip movement.
6) The processes underlying the maintenance of an optimal postural stability may be mature at least as soon as 6 years of age.
7) Female showed the greater COP movement and higher frequency band power on static standing than Male.
8) A low alcohol dose (men 0.54g and women 0.44g alcohol per kg body weight) had enough effects on static balance and mental performance.
9) The balance of the day was worse than that of in the morning.

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