ORIGINAL ARTICLE

USE OF STABILOMETRIC PLATFORM AND EVALUATION OF METHODS FOR FURTHER MEASUREMENTS – A PILOT STUDY

Jitka Jančová[1], Vlasta Tošnerová[2]

Charles University in Prague, Faculty of Physical Education and Sport, Czech Republic: Department of Sport Medicine and Adapted Physical Education[1]; University Hospital in Hradec Králové, Czech Republic: The Rehabilitation Clinic[2]

Summary: Posture in a still stance has been quantified by changes in the center of pressure (COP), in both anterior-posterior (A/P) and medial-lateral (M/L) directions and measured on a single force platform (Bertec PRO VEC 5.0). The purpose of this study was to estimate the variance in error and the intrasession test-retest reliability, and to determine which measures shall be taken for further measurements, especially with adults age 65 and older.
We used two types of approximation for the reliability coefficient. Firstly, we used the equation according to Blahuš (2) and secondly we used the Pearson's correlation coefficient for test-retest measurements. The findings allow us to say, among other things, that the tests of quiet standing Double Narrow Stance Eyes Open (DNSEO) and Double Narrow Stance Eyes Closed (DNSEC) are parallel, in the sense of parallel testing.

Key words: *Stability; Stabilometric Platform; Center of Pressure; Intrasession Reliability*

Introduction

The ability to maintain the body's position over its base of support (BOS), whether this base is stationary or noviny, is called balance. Controlling postural sway while standing still is called static balance. However, it is impossible to stand absolutely motionless (21, 25). Even when people stand still on both feet, the body sways over its base of support. Postural sway is determined by measuring the location and amount of changes that occurs in the position of the total vertical force vector projected onto a horizontal plane. These measurements determine where the average center of pressure (COP) is located and how much variability of this location occurs during the measurement.

Generally, we may state that the way of loading both lower extremities, while standing on stabilometric platform (SP), is in each and every case very individual and influenced by anthropometric variables, such as i.e. height, weight, distribution of the liquids and fats in the body, sometimes also by asymmetric parameters of the body, and at last but not least by former therapeutic and surgery interventions (3).

Postural stability (PS) of different subjects has been compared by means of body sway measurements. A common quantitative index of body sway is obtained by observing the subject standing still on a force plate and measuring the length of the trajectory of the COP over the surface of the plate during a specified period of time.

The use of a force plate for the determination of COP is being accepted as a method to evaluate postural balance. Unfortunately, there is no generally accepted standard situation under which the tests are carried out, and this makes it difficult to compare our results with those published elsewhere.

Lafond, Duarte and Prince (14) use besides their posturographic measurements also other biomechanical variables such as Center of Mass (COM) and Gravity Line Projection (GLP), while standing still projects the COM in the COP. In the present study we considered only the COP.

Purposes of the study

The purpose of this study was to extend experiences with practical issues, such as the reliability of stabilometric measurements, when using stabilometric platforms. For this reason it seems to be useful to treat the following points:

1. **a)** to estimate variance in error (because we suppose that the measurement error will remain the same during further measurements) in order to evaluate whether the first two tests of standing could be recognized as parallel.
   b) to estimate the variance in error and the intrasession reliability.
2. to see how many records can be taken per day with respect to healthy older adults and which measures should be taken regarding the surroundings.

3. to see whether the conditions under which the study was taken are sufficient for the following studies, and why it is better to use stabilometric platform (SP), posturographic or Kistler's platform.
4. to compare our experience with younger adults with the literature reviews dealing with the healthy elderly who will be the subject for the main study.

Only the points will be experimentally tested **1. a)** and **1. b)** and the other points of interest are treated in discussion and considered rather as suggestions for further measurements. First, the author plans to extend those experiences in specific measurements of PS in elder adults, which shall be the main purpose of future studies.

Material and methods

Participants selected for the study were free of neurological and orthopedic disorders, and had no history of neuromuscular skeleton disease, as verified by self report. All subjects were medication free and had no neurological or orthopedic abnormalities and no active disease at the time of testing. Different subjects were tested in each study.

Subjects ad 1.a)

One healthy adult, age – 28 years, weight – 63 kg, woman – Caucasian.

Subjects ad 1.b)

Three healthy adults. Their age ranged from 28 to 30 years, and their body weight from 60 to 100 kg. Caucasians.

Stabilometric Platform

The stabilometric platform (SP) (Bertec PRO VEC 5.0) located in the laboratory of kineziology at the Rehabilitation Clinic of the Faculty Hospital in Hradec Králové. The platform is equiped with tension sensors for measuring three coordinate components of the force acting on SP on arbitrary directions, and three components of the moments of force. Swayings of the individual are projected onto the plate as variations in COP. The position of the COP on the surface of the force plate at any point in time, is calculated from the knowledge of the tension of the transducers, at the corners of the force plate, in proportion to the total force each of them records.

Amplitude and frequency measurements were used to summarise the COP time series in the M/L and A/P directions. The amplitude measurements include the peak to peak difference, the root mean square value for standard deviation, and the mean absolute deviation from the average value. The two-dimensional kinematic data were sampled at 25Hz MPF (Mean Power Frequency).

To maintain the same position for all balance measurements, the foot position was traced by a marker on amorgraphic LP overhead transparency film for laser printers (ATFLP).

Standing position

For this study we chose the feet together stance because this stance minimizes the BOS area on the ground (3). If feet are apart or at an angle, the BOS increases and the subject has greater scope to voluntarily shift the weight distribution under the feet and influence the pathway of the COP over the plate surface. The first two positions we consider as opposite.

Tests of quiet stance used in this study:
1. Double narrow stance eyes open/eyes closed (**DNSEO/DNSEC**) feet together stance, because this stance minimizes the BOS area on the ground (3,7,8,20,23).
2. Double narrow stance with outer rotation eyes open/eyes closed (**DNSOREO/DNSOREC**) an angle stance – if the feet are apart or at an angle- the BOS is increased and the subject has greater scope to voluntarily shift the weight distribution under the feet and influence the pathway of the COP over the plate surface (3,7,8,11,23).
3. Tandem stance eyes open/ eyes closed (**TSEO/TSEC**) right or left foot is leading also in the individual stance (11,25).

Study 1.a)

The subject was measured in double narow stance eyes open DNSEO.

During the measurements the subject was instructed to look straight ahead at a white surface (200 cm x 200 cm) placed 100 cm away and to keep arms comfortably at his sides during the stances. The trial was repeatd 40 times. Each trial lasted 40 sec. During the study the subject wore comfortable T-shirt and pants, no shoes, no socks. The subject had his personal ATFLP. In each 40 sec trial, the force data were acquired and COP displacements were traced with the sampling frequency 25 Hz.

Study 1.b)

Participants were required to stand still on a force plate with their feet positioned comfortably within a box defined by dimensions equal to their foot length. Traces were made around the feet of each participant on ATLFP attached to the surface of the force plate to ensure contact positioning between standing trials. The participants were instructed to stand still with their arms hanging at their sides and thein head in a normal forward-facing position, with eyes focused on a stationary target located approximately 2 m away, 170 cm high. Each participant performed a 120 sec standing trial, two times (test-retest) for each type of stance. They were offered a 60 sec rest in between each standing trial to minimize any effects due to fatigue.

The directives were: „Keep your stance still, please, as you are used to standing, and concentrate on maintaining your body as stable and balanced as possible."

Data Analysis

Reliability was calculated for each of the initial 120 sec samples across three trials using the folowing equation (1):

$S^2 (\tau) = S^2 (X) - S^2 (\Delta)$
from which:
$R^2 (x, x') = S^2 (\tau) / S^2 (X)$

As a second way for measuring reliability we use the test-retest correlation, which also may be used as an approximation of reliability (2).

Results

The following results contain reliability output, which deals only with 1.a) and 1.b) (see „Purposes of the Study“). The other points (2., 3., 4.) are described in „Discussion“.

Ad 1.a)

- We found that the *variance in error* was 0.129.
- We found that the *intrasession reliability* was very poor, which is for us very surprising.

Ad 1.b)

- We found that the *variance in error* of the test with eyes open (EO) is 0.036 (axis X) and 0.031 (axis Y) and the test with eyes closed (EC) gave the value of 0.039 (axis X) and 0.025 (axis Y). These findings allow us to say that the tests of still standing DNSEO, and DNSEC are parallel, in the sense of parallel testing.
- We found that the *intrasession test-retest reliability* was for the **DNSEO** 0.82 (axis X) and 0.64 (axis Y), and for the **DNSEO** 0.44 (axis X) and 0.51 (axis Y).
- The *intrasession test-retest reliability* was for the **DNSOREOC** 0.67 (axis X) and 0.5 (axis Y) and for **DNSOREC** 0.65 (axis X) and 0.5 (axis Y).

Tab. 1: Pearson correlation coefficient for test-retest measurements.

		X_{01}	X_{02}
X_{01}	Pearson Correlation	1	.916(**)
	Sig. (2-tailed)	.	.000
	N	18	18
X_{02}	Pearson Correlation	.916(**)	1
	Sig. (2-tailed)	.000	.
	N	18	18

**Correlation is significant at the 0.01 level (2-tailed).

Tab. 2: Pearson correlation coefficient for test-retest measurements.

		Y_{01}	Y_{02}
Y_{01}	Pearson Correlation	1	.909(**)
	Sig. (2-tailed)	.	.000
	N	18	18
Y_{02}	Pearson Correlation	.909(**)	1
	Sig. (2-tailed)	.000	.
	N	18	18

**Correlation is significant at the 0.01 level (2-tailed).

When we used the Pearson's correlation coefficient for test-retest measurements, which may also serve as an approximation of reliability, we reached a very high value rel_x=0.916 for Xo and rel_y=0.909 for Yo (Table 1., Table 2.).

Discussion

Fleiss (11) offered an opinion about acceptable reliability for tests, proposing guidelines as follows:
- over 0.79 as *high*
- 0.40–0.79 *moderate*
- less – *poor*

Nevertheless, other authors have suggested a more rigorous acceptable coefficient of test reliability. Kelley (13) recommended a minimum of 0.94, Weiner and Stewart (24) suggested 0.85. Unfortunately, none of them indicated how their reliability was measured.

Regarding the intrasession reliability, the best values, in the sense of stability and reliability, were present during the first tests. Fatigue is one of the possible explanations. Nevertheless, we would consider it when working with elderly subjects, and we intend to make the intersession measurement (i.e. within one week).

We may state that the range of titubation increases with every trial. Those who were less stable in A/P in the first test, showed an even larger range in the other tests.

Those who had a tendency to stand on the front part of the feet, showed the same tendency in the other tests.

Trials when subjects were standing with eyes closed showed nearly the same titubation as trials with eyes open. We may also consider it as a factor related to youth. We, however, are not about to make a definite statement before repeating the same trials with the elderly, as did Chiari et al. (4) for whom vision had a clear effect on the correlation between parameters and BF (biomechanical factors). Chiari's correlation (4) was stated as typically higher with EC than with EO, and can be interpreted as a major influence of body biomechanics on postural sway with eye closure. In this condition the inertial properties of the body, dependent on height and weight, may become preponderant because of the removal of the visual afferent input to the postural control system. In fact, the loss of visual input has been shown to force, in most subjects, an increase in muscle stiffness (5). For the purpose of this study it was important to obtain a more reliable value, since intersession retest and interrater factors will add measurement errors.

Like any other measurements, postural control measurements are not perfectly reliable and are subject to measurement error, which includes three types of variability:
- *intrasession retest* (within a single session) immediate test-retest reliability, which is related to the random variability of the measurement when the measurement is repeated immediately. There are variations in results related to the lack of precision of the instrument or the variability and the phenomena measured. One way to improve this relia-

bility is by averaging the results of many repetitions. This is what we have done.

- *intersession retest* is a delay retest reliability which also includes the stability of the phenomena over a longer period of time, along with variations related to the procedures (i. e. positions of the markers). We did not involve it in the present study. However, we will consider it for the future one; also related to the assessment of postural stability.
- *interrater* adds another factor: variations related to the standardization of the procedure, i. e. the extent to which the procedure is applied similarly by different observers, was not applied in the present study. We are not considering it for the future study.

From four to six measurements over 60 sec-periods seems to be the limit of a reasonable requirement of the elderly, even if dealing with elderly without impairments. From the literature it appears that repeated measurements upon the same individual show a very large spread of values. Many of the subjects did not show consistent results when means of 10 trials, each of one minute duration, were measured on consecutive days.

Past studies of postural control during standing have also employed wide range of procedures, including the outcome measures used to quantify postural control, the duration of the sample collected, sampling frequency and methods for data processing (11). Due to these differences there remains little, if any, common ground for comparison among studies to establish a concrete understanding of the features which characterizes normal healthy postural control.

We will not take more than 4 records per day. We agree with Corriveau et al. (6) that it is too much to ask of the subjects, even though they might be healthy and willing to participate. It is out of consideration, especially when we expect to deal with elderly subjects, to perform these protocols. Nor would we be able to reliably monitor the progress of a disorder or the effect of the therapy where the changes might be small in relation to the range of spread of the measured data for an individual. It is the same for the short term effects of drug taking or hyperventilation. Therefore, we consider the changement of breathing stereotype has a longer effect than hyperventilation on postural stability. We would like to investigate more deeply this phenomenon in future studies, with a group of approximately 10 elder people, which undertake a breathing programme intervention. We expect the changement of the process of stabilization, changement in positionning of their body in space and least but not last changements on every day living activities.

As to the surroundings, it would be better to make use of the target (3 cm in diameter) 200 cm away from the subject and 170 cm high (which is a common alternative for stabilometric measurements), than to use the neutral white surface 100 cm away from the subjekt, which was found to be disturbing for the subject. The neutral white surface was not comfortable and the subject standing on the platform almost felt sick and lost balance. That is why using the neutral surface will not be repeated for further measurments.

A safety belt could be placed around the subjects during testing, and the investigator would be in any case present beside the subject as a protective measure against falling.

As to the conditions under which the study was taken it is better to use a „two desk“ posturographic platform because of the possible noise caused by movements in M/L direction which attain the whole desk (when used one desk SP like in Hradec Králové). This was reported also by different authors (15, 17). Some of specific conditions are treated in detail (below).

What is practical at The Faculty of Physical Education and Sport (FTVS) is that:

- desks are separate, so it measures the M/L directions movements better, the COP of each foot can be also separately measured. It is more accurate and does not produce the noise caused by M/L sway movements, which affect the whole platform and „noise“ measurement.
- The posturographic platform at FTVS UK is movable and it is possible to go to a residence or to a center of active seniors or elsewhere. The fact that the platform should be moved may affect the repeatability of the data and consequently the reliability, but it is an indispensable measure while working with elder adults. It would be readily accessible for testing not only by the authors but especially by the elder population.

When we compare our experience with younger adults with the literature reviews, we may see that the ability to control posture has been shown to decline in the elderly (6). Studies of young and elderly adults report that the elderly show increased postural sway while standing still. Although the literature also indicates report, that older women fall more frequently than men, gender differences were not reported to be found, except the higher weight of men, which was normalized and not recorded as evidence of gender differences.

The findings that swaying increases with age, even when the subject inclusion criteria were adhered too strictly, were consistent with previous research findings on standing body sway using other system and measurement techniques (1,10,12,16,19,26). Values of body sway were smaller during open-eyes testing. Researchers in this field agree that vision plays a strong stabilizing influence on postural control and that sway measurements are greater with EC than with EO. It may certainly be stated that in this present pilot study we did not perceive great differences between EC and EO titubation while measuring adults around 30 years old. Nevertheless, we expect this to change when dealing with elderly adults.

Spirduso (21) is not the only one (18,22) who suggests that many older people cannot maintain balance on one foot long enough to obtain reliable measures. That is one of the reasons why we will not proceede to one foot balance tests, The second reason is that we probably could not provide the necessary help to the elderly when loosing their balance. We suppose that it is demanding enough to stay still for a few minutes.

Makki (16) also studied 100 elderly subjects to detect differences between fallers and non-fallers, and confirmed the importance of averaging a number of trials to find a difference between young and old people. Makki (16) found that to detect the difference, it was necessary to average responses over multiple trials for three variables (ground reaction force, horizontal force and COP displacement). The author suggested that the practical utility of using biomechanical variables to measure the postural control of an elderly population is limited, and that it would be preferable to try to improve the reliability of used variables. Unfortunately, the author did not indicate how this could be done. Postural control laboratories are now showing great potential in contributing to understanding postural disorders in many clinical areas. The results from this study show that even when the instrument used for the analysis of the postural control is very accurate, it does not mean that the measurement of this phenomenon is reliable, which is a quite specific question we also faced in the present study. Furthemore, for any measure of postural control, it is crucial to ask whether the results from a single measurement are representative of a subject's balance perfomance.

Generally, caution is advised when applying the results of this study to other populations because of the differences in subject selections and measuring technicques. The subject's motivation and ability to follow the instructions may also influence the results. Despite strict adherence to the guidelines established for subject selection, some subjects may have an undiagnosed or unrecognized pathological conditions that may affect their postural control abilities.

Unfortunately, we did not weight the subjects before the trials on laboratory weight. It may also affect the final error of measurement and result reliability. We will consider it in the next study.

In conclusion we can really confirm, that SP represents for us a modern approach to the standardization of postural system stabilization (6,14,23,25).

Despise the fact that results show quite a large amount of unreliability, slony with the fact that we can hardly obtain two identical values after two measurements, we have to acknowledge the possibility of using it and deal with the individuality of each and every one of us.

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Corresponding author:

Mgr. Jitka Jančová, Charles University in Prague, Faculty of Physical Education and Sport,
Department of Sport Medicine and Adapted Physical Education,
José Martího 31, 162 52 Praha 6 – Veleslavín, Czech Republic, e-mail: jitka.vseteckova@post.cz