International Journal of Human Movement and Sports Sciences 11(3): 564-571, 2023 http://www.hrpub.org
DOI: 10.13189/saj.2023.110308

Analysis of Biomechanical Parameters on IL_EO and 1L_EC Tests on 10-14 Years Old Players of Tirana FC

Aida Bendo*, **Lindita Agolli, Agron Kasa**

Sports University of Tirana, Tirana, Albania

Received February 6, 2023; Revised March 23, 2023; Accepted April 16, 2023

Cite This Paper in the Following Citation Styles

(a): *[1] Aida Bendo, Lindita Agolli, Agron Kasa , "Analysis of Biomechanical Parameters on IL_EO and 1L_EC Tests on 10-14 Years Old Players of Tirana FC," International Journal of Human Movement and Sports Sciences, Vol. 11, No. 3, pp. 564 - 571, 2023. DOI: 10.13189/saj.2023.110308.*

(b): *Aida Bendo, Lindita Agolli, Agron Kasa (2023). Analysis of Biomechanical Parameters on IL_EO and 1L_EC Tests on 10-14 Years Old Players of Tirana FC. International Journal of Human Movement and Sports Sciences, 11(3), 564 - 571. DOI: 10.13189/saj.2023.110308*

Abstract Equilibrium is described as the ability to maintain the body's position within its base of support. Often the equilibrium is measured from the use of the force plate and the excursion of the center of the pressure (COP), whose shift presents a target point energetically cost, to maintain the equilibrium. The purpose of this study is to analyze the effect of proprioception training in improving the balance conditions. The measurements were performed on the licensed force platform in a group of children aged 10-14, who are the players of Tirana football club. The study period includes three phases: the first phase initial, the second phase 24 weeks and the third phase 12 weeks. The frequency of exercises is three times a week, with duration of 60 minutes for every session, following the proprioceptive training program. Subjects performed balance tests in two different conditions: one leg open eyes (1LEO) and one leg closed eyes (1LEC). The equilibrium parameters are analyzed through the statistical package SPSS version 20. Data were analyzed using t-test, which showed statistically significant changes at major biomechanical variables, in one of the most important disciplines of motor skills such as balance. The results confirmed the need to develop balance exercises to improve the quality of life in other psychological and emotional dimensions. The results showed that equilibrium variables increased after proprioception training, while the sway index and sway area decreased. The differences in equilibrium variables showed a significant result of $p < 0.050$. In conclusion, proprioception training was very effective in reducing sway indexes at athletes, in order to improve and increase their balance condition and sport performances. The results of this study expect to be useful for athletes, coaches, and sport teams and all subjected engaged to physical activity and education.

Keywords Equilibrium One Leg Open Eyes Test, One Leg Closed Eyes Test

1. Introduction

Balance is an important element in the performance of life's tasks, from the simplest to the most difficult ones. There are different methods for evaluating balance performance [1], but the most frequently used method is the evaluation of the center of pressure (COP) for measuring postural sway. Center of gravity (COG) and COP are the two main concepts used to assess postural sway. COG is an important concept for the analysis of human motion, because it is an imaginary point in which all the mass or weight of the body is thought to be concentrated. COG is a displacement measurement, because it represents a real movement and is completely independent of the speed or full acceleration of the body and its moving segments. COG is maintained through the dynamic integration of internal and external forces as well as the environmental factors involved in them [2]. The equilibrium parameters were taken during the COP shifts during the time interval of 10 s. The sway index is defined as a numerical value of the standard deviation of the distance subject spent away from his center of balance. It is calculated according to the following formulae [3]:

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

The modified equilibrium is a measure of actual A/P sway in relation to the theoretical limits of stability.

$$EQ(AP) = \frac{B-A}{B} \times 100\% \quad (2)$$

Where A represents actual A/P sway and B represents the theoretical limits of stability [4]. The sway index is related to the equilibrium with a negative correlation, when the equilibrium increases, the sway index decreases, hence it is used as a body stability index. The movement of the COG is a result of muscular contractions that attempt to maintain a vertical position and is physically associated with several degrees of sway movement [5]. The direct measurement of COG is difficult; therefore, the most common way is to measure COP deviations [6]. Although COP is not a direct measurement of tremor, it is known that it is highly correlated with COG in the resting position [7]. In biomechanics, COP is the term given to the point of application of the ground reaction force vector. This vector represents the sum of all forces acting between the subject and its supporting surface. COP is simply the location point of the ground reaction force vector. COP localization measurements are carried out in tests performed on a force platform [8, 9]. The postural sway of the COP during resting positioning was studied in basic and applied studies of postural control [10]. COP analysis is common in studies of human postural control and gait.

Large COP movements are associated with decreased postural control, an indicator of postural instability and weakness [11]. Increased postural sway can cause a loss of balance in healthy people and in unstable conditions [12]. Balance is described as the ability to maintain the position of the body on its base of support [13, 14]. In biomechanics, balance is the ability to maintain the line of gravity of a body within its base of support with minimal postural sway [15]. Since the human body is never absolutely fixed, a control system is needed to stabilize the body. Balance is often measured by the use of force plate and COP orientation in the medial-lateral (M/L) and anterior-posterior (A/P) directions [8, 16].

2. Materials and Methods

2.1. Study Design

This is experimental research using pre and posttests equilibrium measurements. Routine training program was applied to this group with a frequency of exercises three times a week, with a duration of 60 minutes, followed by a program of proprioception training for 30 minutes for each session. The results of the group were based on the effect of proprioception training program, which occupied about 30% of the volume of training loads. This program was implemented gradually increasing the level of difficulty. This type of exercises was performed under imbalanced conditions.

2.2. Study Participant

This study involved 29 male subjects, aged 10-14, who are players of Tirana football club. The recruited sample was based on considerations, namely players, who had trained and actively participated in football matches for the same age group. The parent's written consent was carried out on this sample and the involvement in the study was voluntary.

2.3. Instrument & Protocol

The measurements were recorded and performed in force plate Leonardo Mechanography, Biomechanics Laboratory of Sports University of Tirana (SUT). Romberg protocol for balance measurements was used to collect data in two different conditions: Romberg One Leg Eye Open (1L_EO) and One Leg Eye Closed (1L-EC) [9]. The equilibrium variables were taken during the COP shifts during the time interval of 10s in these tests. This study was approved by Sports University of Tirana, Albania.

2.4. Procedure

The procedure in this study consisted of three phases: the first phase, initial. The data for this phase, were collected on equilibrium measurements for sway area, equilibrium and sway index for the players of Tirana football club (n = 29 subjects). The second phase includes an exercise training program three times a week with a duration of 60 minutes, followed by a program of proprioception training 30 minutes for each session, for 24 weeks. The third phase includes an exercise training program three times a week with a duration of 60 minutes, followed by a program of proprioception training 30 minutes for each session, for 12 weeks.

2.5. Statistical Analysis

The Kolmogorov-Smirnov normality test to determine whether the data has a normal distribution was used in this study. The Levine's test for the variance homogeneity was applied to this team, to determine whether the population number variations are the same, which showed a significance value of $p > 0.050$. Descriptive statistics which include mean values and their respective standard deviations were calculated for anthropometric and biomechanical variables. The t-test was conducted to determine whether was a variable difference between the postural sway parameters in three different phases of measurements. Equilibrium and sway parameters were compared using an independent t-test [17]. All the data were utilized to identify the variation between these phases The data obtained from these measurements, were analyzed statistically descriptively using paired samples t-test utilizing the SPSS version 20 program with a significance level of 5% ($p < 0.050$) [18].

3. Results

Analysis results taken from independent t-test independent applied by this team, through the mean comparisons in three different phases of measurements, emphasize the differences between subjects in Romberg balance tests and their statistical and practical significance. Table 1 gives descriptive statistics of anthropometric parameters of this team. Subjects participating were 29 boys aged 10-14, mean (12.1 ±0.62) years old, with these anthropometric characteristics: height (1.54 ± 0.94) m, body mass (46.55 ±9.74) kg and BMI (19.3 ±2.37).

1L_EO test is a balance test in eyes open conditions, which is used to assess the anterior-posterior equilibrium EQ(AP) and sway index (SI) with the variables taken in different phases of training. In function of the main parameters such as: sway area (SA) measured in cm^2, equilibrium EQ(AP) in percentage and sway index (SI) in cm, all other parameters of the balance have been studied. Table 2 generates descriptive statistics for variables taken during three measurements in IL_EO test. Results of these measurements are used to describe the characteristics of equilibrium and postural sway.

Table 3 shows the results of t-test. This information is related to the differences between three balance measurements, based on the mean values of biomechanical parameters measurements on IL_EO test and if these differences are statistically significant.

Table 1. Descriptive statistics of anthropometric parameters

Parameter	Mean ±SD	Range	Min. value	Max. value	Variance
Age (years)	12.10 ±0.62	4.00	10.00	14.00	0.38
Height (m)	1.54 ±0.94	0.40	1.36	1.76	0.01
Weight (kg)	46.55 ±9.74	38.40	31.90	70.30	94.81
BMI (kg/m^2)	19.30 ±2.37	8.71	15.58	24.29	5.63

Table 2. Descriptive statistics of postural sway parameters in Eyes Open Conditions

Measurement	Parameter	Mean ±SD	Range	Min. Value	Max. Value	Variance
Phase I	Sway Area	30.12 ±67.38	297.05	4.45	301.50	4540.47
	Equilibrium	0.71 ±0.21	0.90	0.00	0.90	0.04
	Sway Index	3.48 ±2.49	10.80	1.20	12.00	6.18
Phase II	Sway Area	9.18 ±6.54	34.45	3.19	37.64	42.81
	Equilibrium	0.82 ±0.07	0.37	0.54	0.91	0.006
	Sway Index	2.21 ±0.89	4.44	1.08	5.52	0.80
Phase III	Sway Area	5.43 ±2.94	15.15	3.12	18.27	8.62
	Equilibrium	0.86 ±0.05	0.28	0.65	0.93	0.003
	Sway Index	1.72 ±0.64	3.36	0	4.20	0.41

Table 3. Pair of variables comparison in Eyes Open condition before and after training period

Parameter	Pair of variables	Mean±SD	95% CI of difference		t-value	*p*-value
			Low bound	Upper bound		
Sway Area (SA)	SA_1- SA_2	20.94 ±62.05	- 2.66	44.54	1.818	0.080
	SA_2- SA_3	3.75 ±3.85	2.28	5.22	5.238	0.000
	SA_1- SA_3	24.69 ±65.01	- 0.03	49.42	2.046	0.050
Equilibrium EQ(AP)	EQ_1- EQ_2	-0.10 ±0.15	- 0.16	- 0.04	- 3.662	0.001
	EQ_2- EQ_3	-0.04 ±0.02	- 0.05	- 0.03	- 7.633	0.000
	EQ_1- EQ_3	-0.15 ±0.16	- 0.21	- 0.08	- 4.688	0.000
Sway Index (SI)	SI_1- SI_2	1.27 ±1.86	0.56	1.98	3.662	0.001
	SI_2- SI_3	0.49 ±0.34	0.36	0.63	7.633	0.000
	SI_1- SI_3	1.76 ±2.02	0.99	2.53	4.688	0.000

In order to assess the equilibrium and sway index, some measurements are performed by comparing mean values between respective paired variables, based on the results is reported that the main variables of 1L_EO test are: Sway area variable (SA), Equilibrium Index variable in Anterior-posterior direction [EQ (AP)] and Sway Indes variable (SI).

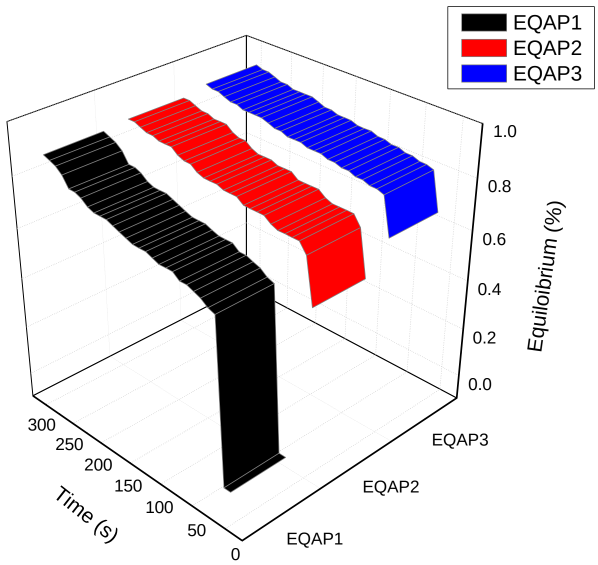

Figure 1. 3D graph of EQ(AP) parameter and training phases of Tirana FC team, on 1L_EO test

Based on the results reported in table 2, from the comparison of sway areas SA_1 (30.12 ±67.38) to SA_2 (9.18 ± 6.54), it is noticed a decrease of sway area in means by (20.94 ± 62.05) or 69.5%, which is followed by an improvement of balance, by comparison of SA_2 with SA_3 (5.43 ± 2.94), sway area is decreased in mean value with (3.75 ± 3.85) or 40.8%, which is smaller compared to the first measurement 69.5%, but it results in an improvement of equilibrium, meantime while by comparison of SA_1 to SA_3 (5.43 ±2.94) there is a decrease of sway area in mean of (24.69 ±65.01) or 82%, which results in a considerable improvement of equilibrium of whole team. Accordingly, to table 3, t-test analysis shows respectively the values: $t(28) = 1.818$, $p = 0.080 > 0.050$. For the first phase, the value of area is significantly reduced in the second measurement, but this is statistically not distinguishable, since the standard error of the mean of the selection is very large. In the second phase, the corresponding value $t(28) = 5.238$ and $p < 0.005$ indicates a statistically significant difference, which is clear, although the test is performed in conditions with eyes open on 1L_EO test. In the third phase, the values of $t(28) = -2.046$, and $p \leq 0.050$ confirm a difference that is within the limits of statistical significance and as such it will be considered a statistically significant value in the conditions of this study. The 3D graph of EQ(AP) parameter and training phases of Tirana FC team, on 1L_EO test are shown in figure 1.

Regarding the Equilibrium index from table 2, from EQ_1 (0.71 ± 0.21) to EQ_2 (0.82 ± 0.07) an increase of this variable is observed in the mean value by (0.10 ± 0.15), which indicates an improvement in balance skills, calculated with 13.4%, as a result of proprioception training. From EQ_2 to EQ_3 (0.86 ±0.05) there is an increase in this index in mean value by (0.04 ± 0.02) or calculated by 4.7%, which is smaller than in the first phase, almost 1/3 of it, while from EQ_1 to EQ_3 (0.86 ± 0.05) there is an increase in the equilibrium in mean value by (0.15 ± 0.16) or in total by 17.4%. The reported values according to the t-test, table 3, are as follows: $t(28) = -3.662$, $p = 0.001$; $t(28) = -7.633$; $t(28) = -4.688$, $p < 0.005$ which confirm that this difference is significant from a statistical point of view, as well as from a practical perspective it shows the importance of proprioceptive training.

The evaluation of the results obtained from table 2 for Sway Index between the first measurement of SI_1 (3.48 ± 2.49) and SI_2 (2.21 ± 0.89) shows a reduction of this variable on mean value by (1.27 ± 1.86), calculated with 36%; between SI_2 and SI_3 (1.72 ±0.64) there is a reduction of the SI in the mean value by (0.49 ± 0.34), or an improvement of balance skills by 22.1%, which is a little smaller compared to the first phase measurement, about as 2/3 of it, a value that shows the improvement of balancing (or equilibrium skills).

From the comparison of SI_1 and $SI_{3,}$ there is a considerable reduction of SI, in means by (0.07 ± 0.03), which indicates a fairly good improvement of balancing skills, calculated in the 50.6% measure. The statistical values according to the results of t-test on table 3, are reported as below: $t(28) = 3.662$; $t(28) = 7.633$; $t(28) = 4.688$ and $p < 0.005$. They show that these differences are statistically significant and important values in this study.

Results of 1L_EC test are taken for each phase of measurement. One leg eyes closed (1L_EC) test is a balance test to assess the equilibrium in anterior-posterior direction [EQ(AP)] and sway index (SI) for the variables taken during the measurements in three different phases of proprioceptive training. Figure 2 shows the 3D graph of sway index (SI) parameter and training phases of Tirana FC team, on 1L_EO test. Table 4 generates the descriptive statistics for these variables: sway area (SA), EQ(AP) and SI. Results taken from three phases of measurements are used to describe the balance characteristics in this test (1L_EC test).

Table 5 gives the t-test results. This information is related to the differences between the balance measurement, based on the mean values of biomechanical parameters measurements on 1L_EC and if these differences are statistically significant.

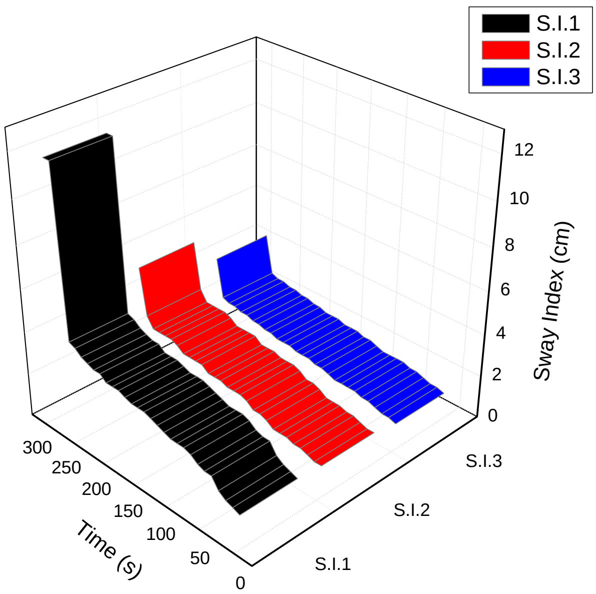

Figure 2. 3D graph of sway index (SI) parameter and training phases of Tirana FC team, on 1L_EO test

Table 4. Descriptive statistics of postural sway parameters in Eyes Close conditions

Measurement	Parameter	Mean ±SD	Range	Min. Value	Max. Value	Variance
Phase I	Sway Area	134.69 ±183.69	814.69	9.51	824.20	33743.56
	Equilibrium	0.43 ±0.25	0.82	0.00	0.82	0.06
	Sway Index	6.88 ±3.02	9.84	2.16	12.00	9.09
Phase II	Sway Area	45.61 ±40.45	133.61	9.12	142.73	1635.86
	Equilibrium	0.62 ±0.16	0.56	0.28	0.84	0.03
	Sway Index	4.51 ±1.89	6.72	1.92	8.64	3.57
Phase III	Sway Area	23.54 ±22.56	91.79	6.95	98.74	508.84
	Equilibrium	0.73 ±0.12	0.46	0.42	0.88	0.02
	Sway Index	3.28 ±1.48	5.52	1.44	6.96	2.20

Table 5. Pair of variables comparison in Eyes Close condition before and after training period

Parameter	Pair of variables	Mean±SD	95% CI of difference		t-value	*p*-value
			Low bound	Upper bound		
Sway Area (SA)	SA_1- SA_2	89.08 ±162.52	27.26	150.90	2.952	0.006
	SA_2- SA_3	22.07 ±28.50	11.23	32.91	4.170	0.000
	SA_1- SA_3	111.15 ±172.39	45.58	176.73	3.472	0.002
Equilibrium EQ(AP)	EQ_1- EQ_2	-0.19 ±0.15	- 0.25	- 0.14	- 6.959	0.000
	EQ_2- EQ_3	-0.10 ±0.08	- 0.13	- 0.07	- 7.316	0.000
	EQ_1- EQ_3	-0.30 ±0.19	- 0.37	- 0.23	- 8.480	0.000
Sway Index (SI)	SI_1- SI_2	2.37 ±1.83	1.67	3.07	6.959	0.000
	SI_2- SI_3	1.23 ±0.91	0.86	1.57	7.316	0.000
	SI_1- SI_3	3.60 ±2.28	2.73	4.47	8.480	0.000

In order to assess the equilibrium of swing index, some measurements are performed by comparing mean values between respective paired values, based on the results are reported below: The evaluation of the sway area (SA) according to table 4, of SA_1 (134.69 ± 183.69) with SA_2 (45.61 ± 40.45) indicates a reduction of sway area in average with (89.08 ± 162.52) or 66.1 %, which follows an improvement of balance. From measurement of SA_2 to SA_3 (23.54 ± 22.56), it is noticed that sway area decreases on average with (22.07 ± 28.50) or 48.3%, which is smaller compared to the first phase measurements by 66.1%, but which results in an improvement in balance, while from SA_1 to SA_3 measurements, a decrease of sway area on average values is observed with (111.15 ± 172.39) or 82.5%, which is reflected in a considerable improvement in the balance of the whole team. The results of the t-test reported according to table 5 are: $t(28) = 2.952$, $p = 0.006 < 0.050$, and its results are statistically significant. In the second phase, the t-test value $t(28) = 4.170$ and $p < 0.005$ indicates a statistically significant difference. This difference is statistically significant, although the test is performed in eyes closed conditions. In the third phase the t-test results $t(28) = 3.472$, and $p = 0.002 < 0.050$ confirms a statistically significant difference.

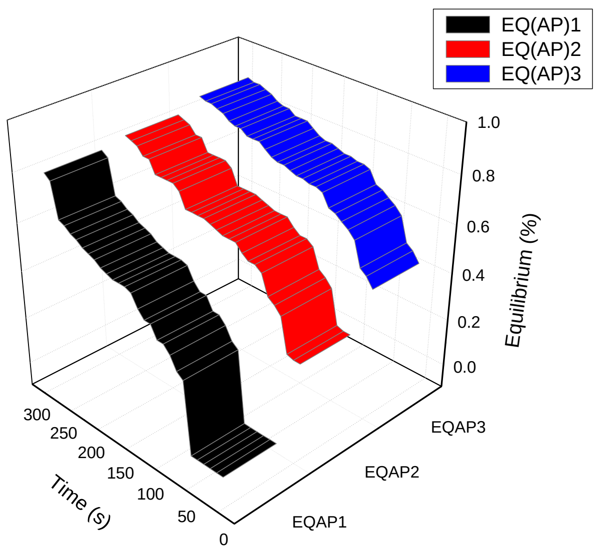

Figure 3. 3D graph of EQ(AP) parameter and training phases of Tirana FC team, on 1L_EC test

From the results obtained from table 4 for EQ_1 (0.43 ± 0.25) and EQ_2 (0.62 ±0.16), an average in equilibrium with (0.19 ± 0.15) is seen, which shows an improvement in balancing skills calculated with 30.6%, as a result of proprioceptive training. For EQ_2 and EQ_3 (0.73 ± 0.12) measurements, an increase in the balance in the average with (0.10 ± 0.08) or calculated with 15.1% is noticed, which is smaller than the first phase, almost 1/2 of it. Regarding the results between EQ_1 and EQ_3 measurements, there is an increase in equilibrium with (0.30 ± 0.19) or in total with 41.1%. Figure 3 gives the 3D graph of EQ(AP) parameter and training phases of Tirana FC team, on 1L_EC test. According to the t-test results, the respective values are as follows: $t(28) = -6.959$; $t(28) = -7.316$; $t(28) = -8.480$, $p < 0.005$. From the table 5, the values confirm that these differences are significant from a statistical point of view, but also from a practical point of view they show the importance of proprioceptive training.

Regarding the measurements of the sway index taken from table 4, by comparing SI_1 (6.88 ±3.02) with SI_2 (4.51 ± 1.89) a decrease in the average with (2.37 ± 1.83) is noticed, calculated with 34.4%, a value that shows the improvement of balancing skills from SI_2 to SI_3 (3.28 ± 1.48) a decrease of sway index in average with (1.23 ± 0.91), or an improvement of balance skills with 27.3 % is observed, which is a little smaller, compared to the first phase measurements, approximately 2/3 of it. While from SI_1 to SI_3 (3.28 ± 1.48) a considerable reduction of sway index can be seen, averaged with (3.60 ± 2.28), which indicates a fairly good improvement of balancing skills, calculated in 52.3% measure. Figure 4 shows the 3D graph of sway index (SI) parameter and training phases of Tirana FC team, on 1L_EC test. From table 5, is observed that the statistics t-test values are respectively: $t(28) = 6.959$; $t(28) = 7.316$; $t(28) = 8.480$ and $p < 0.005$, and they show that these differences are statistically significant for this study.

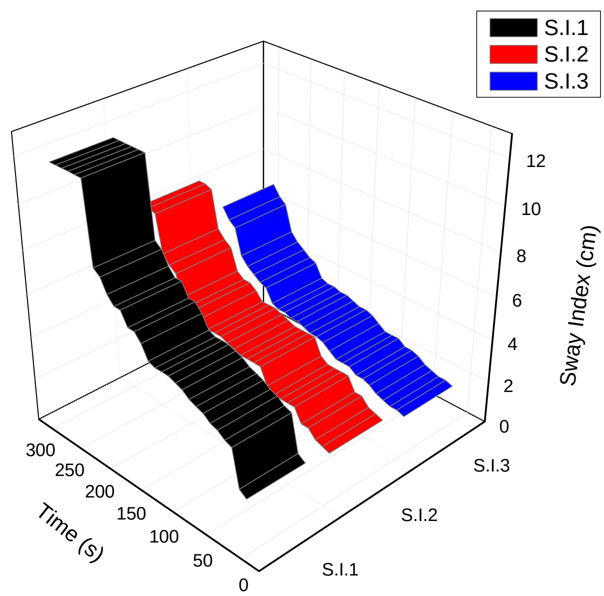

Figure 4. 3D graph of sway index (SI) parameter and training phases of Tirana FC team, on 1L_EC test

4. Discussion

The evaluation of the main parameters of the averages of the three balance measurements in the 1L_EO test condition results in a significant improvement in balance ability following the proprioceptive training program. For the first phase of measurement, the value of sway area is significantly reduced in the second measurement, but this is not distinguishable, from a statistical point of view, since the standard error of the mean of selection is very large and 95% CI, table 3, which lies in the limits of $]2.66; 44.54[$, it shows this fact, because of the very wide, large Standard deviation (SD) intervals, that is the confidence interval (CI). In the second phase measurements, this difference is statistically clear, because the test is performed in eyes open (EO) conditions. This is also confirmed by the very large concentration of values in the 95% of CI, $]2.28; 5.22[$. In the third phase, the obtained results confirm a difference that is within the limits of statistical significance. This happens because even in this case, the standard error of selection is again quite large, which is proven by the very wide confidence interval CI, $]-0.03; 49.42[$. However, since the area is significantly reduced from measurement SA_1 to SA_2, the improvement of the team is also calculated in 82%. So, thus, the proprioceptive training improves the average results: for sway area (SA) with 24.69 mm^2 (or 82%); for EQ(AP) with 0.15 and improvement (17.4%) and sway index (SI) with 1.76cm (or 50.6%). From table 3, the 95% CI re respectively: for sway area (SA) from (0.03 cm^2 to 49.42 cm^2); for EQ(AP) from (-0.21 to -0.08), and for sway index (SI) from (0.99 cm to 2.53 cm). The assessment of the main parameters is confirmed by the p-value ($p < 0.001$), which shows that the differences found are statistically and practically significant.

From the comparison of the balance parameters in the 1L_EC conditions test, it is concluded that there is a significant improvement in the ability of the balance, by following the proprioception training program in this test as well [19]. The value of the sway area decreased significantly in the second phase measurement, statistically this is noticeable, but the standard error of the mean of the selection is very large, table 5, and the 95% CI, table 3, which lies within the limits of $]27.26; 150.90[$, shows this fact, because of the very wide Standard deviation (SD) intervals, i.e., confidence intervals (CI). In the second phase measurements, $t(28) = 4.170$ and $p < 0.005$ indicates a statistically significant difference. This difference is statistically significant, regardless of the fact that the test is performed under conditions with eyes closed. This result is also confirmed by the very high concentration of values at 95% of CI, $]11.23; 32.91[$. In the third phase, the standard error of the mean of selection is again quite large, which is proven by the very wide confidence interval CI, $]5.58; 176.73[$. However, since sway area is significantly reduced from measure SA_1 to SA_2, and team improvement is calculated at measure 82.5%, this result is practically quite important for this study. Therefore, as a result, even from the statistical point of view, it will be considered statistically significant. In the 1L_EC test, the proprioceptive training improves the result, on average as follows: for sway area (SA) with 111.15 mm^2 (or 82.5%); for EQ(AP) 0.30 and improvement (41.1%) and sway index (SI) with 3.6 cm (or 52.3%). From table 5, the 95% CI is respectively: for say area (SA) from (45.58 mm^2 to 176.73 mm^2); for EQ(AP) from (-0.37 to 0.23), and for sway index (SI) from (2.73 cm to 4.47 cm). This confirms that these differences are significant from a statistical point of view and from a practical perspective, and they show the importance of proprioceptive training, therefore they will be taken as quite good and significant values for our study.

5. Conclusions

Results of biomechanical analysis show that biomechanical parameters can be used in measuring body movements in postural stability. Postural sway is increased in eyes closed (EC) conditions, compared to eyes open (EO) test conditions, due to the loss of the base of support. Body balance had slight, but considerable effects on the variations of the body in balance test. The results have shown that sway measurements related to sway area (SA), equilibrium in anterior-posterior direction EQ(AP) and sway index (SI) were significantly different in two different conditions: 1L_EO and 1L_EC tests. The assessment of the main parameters which were confirmed by p-vale ($p< 0.001$), have shown that the differences found were statistically and practically significant in this study. The results showed that equilibrium variables increased after proprioception training, while the sway index and sway area decreased. In conclusion, proprioception training was very effective in reducing sway indexes at athletes, in order to improve and to increase the balance condition and sport performances. The results of this study expect to be useful for athletes, coaches, and sport teams and all subjected engaged to physical activity and education.

REFERENCES

[1] Chaudhry H, Bukiet B, Ji Z, Findely T. Measurement of balance in computer posturography: Comparison of methods - A brief review. J Body Mov Ther, 15(1): 82-91, 2011. DOI: 10.1016/j.jbmt.2008.03.003

[2] Wang YT, Yu-tien Tsai, Tzuhui A. Tseng, I-Tsun Chiang, and Alex J.Y. Lee. The effect of neuromuscular training on limits of stability in female individuals. World Academy of Science, Engineering and Technology; Int. Jour. of Health & Sci. 7(7): (381-384), 2013. doi.org/10.5281/zenodo.1087069

[3] Bernier JN, David H. Perrin. Effect of coordination training on proprioception of the functionally unstable ankle. Journal of orthopaedic & Sports Physical therapy, Vol 27(4): 264-275, 1998. DOI: 10.2519/jospt.1998.27.4.264

[4] Winter DA. Biomechanics and motor control of human movement, 4th edition, New York, John Wiley & Sons Inc, 2009.

[5] Rogind H, Lykkegaard JJ, Bliddal H, Danneskiold- Samsoe B. Postural sway in normal subjects aged 20-70 years. Clinical Physiology and Functional Imaging. 23(3): 171-176, 2003. DOI: 10.1046/j.1475-097x.2003.00492.x

[6] Hasan SS, Robin DW, Szurkus DC, Ashmead DH, Peterson

SW, Shiavi RG. Simultaneous measurement of body center of pressure and center of gravity during upright stance. Part II: Amplitude and frequency data, 4(1): 11-20, 1996. https://doi.org/10.1016/0966-6362(95)01031-9

[7] Du Pasquier RA, Blanc Y, Sinnreich M, Landis T, Burkhard P, Vingerhoets FJG. The effect of aging on postural stability: A cross sectional and longitudinal study. Clinical Neurophysiology. 33(5): 213-218, 2003. DOI: 10.1016/j.neucli.2003.09.001

[8] Bendo A, Skënderi Dh, Veveçka A. Effect of vision and orientation in human balance. Jounal of Multidisciplinary Engineering and Technology, JMEST, Vol.1(5: 336-341), 2014. https://www.jmest.org/wp- content/uploads/JMESTN42350275.pdf

[9] Leonardo Mechanography. Ground Reaction Force Platform (GRFP) v4.2. Standard Edition. Getting Started. Document Version: v1.1.0-en, 2010

[10] Latash ML, Sandra S. Ferreira, Silvana A. Wieczorek, Marcos Duarte. Movement Sway; changes in postural sway during voluntary shifts of the COP. Exp Brain Res. Nr.150: (314-324), 2003. https://doi.org/10.1007/s00221-003-1419-3

[11] Palmieri RM, Ingersoll CD, Stone MB, Krause BA. Center-of-presssure parameters used in the assessment of posture control. Journal of Sport Rehabilitation. 11(1): 51-66, 2002. https://doi.org/10.1123/JSR.11.1.51

[12] Duarte M Zatsiorsky VM. Effects of body lean and visual information on the equilibrium maintenance during stance. Exp Brain Res 146(1): 60-69, 2002. DOI: 10.1007/s00221-002-1154-1

[13] Berg KO, Wood-Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Canada. Vol. 6(41): 304-311, 1989 https://doi.org/10.3138/ptc.41.6.304

[14] Spirduso WW. Physical dimensions of aging. Human kinetics. Champaign. Illinois, USA, 2nd edition, 2004

[15] Benda BJ, Riley PO, Krebs DE. Biomechanical relationship between center of gravity and center of pressure during standing. IEEE Transactions on Rehabilitation Engineering, 2(1): 3-10, 1994. DOI:10.1109/86.296348

[16] Eva Ekvall Hansson, Anders Beckman, Anders Hakasson. Effect of vision, proprioception and the position of vestibular organ on postural sway. Acta Otolaryng. 130(12):1358-63, 2010. DOI: 10.3109/00016489.2010.498024

[17] Field A. Discovering statistics using SPSS. 3rd edition, 2009; chapter 2, 3.

[18] Griffiths Mike. Basic Quantitative Methods. Computer exercises & Reference Information, 2011-12; 26-29; 40-42.

[19] Bendo A and Haxholli K. The Improvement of Equilibrium through Yoga Exercises. Sport Mont 15: 7-11, 2017. https://www.researchgate.net/publication/314949545_The_Improvement_of_Equilibrium_through_Yoga_Exercises