The Suitability of the Force Plate to Evaluate the Stability During Quiet Standing and Analyzing the Effects of Shoes, Gender and Age on the Standing Stability

Kuvvet Platformlarının Ayakta Durma Stabilitesini Değerlendirmede Uygunluğu, Ayakkabı, Cins ve Yaşın Ayakta Stabiliteye Etkilerinin Analizi

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ABSTRACT

Objective: The main aim of this research study was to check the effects of efficiency of the force plate to determine the effects of some parameters such as heel height, age and gender on the stability during quiet standing. Moreover, it was aimed to determine the best parameters which can be used to represent the stability.

Methods: A group of 50 normal subjects, 25 females and 25 males, from the staff and students of Bioengineering Unit of University of Strathclyde were recruited and asked to stand on the force plate for one minute. They were selected according to their age and their health conditions. Specific tests were repeated 5 times for each subject. The difference between the mean values of the stability parameters was tested by using student t test and paired t test.

Results: The results of this study showed that the force plate is quiet sensitive to be used to represent the standing stability. Moreover, COP based parameters are more sensitive to be used in this regards. There was no significant difference between stability of male and female participants.

Conclusion: Using parameters based on the COP sway can represent stability better than those parameters based on the forces applied on the force plate. *(J PMR Sci 2010;13:140-5)*

Keywords: Force plate, COP sway, stability

ÖZET

Amaç: Bu araştırmanın temel amacı topuk yüksekliği, yaş ve cins gibi parametrelerin ayakta durma stabilitesine etkilerini saptamakta kuvvet platformunun etki ve etkinliğini saptamaktır. Ayrıca stabiliteyi yansıtan en iyi parametrenin belirlenmesi amaçlanmıştır.

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Yöntemler: Strathclyde Üniversitesi Biyomühendislik biriminde görev yapan ya da eğitim gören 25 erkek, 25 kadın toplam 50 normal denek çalışmaya katıldı ve kuvvet platformunda 1 dakika ayakta durmaları istendi. Denekler yaş ve sağlık durumlarına göre seçildi. Spesifik testler her denek için 5 kez tekrar edildi. Stabilite parametreleri ortalamaları arasındaki fark student t testi ve eşleştirilmiş örnekler arası fark testi ile incelendi..

Bulgular: Bu çalışmanın sonuşları kuvvet platformunun ayakta stabilitenin değerlendirilmesinde oldukça duyarlı bir yöntem olduğunu gösterdi. Ayrıca basınç merkezi temelli parametreler bu amaçlı kullanılabilecek daha duyarlı parametrelerdir. Erkek ve kadın katılımcıların stabiliteleri arasında fark yoktu.

Sonuç: Stabilitenin belirlenmesinde basınç merkezine dayalı parametreler kuvvet platformuna etkiyen kuvvetlere ait parametrelerden daha iyidir. *(FTR Bil Der 2010;13:140-5)*

Anahtar kelimeler: Kuvvet platformu, basınç merkezi kayması, stabilite

Introduction

Stability during standing is achieved by a complex process that involves coordination activities of multiple sensory and motor components. In normal subjects, stability is achieved by coordinative motions that occur in the ankle, knee and hip joints and are done by muscles around theses joints (1). Some strategies such as head movement strategy, trunk strategy, hip, knee and ankle strategies can be used in order to maintain stability. However, in patients it can be enhanced by using external support like an orthosis, that restricts the unnecessary motion of the paralyzed joints during standing (1).

There are two different methods that are used exclusively to check the stability during quiet standing. The first method was developed by Rowery at the beginning of the nineteenth century and was based on body sway under opened and closed eyes (1). The difference in body sway during standing with opened and closed eyes is represented by the functional performance of the somatosensory system.

The second method is to check stability when an unexpected distribution force is applied on the subjects during standing (1). The first method is a common method and is used to evaluate the amount of stability during quiet standing and while doing hand tasks. To assess the stability the location of the COP is checked during a period of time. There are a lot of different parameters that have been used to represent the stability, these include:

a) The COP path length (2,3)

b) The COP excursion (2,4)

c) Average speed of the COP change (5)

d) Mean amplitude of the COP sway (5)

e) Standard deviation of the force applied on the force plate (6)

f) Standard deviation of the COP sway (6)

g) Hip joint motion in standing position (7)

The reliability of the above mentioned parameters depends not only on the accuracy of the instrument but also on the procedure that is used to analyze stability. The repeatability and validity of these parameters depends on the durations of the test and the number of trials carried out (8-10). The condition of the subject during the test, type of wear (the heel height of the shoes), time of data collection, numbers of trials, frequency of collecting data and filtering procedure influence the final results. As can be seen, there is a high level of variability between the researches undertaking to represent the standing stability. Unfortunately, there is not a standard method for doing the stability test, some researchers did not ask the subjects to remove their shoes, while other asked that shoes and socks to be removed. Moreover, the duration of the test and method of filtering varies between the investigators.

There is no consensus in the literature regarding gender differences in stability. The results of the research carried out by Goldie et al (1989), which was done on 14 female and 14 males participants showed that the difference between genders regarding stability was not significant (11). However, it was assumed that the difference between body height of men and women contributes to the poorer stability of men compared to women (12). Ekhdahl et al (1989) showed that females are more stable than males (13). In contrast Overstall found that men are more stable than women in standing (14). Other researchers found no difference between the stability between females and males (12,15).

The other parameter which can influence the stability during quiet standing is wearing shoes. It is well known that the priority role of a shoe is to protect the feet and facilitate propulsion and to improve the performance of the subject in walking and standing. Some parameters such as heel height, sole cushioning properties, collar height, sole flaring, slip resistance sole properties can influence the performance of the subjects while standing and walking (16). However, it can not be concluded based on the results represented in the literature, that wearing shoes can influence stability significantly or not?

It can not be concluded which parameters can be used to represent the stability during quiet standing more efficiency. As there are a lot of variation between the methods selected by investigators, such as the time of data collection and filtering process, it is not possible to have a strong conclusion regarding selecting of parameters (17).

So the main aim of this research project was to do stability test according to a standard way to find the more sensitive, parameters which can represent the effects of aging, gender, body height and weight on stability during quiet standing. Moreover, it was aimed to find the effects of wearing shoes, gender, age and body height on standing stability during quiet standing.

Materials and Methods

Equipment: A Kistler force plate instrumented with piezoelectric force transducers was used to measure the centre of pressure which is considered to be a good approximation of sway. Sway during standing is defined by movements of Centre Of Gravity (COG) in a horizontal plane (16). These movements are due to small deviations of the vertical ground reaction vector. Many researchers have studied sway by measuring the COP on the force platform (18,19).

The force plate and the amplifier associated with it produce six voltage outputs that represents the mechanical inputs in: F_X, F_Y, F_Z, M_X, M_Y, M_Z, which are the forces and moments applied on X, Y, and Z axes. The locations of the COP can be determined according to the following equations (20,21):

$$x_i = \frac{(0.057F_X + M_Z)}{F_y} \qquad \text{Equation 1}$$

$$x_i = \frac{(0.057F_X - M_Z)}{F_y} \qquad \text{Equation 2}$$

Whereby 0.057 metre is the thickness of the force plate.

Subjects

Table 1 shows the number and characteristics of the subjects participated in different parts of this research. The subjects were recruited from the students and staff members of Bioengineering Unit of University of Strathclyde. They reported to have no musculoskeletal disorder, neurological illness, degenerative conditions or any diseases that would interface with their normal balance. Before starting data collection an ethical approval was obtained from Strathclyde University ethical committee. In the first part of the research the difference between the stability parameters of the male and female participants was evaluated. In the second part the effect of the shoe on stability was evaluated. The subjects were asked to wear a sport shoes with a heel height between 1 and 2 cm. The main reason for undertaking the third part of this research was to measure the stability of a group of normal subjects according to a standard way which can be used as a data base in other research projects.

Parameters

The parameters which were used in this research included:

a) Amplitude of anteroposterior COP sway (AAP)

b) Amplitude of mediolateral COP sway (AML)

c) Mean amplitude of anteroposterior COP sway (MAAP)

d) Mean amplitude of mediolateral COP sway (MAML)

e) Standard deviation of the force in anteroposterior direction (SFx)

f) Standard deviation of the force in mediolateral direction (SFy)

g) Standard deviation of the COP sway in anteroposterior direction (SAP)

h) Standard deviation of the COP sway in mediolateral direction (SML)

Procedure

The accuracy of the force plate according to the manufacturer's manual is high and the error of the system is less than 1% (22). However, to maintain a guarantee of the output quality some tests were carried out to evaluate the accuracy of the data for shear loads both in the mediolateral and anteroposterior directions and also for vertical loads. The results of force plate calibration showed that the errors of the system was not high, however it was more than supposed to be (between 1 and 2%).

In the next stage subjects were instructed about the procedure and instruments. Then their weight and their height were measured and recorded. The subjects were asked to stand on the force plate; they were instructed to look straight ahead, with their head erect and their arms at their sides in a comfortable position. The tests were recorded for one minute and were repeated 5 times for each subject (10). Analogue signals were sampled at a frequency of 120 Hz with an analogue to digital convertor and were stored on a computer. The signals of the force plate were filtered with a Butterworth low-pass filter at 10 Hz (5,10). The first and last 15 seconds of the data were deleted and only 30 seconds of the data were used for the final analysis. The 30 seconds of the data was used to show the absolute sway of the COP. The first and last 15 seconds of the data were deleted as the subject may have some small motions during the first part and have some muscle fatigue at the last part of data collection period. For the second part of the test the subjects were asked to remove their shoes and socks and the same procedure was used.

The normal distribution of all aforementioned parameters was analyzed by use of Shapiro-Wilk test. As the parameters have normal distribution, parametric tests were selected for final analysis. The effects of wearing shoes on the standing stability were evaluated by use of paired-t test. The difference between the stability of male and female was determined by student t test. Moreover, the influence of age on the standing stability was analyzed by use of Pearson correlation test with a significant point as 0.05.

Results

Figure 1 shows the excursion of COP in the mediolateral and anteroposterior planes. The mean values of the stability parameters of the females and males are shown in table 2. As can be seen, there was a difference between the mean values of the stability parameters between genders, however, the difference was not significant. The mean values of the stability parameters during standing with and without shoes are shown in table 3. Although the stability of the participants in standing without shoes was better than that with shoes, the difference was not significant. The difference between the mean values of the stability parameters in standing with and without shoes was analyzed by using paired t test. The results of the Pearson correlation test showed that there was a significant correlation between the age of the participants and the amount of COP excursions in both planes, table 4. The Pearson correlation values were 0.446 and 0.394 for the anteroposterior and mediolateral stability, respectively.

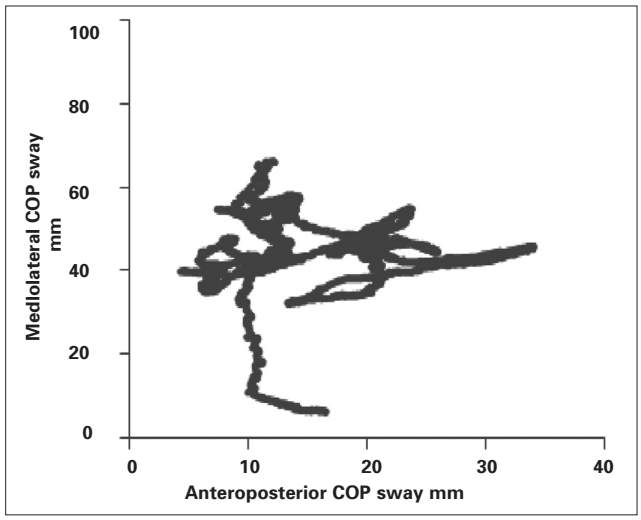

Figure 1. The excursion of COP in the mediolateral and anteroposterior planes (from one subject)

The correlation between the stability and body height was measured in the male and female participants separately. As can be seen from table 5, there is a correlation between some stability parameters and the height of the participants. As it was expected, the stability of longer subjects is less than that of shorter individuals.

Discussion

The results of the stability parameters showed that the stability of the females in the anteroposterior direction is better than males. However, the stability of the males in the mediolateral direction is better than that of the females.

There is no consensus in the literature regarding gender differences in stability. It seems that the stability of female be more than that of male, as the difference between height of men and women contributes to poorer stability of men compared to women. The body weight and height of female and male participated in this research project were nearly the same, so the difference between the stability of the subjects was related to other parameters.

The difference found in the current research may be related to the procedure used to carry out the stability test or to age difference amongst the participants. It worths to be noted that the age of the participants in different studies varies, so any comparison of the results concerning the effect of gender should be made with caution.

The results of this research showed that the amount of stability especially in the mediolateral direction decreased with ageing. This may be related to the effects of ageing on the functions of the systems which are responsible to maintain and control standing stability. It was found that visual, vestibular and somatosensory functions diminish with aging (1). Loss of muscle strength and decreased function of the joint mechano- receptors may be some other factors which influence the stability.

Table 1: The number and characteristics of the subjects that participated in this research

Participants	Number	Age	Height	Weight	Part of the research
Males	25	27.7± 3.45	1.8±0.06	76.2±8	First
Females	25	28± 2.4	1.65±0.06	68±11.8	
Males	25	30.26±8.2	1.74±0.05	76.9± 8.4	Second

Table 2: The mean values of the stability parameters of males and females

Parameters	MAP (mm)	MML (mm)	SFX (N)	SFY (N)	SAP (mm)	SML (mm)	AAP (mm)	AML (mm)
Male	4.33±1.7	2.2±1.05	1.08±0.55	0.622±0.322	5.46±2.15	2.76±1.5	25.66±11.3	15.22±9.02
Female	3.531.3±	2.22±1.15	0.7108±0.27	0.793±0.901	4.36±1.61	2.764±1.32	20.51±6.75	13.76±5.67
p-value	0.298	0.335	0.129	0.476	0.269	0.368	0.174	0.587

Different results concerning the association between balance and age with a platform have been reported. Although the difference between the stability of the young and elderly subjects has been approved by some investigators (23,24), some studies failed to show any significant difference between stability of young and elderly subjects (15,25). The difference between the study results can be caused by many factors, such as the difference between the ages of participants, the method used for data collection and filtering process. However, the mean values of the age of the participants in this research study were 34.4 years, to show the best parameter which can represent the effects of ageing more efficiently.

Although wearing shoes influences stability, the difference between the standing conditions is not significant. This insignificance decrease in stability when using shoes may be related to the effects of heel height on the alignment of the lower limb during standing. The results of the orther research studies which was done with other methods instead of using force plate showed that the heel height of the shoes decreases the stability during quiet standing. The insignificant difference between the stability of the subjects with and without shoes may be related to the sensitivity of the force plate which may not be enough to represent the difference.

Although most investigators use some parameters such as the excursion of the COP in the mediolateral and anteroposterior directions, the results of this research study showed that the sensitivity of the other parameters are more than that of using the excursion, tables 2, 3, 4 and 5. The influences of some parameters such as, age, height on stability can be represented by the standard divisions of the COP in the mediolateral and anteroposterior planes and the COP excursions in the both planes in contrast to other parameters.

There was a limitation that needs to be acknowledged regarding the current study, which was the small size of participants. It was impossible to increase the number of participants, sine it took considerable time and funding.

Table 3: The mean values of the stability parameters during standing with and without shoes

Parameters	With shoes	Without shoes	p-value
MAP (mm)	4.77±1.17	4.3±0.75	0.682
MML (mm)	1.92±0.7	1.42±0.7	0.386
SFx (N)	0.767±0.27	0.71±0.24	0.105
SFy (N)	0.428±0.12	0.395±0.1	0.245
SAP (mm)	5.75±2.1	5.3±0.84	0.696
SML (mm)	2.1±0.81	1.78±0.8	0.563
AAP (mm)	25±6.92	22.5±5.25	0.537
AML (mm)	10.4±3.5	9.3±2.84	0.617

Conlusion

The results of this research also showed that using the COP sway and the standard devisions of the COP seems to be more sensitive method than using other parameters (mean amplitude of COP sways in the mediolateral and anteroposterior planes). It was shown that using the force plate is a good way to measure stability. Although many investigators use the excursion of the COP to represent the stability, the sensitivity of the standard divisions of the force and COP is more than that of the excursions. The effects of aging on stability can be defined by using a force plate;

Table 4: The influence of aging on stability during quiet standing

Parameters	MAP (mm)	MML (mm)	SFX (N)	SFY (N)	SAP (mm)	SML (mm)	AAP(mm)	AML (mm)
Male								
Pearson correlation	0.273	0.451	0.167	0.291	0.322	0.446	0.446	0.394
P_value	0.187	0.024	0.424	0.158	0.127	0.026	0.025	0.05
Female								
Pearson correlation	0.366	0.718	-0.075	0.848	0.352	0.702	0.272	0.67
P_value	0.373	0.045	0.86	0.08	0.393	0.05	0.514	0.069

Table 5: The effect of body height on standing stability

Parameters	MAP (mm)	MML (mm)	SFX (N)	SFY (N)	SAP (mm)	SML (mm)	AAP(mm)	AML (mm)
Male								
Pearson correlation	0.243	0.365	0.551	0.56	0.37	0.394	0.165	0.436
P_value	0.242	0.073	0.004	0.004	0.136	0.05	0.425	0.029
Female								
Pearson correlation	0.073	0.392	0.329	0.659	0.061	0.369	0.107	0.27
P_value	0.864	0.337	0.427	0.075	0.889	0.369	0.801	0.517

however, the test must be carried out according to a standard procedure. It is recommended that the age of the participants, type of shoes and gender should be considered when the difference between the stability of different groups is compared.

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