Effect of vision and orientation in human balance

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***Abstract*—Biomechanical parameters that describe locomotion are important variables for the determination of different diagnosis connected with risk of falls; therefore they are used as reference values in the clinical assessment of pathologies and training programs in physiotherapy. The aim of this study is to investigate how postural sway is affected in balance tests with eyes open and eyes closed conditions. Postural sway was measured by using a force plate system. The balance testing protocol was used to present all data collected by Sway Area, Equilibrium score and Sway Index during time period of 10 seconds on force platform. The results show that biomechanical parameters can be used in measuring body movements in postural stability. Body characteristics had slight but considerable effects on the variations of body balance in balance tests. Orientation, visual and somatosensory systems are important factors in maintaining posture and postural sway was significantly affected by vision factor. It has been shown also that postural sway is increased when eyes are closed, due to the loss of orientation on the base of support.**

Keywords— sway index, biomechanical parameters, force plate, postural stability

I. INTRODUCTION

Vision is a critical part of human body balance which is used to gather information about the orientation of the body in space. Postural orientation is the ability to maintain the relationships between different segments of the human body and its environment [11], while postural stability is the ability to maintain the position of the body within the base of support [6, 12]. Balance, postural control or equilibrium are definitions used to describe how we keep our body in an upright position and, when necessary, adjust this position [13]. Stability can be defined as the sensitivity of a dynamic system to perturbations and local stability is the sensitivity of the system to internal perturbations, such as natural fluctuation (e.g.; changing muscle activity in response to gravity) that occur during posture [6, 7]. Postural stability is an important component in maintaining an upright position and in maintaining balance during normal daily movements and activities [1].

In order to control the orientation and stability in space, the body requires a close interaction between sensory & musculoskeletal system**.** The forces for controlling body position are generated by muscle system [11]**.** The purpose of this study is to examine the effect of vision & orientation of subjects through postural sway in different conditions during balance test in force plate measurement system. The effects of these natural fluctuations were examined for evaluating different measures of Postural Sway. Sway movements are typically recorded through the trajectory of the Center of Pressure (COP) on the support surface [6, 8, 10]. COP is simply the point location of the vertical ground reaction resultant force vector, which can be easily measured by using a force platform [5]**.** COP measures are commonly used to assess individual's postural control [9]. Balance is often measured by using a force plate and measuring the movement of the centre of pressure (COP) in Medio-lateral (ML) direction as well as in Anterior-posterior direction (AP) [14, 16, 17].

Maintaining postural balance involves complex coordination & integration of multiple sensory motor & biomechanical components. The force plate (Leonardo Mechanography) provides valuable objective assessment of neuromuscular control & somatosensory input important to balance. Force plate can also be used as a predictive value for falls [13]. The sensory system is very important in the maintenance of posture & plays a main role in co-coordinated movement of extremities.

Central Nervor System (CNS) is responsible for integrating all sensory information to assess the position and motion of the body in space. Visual input is important to integrate the impulse of CNS via the vestibular apparatus, with the subject's physical environment. The proprioceptive control of balance involves mechanoreceptors, muscle tendons & ligaments surrounding a joint, providing important sensory information to body position and its movement. Visual deprivation caused an increase in postural sway [2] in numerous studies of healthy participants [2, 3, 4]. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. Materials and Methods

A. Subjects of study

29 healthy male subjects, aged 10-14 years, participated in this study. The mean age of subjects was 12.1 years old. The mean height was 1.54 m and mean weight was 46.54 kg. All participants provided written information consent, where they parents confirmed previous administration of balance test. This study was approved by the Sports University of Tirana (SUT).

B. Equipment used

A Force platform measurement (Leonardo Mechanography GRF platform, Novotec medical, Germany) [18] in the Biomechanics laboratory in SUT was used for evaluating the COP data. The COP is the point location of the ground reaction force vector [6]. The platform records three force components along the lateral, horizontal and the vertical axes, together with three respective moments. The force components were measured in Newton's (N).

C. Measurements

The balance testing protocol was used to collect all data during time interval of 10 seconds in two different conditions: Eyes open (EO) and Eyes closed (EC). The sway movements are recorded through the trajectory of COP on the support surface and the sway parameters measured are: horizontal and vertical COP displacements: COP_x , COP_y , standard ellipse Sway Area (SA), Equilibrium Anterior-posterior EQ (AP) score and Sway Index (SI). The COP signal represents a force. The Center of Gravity (COG) signal represents a real movement, the sway of the body inverted pendulum [10]. A subject's COG is approximately 55% of his/her height. COP postural sway was assessed via the force platform of a static balance (Fig. 1). The COP is the response of the body to COG displacement. Physically, it presents the position of the ground reaction force which is the resultant of all the forces acting within the body (internal and external forces). The COP is under continuous control and moves to keep the vertical projection of the COG within the base of support [15].

Sway Area is calculated by integrating the area of COP with regard to reference point in mm²/sec.

x_{ML} and y_{AP} oscillation amplitudes, computed by considering the main axes of the ellipse, which contains 90% of data points.

The dependent measurement was postural sway, which was measured Sway Index; the distance (in cm) that subjects swayed in the Medio- Lateral (ML) and Anterior-Posterior (AP)directions.

The data recorded from the force plate measurements were analyzed and the sway index was calculated by determining the distance from the subject's COP shifts for each of the data points, according to the formula (1):

Fig.1. A subject performing balance test in two different conditions EO and EC.

$$SI = \sqrt{\frac{SD(x^2 \times y^2)}{N}} \quad (1)$$

This study included a 6-months period, followed by a re-evaluation (proprioception training effect). The first evaluation included descriptive information of all anthropometric parameters such as age, height, weight, Body mass index (BMI), and postural assessments with SA, EQ (AP) scores and SI on force platform assessments. After first 6 months period, subjects were evaluated for the second time for the postural assessments.

D. Statistical analysis

We performed repeated measure analysis to test mean differences in two conditions of assessments. Mean differences of each pair of condition were compared with the least significant difference and we used the paired t-test to compare the effect of trainings in different conditions EO & EC.

III. Experimental Results

Table 1 shows the means and SD of all anthropometric parameters (age, height, weight and BMI) and postural sway measurements: SA, EQ (AP) and SI. Table 2 reports pair of variables compared in different conditions, before and after propriception training.

The statistical analysis pair 1 (EO-EC) before training (SI (EO): 3.48±2.48; SI (EC): 6.68±3.11; $t = -5.828$ and $p \le 0.05$); pair 2 (EO-EC) after training SI (EO): 1.72±0.64;SI (EC):3.27±1.48; $t = -6.058$ & $p \le 0.05$), as it is seen in table 2, revealed how postural sway was significantly affected by EO and EC conditions. However, all postural sway parameters such as: SA, EQ (AP) and SI were significantly affected by vision and orientation of the body (as shown in fig. 2, 3 and 4).

TABLE I. DESCRIPTIVE STATISTICS OF ANTHROPOMETRIC AND POSTURAL SWAY PARAMETERS.

Parameter	Mean ± SD	Minimum	Maximum
Age	12.1 ± 0.61	10.0	14.0
Height	1.54 ± 0.09	1.36	1.76
Weight	45.54 ± 9.73	31.9	70.3
BMI	19.29 ± 2.37	15.58	24.29
Sway Area A(EO)	24.25±47.33	4.45	239.50
Sway Area A(EC)	1424.89±7081.72	9.51	38240.20
EQ (EO)	0.70 ±0.20	0.00	0.90
EQ (EC)	0.44 ± 0.25	0.00	0.82
Sway Index SI(EO)	3.48 ±2.48	1.20	12.00
Sway Index SI(EC)	6.68 ± 3.11	2.16	12.00

TABLE II. PAIR OF VARIABLES COMPARISON IN DIFFERENT CONDITIONS

Condition	Pair of variables	Mean ±SD	*t*-value	*p*-value
Before training (EO-EC)	A(EO)-A(EC)	A(EO): 24.25± 47.33 A(EC):1424.89±7081,72	-1.071	0.293
	EQ(EO)-EQ(EC)	EQ(EO): 0.70± 0.2 EQ(EC):0.44±0.25	5.828	0.000
	SI(EO)-SI(EC)	SI(EO): 3.48± 2.48 SI(EC): 6.68±3.11	-5.828	0.000
After training (EO-EC)	A(EO)-A(EC)	A(EO): 5.42± 2.93 A(EC):23.53±22.25	-4.523	0.000
	EQ(EO)-EQ(EC)	EQ(EO): 0.85± 0.53 EQ(EC):0.72±0.12	6.058	0.000
	SI(EO)-SI(EC)	SI(EO): 1.72± 0.64 SI(EC):3.27±1.48	-6.058	0.000
Before & After training (EO_1-EO_2)	A_1(EO)-A_2(EO)	A_1(EO): 24.25± 47.33 A_2(EO):5.42±2.93	1.330	0.194
	EQ_1(EO)-EQ_2(EO)	EQ_1(EO): 0.70± 0.2 EQ_2(EO):0.85±0.53	-4.688	0.000
	SI_1(EO)-SI_2(EO)	SI_1(EO): 3.48± 2.48 SI_2(EO):1.72±0.64	4.688	0.000
Before & after training (EC_1-EC_2)	A_1(EC)-A_2(EC)	A_1(EC): 1424.89± 7081.72 A_2(EC):23.53±22.25	1.066	0.296
	EQ_1(EC)-EQ_2(EC)	EQ_1(EC): 0.44± 0.25 EQ_2(EC):0.72±0.12	-8.48	0.000
	SI_1(EC)-SI_2(EC)	SI_1(EC): 6.68± 3.11 SI_2(EC):3.27±1.48	8.48	0.000

Except comparison of pair of variables, we have calculated too Pearson's correlation coefficient to see the correlation between postural sway parameters and EO, EC conditions. The results are presented in Table 3.

TABLE III. PERSON'S CORRELATION COEFFICIENTS

Condition	A - EQ(AP)	A – EQ(AP)	COPx - COPy
EO	-0.922**		
EC		-0.343	0.398*

Pearson's correlations coefficient
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

In Fig. 2 is shown the variation of Sway Area for all study subjects during time period in EO and EC conditions.

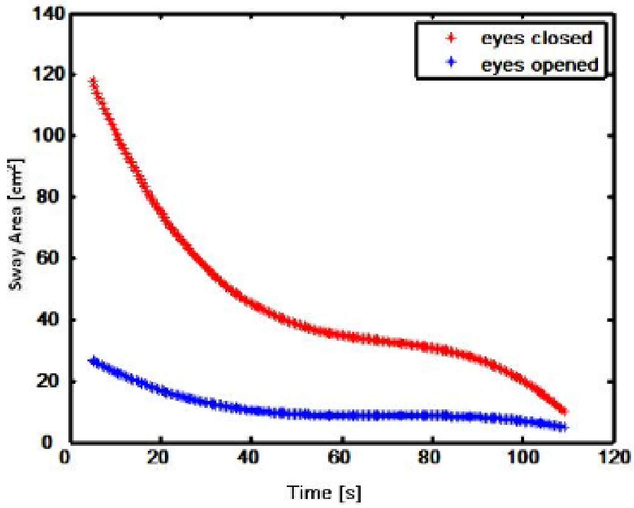

Fig.2 The graph of Sway Area during time period in EO and EC conditions.

While in Fig. 3 is shown the graph of Equilibrium Anterior-posterior scores of all subjects during the same time of period in EO and EC conditions. Fig. 3 shows that after training, the equilibrium score is clearly hihger than before training, when compare EO with EC conditions, due to the effect of vision and proprioception training.

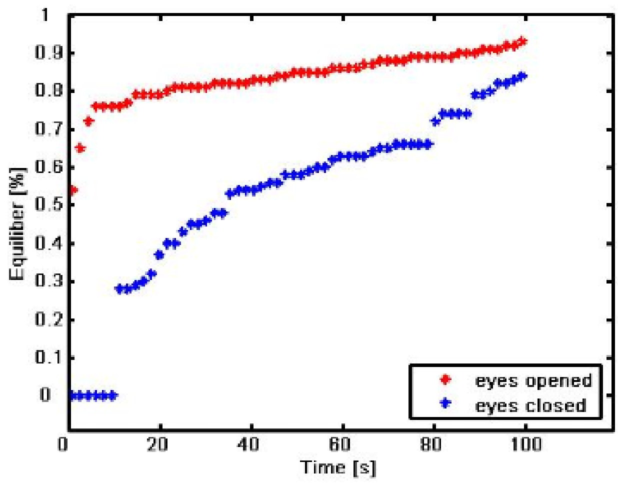

Fig. 3 The graph of Equilibrium Scores during time period in EO and EC conditions.

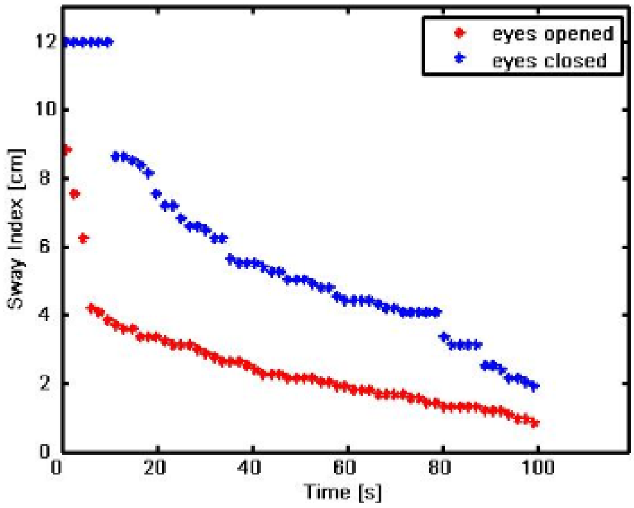

Fig. 4 The graph of Sway Index during time period in EO and EC conditions.

It can be seen that the participants have a greater amount of sway area when standing with EO as compared to standing with EC conditions (fig. 2). When the sway area is decreased, (fig. 2), the equilibrium anteroposterior score is increased (fig. 3), while the postural sway is decreased (fig. 4). Smaller the sway area, greater the equilibrium.

Finally, fig. 4 presents the graph of sway index for the same conditions as above.

The sway Index (SI) is decreased statistically due to the effect of proprioception training. The postural sway values for EC condition are significantly greater when compared with EO condition before and after proprioception training (fig. 4).

IV. Discussion

Pair 1. The comparison of parameters in two different conditions: EO and EC before training.

In Table 2, it is noticed a big difference of the mean of SA (EO) with SA (EC) before training, as a result of a considerable Standard Deviation. The control analysis (paired t-test) shows that there is no essential difference, despite the fact that the test is carried out with EO or EC, as indicated by the respective values (t value $t=-1.071$ and p value $p=0.293$).

It should be highlighted that the confidence interval $\gamma = 0.95$ proves to be very wide, $]-4078;1277[$ this as a result of the standard error mean.

Whereas, EQ (EO) before training varies considerably from EQ (EC), respectively with a mean value 0.7097 and 0.4428 and are accompanied with a standard error mean (0.038 and 0.048), statistically the same. However, the confidence interval of equilibrium values differentiation is $]0.1730;0.36071[$ the t-test value $t=5.828$ and $p \le 0.05$ indicated a good equilibrium in statistical terms of the test performed with EO.

Sway Index (SI) performed with eyes opened (EO) is statistically different from SI(EC),but $SI(\text{EO}) < \text{SI(EC)}$, correspondingly($\bar{X}_{SI(\text{EO})} = 3.4841$ & $\bar{X}_{SI(\text{EC})} = 6.6865$) point out a p-value $p \le 0.05$, and this is effect of vision.

Pair 2. The comparison of parameters in two different conditions: EO and EC after training.

Whereas after training it is observed that mean values of SA (EO) and SA (EC) are respectively 5.42 and 23.53, these values are smaller than the ones before training which were 24.25 and 1424.89. However, standard deviation of the mean value in pair 1 is much higher when performed in EC condition then in EO.

Yet the SA values are statistically different when the test is carried out in EO condition rather than in EC condition as the statistical findings show ($t=-4.523$ and $p \le 0.05$), since SA (EO) is statistically lower than SA (EC).

The equilibrium is observed to be changed even after training, with these values ($t=6.05$ and $p \le 0.05$), although the value interval $]0.08582;0.17349[$ indicates a greater approximation of the equilibrium values EQ (EO) and EQ (EC), smaller differences of these equilibrium values are as a result of proprioception training.

SI (EO) and SI (EC) are still different, although $\bar{X}_{SI(\text{EO})} < \bar{X}_{SI(\text{EC})}$, respectively (1.72 and 3.2). The mean value is the same with the one EO test before training. These results are due to the vision and proprioception training.

Pair 3. The comparison of parameters in EO condition before and after training.

Statistically SI(EO) before training is smaller than SI(EO) after training, thus the equilibrium values increase after the training; this is statistically distinct even though the test is performed in EO conditions EO ($t=4.688$ and $p \le 0.05$). However, Standard error mean for the selection before training is considerably higher (0.46) than after training (0.119). This shows a greater concentration of the values to the mean value after training. Here it is made evident the effect of vision and proprioception training.

Pair 4. The comparison of parameters in EC condition before and after training.

In EC condition, SA seems to be the same as before and after training ($t=1.066$ and $p=0.296$); this is shown also by the value interval $]-1291.6;4094[$ and this is because of very wide intervals of standard deviation.

Whereas the equilibrium is definitely higher after training; the value interval is $]-0.37;0.227[$, which is confirmed by the observed value ($t=-8.480$ and $p \le 0.05$).

Whereas SI is decreased statistically due to the effect of proprioception training ($t=8.480$) and as is shown by ($p \le 0.05$).

After the study of Pearson's correlation coefficient in Table 3, it is noticed a strong linear relevance ($r=-0.922$) between Sway area (SA) and Equilibrium in EO condition. The relevance is negative, thus the decrease of SA increases equilibrium, yet this relevance is inexistent when the test is performed in EC condition ($r=-0.343$).

Moreover, it is observed a weak linear relevance between COP_x and COP_y ($r=0.398$) in EC condition. This coefficient cannot be disregarded with an error of $p=0.05$. Meanwhile, in EO conditions it cannot be discussed on any kind of linear relevance between them.

The relevance in EC condition is explained by the fact that $SI_{EC} > SI_{EO}$ before training, respectively with mean values $\bar{X}_{SI(\mathrm{EC})} = 6.68$ and $\bar{X}_{SI(\mathrm{EO})} = 3.48$.

V. Conclusions

Sway measurements were significantly different between two different conditions EO and EC. The results show that biomechanical parameters can be used in measuring body movements in postural stability. Body characteristics had slight but considerable effects on the variations of body balance in balance tests. The effect of visual information on balancing the body movements is essential. Orientation, visual and somatosensory are important factors in the maintained posture, however Sway Area was significantly affected mainly by vision factor. Postural sway is increased when eyes are closed, due to the loss of orientation on the base of support. In our study the limitation consists in the difficulty of assessment's separation of vestibular and somatosensorial sensory system, so their role in postural control was not estimated in detail.

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