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Original Article

A statistical model using multiple regression analysis to predict equilibrium and sway index

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Abstract:
Balance and equilibrium refer to the ability to maintain an upright position and make the necessary adjustments. Achieving and maintaining postural balance requires intricate coordination and integration of various sensory-motor and biomechanical factors. The main objective of linear statistical analysis is to predict the relationship of a respondent variable in terms of predictor variables in a linear function or multiple linear functions. The purpose of this study is to estimate and select the best model on the variables that affect the balance, through the application of the multiple regression method in both 1L_EO and 1L_EC balance tests, to a sports team. This method allows for determining the overall fit and the relative contribution of each of the predictors to the total variance explained. The equation of the regression of a female volleyball player's team emerged these parameters as the best predictor of biomechanical parameters for the balance tests: sway area is the only best predictor for the equilibrium according to this model for 1L_EO, any increase of sway area of 1cm^2, there is also an increase of sway index with 0.195 cm, followed by a decrease of equilibrium with 0.2%. Postural sway is increased when eyes are closed, due to the loss of the orientation on the base of support. The training technique strongly affect the mechanical output muscles, as the motors that generate explosion maximal force and also improving equilibrium. Application of this statistical model in a sport team such as volleyball, has confirmed that Multiple Linear Regression (MLR) method is very effective and it is highly recommended to estimate and to select the best model on the variables that affect the balance. Finally, all strength exercises have improved the biomechanical parameters, including the balance ability.
Key Words: **- Multiple linear regression, sway area, equilibrium antero-posterior EQ(AP), sway index**

Introduction

The bipedal locomotion natures of humans, and various foot contact states, pose a major challenge to the balance control system of the human body (Basma et al., 2023). Balance is defined as the process by which the body attempts to maintain its position while performing different tasks, including different movements in each body segment supported by the support plane, which enables humans to move effectively and efficiently (Syafrianto et al., 2023). Mechanically it can be defined as the ability to sustain the centre of body gravity (COG) in limits of the support surface (Nejc et al., 2010), and it is a prerequisite to the maintenance of a sitting or standing posture, and mobility, while counteracting external or internal conflicts (Bendo et al., 2023b). It is a well-known fact that balance is very important in sports performance, being necessary for several sports skills, such as changing direction, stopping, starting, holding, kicking the ball or holding the body in a certain position. If balance is not achieved in a short period of time, the athlete can get injured (Culea et al., 2023).

The ability to maintain a stable posture while making contact with the ball is rather important for the player's performance in the match (Achilleopoulos et al., 2022), so in all volleyball actions during which the player has contact with the floor, maintaining postural stability is crucial. Static balance of the human body is the ability to maintain a specific posture (Andrej & Nejc, 2010). Maintaining balance during anti-gravitational activities is very important for the execution of other secondary movements, which are necessary to manipulate and interact with the surrounding environment. Reliable balance and perpetration response metrics are commonly used to assess normal performance and finding indicate that possible motor control deficits in both upper and lower extremities in those who eventually sustained an ulnar collateral injury (Brent et al., 2023). One informative standing balance measure is sway-area rate, which is a compound metric representing the rate of change in the forward-backward and side-to-side displacement of an individual's center of pressure (COP), (Carzoli & Enoka, 2023). The center of gravity (COG) is an imaginary point in which all the mass or weight of the body is thought to be concentrated, while the center of pressure (COP) is the point location of the vertical ground reaction force vector and represents a weighted average of all the pressures over the surface of the area in contact with the ground. The direct measurement of COG is difficult; therefore, the most common way is to measure the COP deviations, because they are highly correlated with COG in the resting position (Bendo et al., 2023a). In all studies of normal subjects, when the subjects stood with their eyes closed (Black, 1982; Hasan,

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1990), the COP amplitude was higher in both the A/P and M/L directions. In single support, not only were the COP amplitudes higher for eyes closed, but also the fluctuations in the three ground reaction forces were significantly larger (Goldie, 1992). In other standard positions, such as the Romberg position (one foot directly in front of the other), there were differences in the M/L versus A/P fluctuations. In reaction to variations in internal and external circumstances, balance is the result of a complex interplay between the sensory systems (Syafrianto et al., 2023). Three major sensory systems are involved in balance and posture: vision, the vestibular system, and the somatosensory system. Vision is the system primarily involved in planning our locomotion, which senses information about the position and velocity of the visual surround motion to improve balance by reducing the sway evoked by external disturbances (Mohebbi et al., 2022), and as such, it is an essential component of sports performance (Short & Trevor, 2023). Balance is closely related to injury and therefore also closely related to sports and injuries in sports. Recently, applied linear statistical models have been used in many fields such as medication, economy, social science, and many more (Shafi et al., 2018). We took the responsibility to apply a statistical model for the prediction of equilibrium and sway index through multiple linear regression methods in the biomechanical variables of a sports team.

The multiple Linear Regression (MLR) model can be described as a statistical approach to describe the association between two or more quantitative variables so that the dependent variable can be predicted from others (Mohd et al., 2020). A statistical linear regression model can be applied only if the dependent variables are continuous and distributed according to a statistical model (Muhammad et al., 2021). The main objective of linear statistical analysis is to predict the relationship of a respondent variable in terms of predictor variables in a linear function or multiple linear functions. The regression model is applied for prediction in many fields (Jetsada et al., 2021). Predictions about the relationship between variables in the observed system are used to formulate the behavior of the system in various situations (Agung et al., 2020). Prediction is the process of forecasting and it involves time-series data (Hemantajit et al.,2021). To make scientific discoveries or anticipate future outcomes, data analysis uses a variety of statistical models and methodologies to analyse observable data (Nur et al., 2022).

There are numerous applications in which the data are correlated such as time series data in natural sciences and as well as environmental science settings (Azumah et al., 2020). An essential part of data analysis for scientific investigations is model selection, which is essential for obtaining accurate statistical inferences or predictions (Laredo et al., 2020). There has been a recent increase in the pursuit of developing new and more adaptable statistical distributions to fit the vastly expanding diversity of data collected in real life (Ahmed & Wasan, 2023). Many regression problems require the analysis of large datasets (Ugah et al., 2023). There are several methods to predict the parameters in regression, one of the methods is Multiple Linear Regression (MLR), which is a statistical analysis used only if there is more than one predictor variable (x) which can affect the response variable (y) (Waego et al., 2020). Therefore, in the present study, the researchers intend to develop a statistical predictive model to predict biomechanics variables that affect equilibrium and sway index. Furthermore, the logistic regression model is written as the following equation (Budi et al., 2023):

$$p(x) = \frac{e^Y}{1+e^Y} = \frac{e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_k x_k}}{1+e^{\beta_0+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_k x_k}} \quad (1)$$

With e = 2.718, $p(x_i)$ is probability of predictive variables, the linear equation of above equation is then given as a MLR equation :

$$\ln\left(\frac{p(x)}{1-p(x)}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \quad (2)$$

Regression Equations on the dependent variable are computed using the formula (Hussein & Hytham, 2021):

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + \varepsilon_i \quad (3)$$

with (y_i) the response and $i = 1, 2, 3.....n$; $\beta_0, \beta_1, \beta_2, \beta_3.....\beta_k$ are the coefficients of regression parameters, $x_1, x_2, x_3.....x_k$ are predictors, and ε_i is the error. The multiple linear regression theory responds to the objective of studying the dependence of a quantitative variable *y* on a set of *k*-variables explanatory quantitative using a linear model ((Izzo et al., 2023). Here it is considered a linear regression model with three regression coefficients:

$$y = \beta_0 + \beta_1 x_1 + \beta_1 x_1 + \beta_3 x_3 + \varepsilon_i \quad (4)$$

First a linear regression model with two regression coefficients or parameters is considered:

$$y = \beta_0 + \beta_1 x_1 + \varepsilon_i \quad (5)$$

Application of regression model prediction in different situations showed that for a good number of test statistics for single outlier detection a least squares analysis based on a linear regression has been developed, however exact critical values of these test statistics are not available (Ugah et al., 2021). The usual form of a multiple linear regression model is:

$$y = \beta x + \varepsilon \quad (6)$$

Every equation can be estimated independently, even though the error terms are considered. More studies have also been spurred by improvements and expansions to the original equations (Lai Pin, 2021; Liu & Xia, 2020). Multiple equations models can be selected by using one equation at a time or all equations at the same time: the study revealed that system selections for multiple equations systems are more competent than individual selections; The multiple regression with backward stepwise elimination goes to quantify how much all predictive variables affect the outcome (Izzo et al., 2023). The main focus of this study is to observe a relationship between variables. One method of statistical analysis that can be used is regression analysis, where regression analysis is a method used to observe the relationship between two or more variables and can be used to determine the pattern of the relationship from a model whose form is not yet known (Uyanik & Güler, 2013). The objectives of this study are: to identify the significant anthropometric and biomechanical variables that affect equilibrium and sway index by using a multiple linear regression model, to apply the regression method to the volleyball player's data, and to measure the performance of this method by comparing the predictors and to find the best of them.

The purpose of this study is to estimate and select the best model on the variables that affect the balance, through the application of the multiple regression method in both 1L_EO and 1L_EC balance tests, for a sports team. In addition, his study aims to test the hypothesis to determine the variables that have a significant effect on balance.

Material & methods

Participants

The participating subjects were taken from the Tirana football club team, through the application of test measurements performed at the Sports University of Tirana, in the Biomechanics laboratory. Subjects participating were 25 female volleyball players of the Partziani team, aged 12 - 17, a mean of (14.44 ± 1.47) year old. The players were actively regularly in volleyball training for at least 2 years. The frequency of training is 3 times a week, 60 minutes for each training session.

Procedure

Informed consent was obtained from the parents of subjects, to consider them as participants of the study. The subjects were tested in two forms: 1L_EO and 1L_EC, Romberg balance tests, in two different conditions: with eyes open and eyes closed. The study period includes two phases. The initial phase: is before training measurements, and after six months, the final phase is after training measurements. The program was based in combined general training which included: plyometric, izokinetic, and kinetic chain exercises as well as specific proprioception training. 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. The sway index is defined as a numerical value of the standard deviation of the distance the subject spent away from his center of balance and it is calculated according to the following formulae:

$$SI = \sqrt{\frac{SD\,(x^2+y^2)}{N}} \tag{7}$$

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

$$EQ(AP) - \frac{B-A}{B} \times 100\% \tag{8}$$

Where A represents actual A/P sway and B represents the theoretical limits of stability. The Limits of Stability (LOS) are defined as the points where the center of gravity approaches the limits of the base of support; in other words, the limits of stability represent the maximum amount of movement that a person can intentionally make, in any direction, without losing his/her balance (Culea et al., 2023). 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 sway movement (Bendo, 2015).

Instrument & Protocols

This study was approved by the Ethical Committee of the Sports University of Tirana (SUT), and the experimental procedure was conducted at the biomechanics laboratory of this university. The instrument used for this study was a force plate Leonardo Mechanograpy GRF (Leonardo, 2010). The test procedure is simple and comfortable, after recording the weight, and the height, the participant is asked to stand still with one leg on the force plate, arms out to the sides, looking ahead at a maker (sticker) for concentration, placed in a 3 m distance To examine the effect of sensory feedback and size of BOS on human balance, the following Romberg protocol is performed in two different conditions:(1) One leg Eyes Open (1L_EO) and (2) One leg Eyes Closed (1L_EC). Each protocol is recorded within 10 seconds. The data (COP) in the mediolateral and anteroposterior directions were collected at a rate of 100 Hz and filtered with a zero-phase second-order Butterworth filter with a 5 Hz cut–off frequency. The experiment was performed in the same environmental conditions for all subjects, to avoid metabolic and physiologic changes.

Statistical analysis

Data analysis: The classical stability parameters were computed to quantify the difference between the biomechanical variables, applying the Romberg stability protocols on the force plate. The following variables were calculated from postural sway: the COP displacements and the related velocities in the AP and ML directions (cm); the average velocity (V_{avg}), which represents the ratio of the path length to the trial duration (cm/s); the path length (cm); the surface area of 95 % confidence ellipse, that is, the smallest surface area occupied by the ellipse (cm^2). The formulas used for calculating the aforementioned variables can be found in (Quijaux et al., 2021). Statistical analyses were performed using SPSS version 20. During the processing of the results, the regression method was used. This method allows us to determine the overall fit of the model and the relative contribution of each predictor to the total variance explained. The study produced model equation summaries, including multiple R^2, multiple R, and adjusted R^2, as well as F-value and significant data (Sukko et al., 2024). To test the goodness of fit of the model, we use the level of significance ($p < 0.05$), for obtaining the significant model. This statistical significance was set for all statistical procedures.

Results

Adjusting the overall model

The regression methods allow determining the overall fit of the model and the relative contribution of each predictor in complete variance to explain. In the 1L_EO test should be known the percentage of variation of test performance on the dependent variable sway area (SA) can be explained by all parameters taken into consideration as a whole, but also the "relative contribution" of each of the independent variables in explaining variance. By the application of the MRL method for the volleyball team data obtained for the two balance tests, the following table is generated. **Table 1** gives the descriptive statistics of the anthropometric parameters and generates also the variables obtained during the two phases of measurements on the 1L_EO and 1L_EC test, which are used to find the best predictor in linear regression analysis.

Table 1. Statistical descriptive of anthropometric & biomechanical parameters in two different phases of 1L_EO & 1L_EC tests.

Measurement		Parameter	Mean±SD	Rank	Min. Value	Max. Value	Variance
Anthropometric characteristics		Age (years old)	14.44 ± 1.47	5.00	12.00	17.00	2.17
		Body Height (m)	1.66 ± 0.06	0.26	1.51	1.77	0.004
		Body mass (kg)	59.00 ± 6.24	22.32	49.60	71.92	38.93
		BMI (kg/m^2)	21.54 ± 2.12	8.39	17.74	26.13	4.49
1L_EO test	Phase I	Sway Area (SA) (cm^2)	10.80 ± 6.66	32.37	4.51	36.88	44.37
		EQ(AP) %	0.79 ± 0.06	0.25	0.63	0.88	0.003
		Sway Index (SI) (cm)	2.50 ± 0.68	3.00	1.44	4.44	0.46
	Phase II	Sway Area (SA) (cm^2)	6.35 ± 2.32	8.41	3.48	11.89	5.37
		EQ(AP) %	0.84 ± 0.05	0.24	0.68	0.92	0.002
		Sway Index (SI) (cm)	1.89 ± 0.59	2.88	0.96	3.84	0.35
1L_EC test	Phase I	Sway Area (SA) (cm^2)	52.96± 54.65	244.03	6.23	250.26	2986.25
		EQ(AP) %	0.59 ± 0.14	0.70	0.15	0.85	0.02
		Sway Index (SI) (cm)	4.88 ± 1.70	8.40	1.80	10.20	2.89
	Phase II	Sway Area (SA) (cm^2)	21.43 ± 11.87	49.23	4.38	53.61	140.79
		EQ(AP) %	0.71± 0.08	0.33	0.56	0.89	0.006
		Sway Index (SI) (cm)	3.43 ± 0.90	3.96	1.32	5.28	0.81

Results in finding the best models for EQ(AP) in 1L_EO test

By application of the method of regression for the anthropometric and biomechanical data obtained for 1L_EO test, **Table 2** is generated. This table gives a summary overview of the model. R→ value represents the coefficient of correlation. R can be considered to be a measure of predict quality (SA). A value of R = 0.764 in this case, shows a good level of prediction. Value R^2, is also the coefficient of determination, which is part of the variance in the dependent variable that can be explained by the independent variables, values R^2=0.584 shows that independent variables taken on this model can explain 58.4 % of the variance of the sway area in 1L_EO test. In the ANOVA table, value of Fisher test provides whether the full regression model fits well with the data. For this parameter, the value of Fischer's, $F(1, 23)=32.227$ and $p < 0.001$. Since $p < 0.001$, it means that the regression model fits well with the data.

Table 2. Summary of the overall model.

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	.764[a]	.584	.565	.03244
a. Predictors: (Constant), SA.				

Results in finding the best models for Sway Index in 1L_EO test

Table 3 gives a summary of exploratory model for sway index. According to this model, SA is the best predictor alone. The correlation coefficient R = 0.764 shows a good relationship to sway index, $R^2 = 0.584$ and this step estimates 58.4% of variance of this independent variable. The reported ANOVA values: F(1; 23) = 32.227 and p < 0.001 shows that this model has significant results.

Table 3. Summary exploratory model.

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	.764[a]	.584	.565	.038923
a. Predictors: (Constant), SA.				

The regression results finding the best models for EQ(AP) in 1L_EC test

Table 4 shows a summary of explanatory model of EQ(AP) in 1L_EC test. Based on the results, the value generated by this explanatory model reveals three kinds of models: A, B and C.

Table 4. Summary exploratory model

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	.857[a]	.734	.723	.03949
2	.884[b]	.782	.762	.03659
3	.910[c]	.828	.803	.03325
a. Predictors: (Constant), v(COP) b. Predictors: (Constant), v(COP), SA c. Predictors: (Constant), v(COP), SA, Body Height				

According to model A) → sway velocity of the center of pressure v(COP) → is the best predictor alone. For this variable, R= 0.857 shows a strong correlation to the equilibrium, $R^2 = 0.734$, and this step estimates 73.4% of the variance of the equilibrium from sway velocity. The reported Fisher values are as follows: F (1, 23) = 65.563 and p <0.001, statistically significant.

According to model B) → Sway velocity of the center of pressure v(COP) and sway area (SA) are the best predictor models. So, SA is the second best predictor added after v(COP), which is included in this model. For both variables, R = 0.884 shows a very good relationship to equilibrium. $R^2 = 0.732$ and the second step calculates the 78.2% of the variance of equilibrium from both independent variables. The values reported by ANOVA are respectively: F(2; 22) = 39.413 and p < 0.001.

According to model C) → Sway velocity of the center of pressure v(COP), sway area (SA), and body height (H) are the three best predictors of the model. This way, body height is the third predictor after v(COP) and (SA) in the model. For all three of these variables, R =0.910 shows a very strong correlation. The value R^2 =0.828 and the third step estimates 83% of the variance of equilibrium from these three variables. According to ANOVA results; the respective values are F (3; 21) = 33.695 and p < 0.001. All three models together have significant results, since both of them p < 0.001.

Finding the best model for Sway Index (SI) in 1L_EC balance test

A summary of exploratory models indicates which variables included in the model step by step, is shown in **Table 5**, for sway index.

Table 5. Summary exploratory model.

Model	R	R Square	Adjusted R Square	Std. Error of The Estimate
1	.857[a]	.734	.723	.47390
2	.884[b]	.782	.762	.43910
3	.910[c]	.828	.803	39904
a. Predictors: (Constant), v(COP) b. Predictors: (Constant), v(COP), SA c. Predictors: (Constant), v(COP), SA, Body Height				

*According to the model A)*Sway velocity of the center of pressure v(COP)→ is the best predictor alone. For this variable. R = 0.857 shows a very good correlation to the sway index (SI). $R^2 = 0.734$ and this step calculates the 73.4% of variance of sway index from the independent variable v(COP). The Fisher values are respectively: F(1; 23) = 65.563 and p < 0.001.

According to the model B): Sway velocity of the center of pressure v(COP) and sway area (SA)→ are the best predictors model. So SA is the second best predictor added after v(COP) is included in the model. For both variables, R=0.884 shows a very strong relationship. $R^2=0.784$ and the second step estimates 78.2% of the variance of SI and these two variables. The corresponding ANOVA values reported are as following: F (2, 22) = 39.143 and p< 0.001.

According to the model C): Sway velocity of the center of pressure v(COP), sway area (SA) and body height→ are the best predictors model. Body height is the third best predictor added after v(COP) and SA in this model. For all three of these variables, R=0.910 shows a very strong correlation. $R^2=0.828$ and the third step estimates 82.8% of the variance of SI and these three variables. The corresponding ANOVA values reported are as following: F (3, 21) = 33.695 and p< 0.001. All three models have statistical significant results, since for all models p < 0.001.

Discussion

The regression equation for the best predictor of EQ(AP) in 1L_EO test

The table 6 of beta coefficients (β), gives the corresponding values for the best predictor model, therefore based on them, the regression equation can be set.From this table, it is noticed that β coefficients vary depending on the predictors that are included in the model. The regression equation for the model included in the explanatory model in table 6, is as follows:

$$\text{EQ(AP)}(\textit{predicted}) = 0.946 - 0.016(SA) \tag{9}$$

According to this model, SA is the best predictor alone, and for any 1 cm^2 increase of SA, there is a 1.6% decrease in equilibrium.

Table 6. Beta coefficients of EQ(AP) dependent variable in 1L_EO test.

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	**.946**	.019		49.114	.000
S	**-.016**	.003	-.764	-5.677	.000
a. Dependent Variable: EQ(AP)					

The regression equation for the best predictors of SI in 1L_EO test

Table 7 of beta coefficients provides the corresponding values for the best predictor of the model, therefore based on them the regression equation can be formulated. These coefficients change depending on the predictors that are included in the model. According to this model, the regression equation can be written:

$$(SI)(\textit{predicted}) = 0.651 + 0.195(SA) \tag{10}$$

This is the weight of an equation that includes: sway area (SA) as the best predictor of this model. According to this equation, for any 1 cm^2 increase of SA, there is a 0.195 cm increase of sway index (SI).

Table 7. Beta coefficients for Sway Index (SI) dependent variable in 1L_EO test

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	**.651**	.231		2.819	.000
S	**.195**	.034	.764	5.677	.000
a. Dependent Variable: Sway Index (SI)					

The regression equation for the best predictor of EQ(AP) in 1L_EC test

The beta coefficient table gives the corresponding values for the best predictor model, based on them the regression equation can be constructed. From the **Table 8**, it is noticed that the beta coefficients change depending on the predictor included in the model. The regression equations for each model included in the explanatory model are as following:

According to the model A)

$$\text{EQ(AP)}(\textit{predicted}) = 0.933 - 0.002v(\text{COP}) \tag{11}$$

This equation includes the sway velocity of COP in 1L_EC balance test as the best predictor of this model. This means that for any sway velocity increase of 1mm/s, there is a 0.002% decrease of EQ(AP) term.

According to the model B)

$$\text{EQ(AP)}(\textit{predicted}) = 0.917 - 0.001v(\text{COP}) - 0.002(\text{SA}) \tag{12}$$

In this equation, the sway velocity of COP and SA are included as the best predictors of the model B. For any 1 mm/s increase of v(COP), there is a 0.1% decrease of equilibrium and for any 1cm^2 increase of SA there is a 0.2% decrease of equilibrium.

According to the model C)

$$EQ(AP)(predicted) = 0.487 - 0.001v(COP) - 0.002(SA) + 0.259(Height) \quad (13)$$

There are respectively weight for an equation that includes: v(COP), SA and body height as the best predictors of this model. According to the model C, for any 1 mm/s increase of v(COP) there is a 0.1% decrease of equilibrium, for any 1 cm^2 increase of SA there is a 0.2% decrease of equilibrium and for any 1 m increase of body height there is a 25.9% increase of equilibrium.

Table 8. Beta coefficients for EQ(AP) dependent variable in 1L_EC test

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1. (Constant)	**.933**	.029		32.621	.000
S	**-.002**	.000	-.857	-7.973	.000
2. (Constant)	**.917**	.028		33.246	.000
v(COP)	**-.001**	.000	-.623	-4.256	.000
SA	**-.002**	.001	-.320	-2.189	.040
3. (Constant)	**.487**	.183		2.663	.015
v(COP)	**-.001**	.000	-.600	-4.504	.000
SA	**-.002**	.001	-.365	-2.720	.013
Height (H)	**.259**	.109	.217	2.375	.027
a. Dependent Variable: EQ (AP)					

The regression equations for the best predictors of Sway Index (SI) in 1L_EC balance test

The regression equations for the best predictors of the model are based on the values of beta coefficients in **Table 9**, which can be vary depending on the predictors included in each of the model. The respective equations are as following:

According to the model A)

$$(SI)(predicted) = 0.801 + 0.021v(COP) \quad (14)$$

Which includes the sway velocity of COP in 1L_EC balance test as the best predictor of this model. According to this model, for any 1 mm/s increase of the sway velocity of COP, there is a 0.021 cm increase of the sway index (SI).

According to the model B)

$$(SI)(predicted) = 1.001 + 0.015v(COP) + 0.024(SA) \quad (15)$$

The weights for this equations includes: the sway velocity of COP and SA as the best predictors of the model B. So, for any 1 mm/s increase of v(COP), there is an increase of SI with 0.015 cm, and for any 1 cm^2 increase of SA, there is also an increase of Si with 0.024 cm.

According to the model C)

$$(SI)(predicted) = 6.159 + 0.014v(COP) + 0.028(SA) - 3.103(Height) \quad (16)$$

This equation includes: v(COP), SA and body height as the best predictors. Based on the model C, for any 1 mm/s increase of v(COP) there is an increase of 0.014 cm of SI, for any 1 cm^2 increase of SA there is an increase of SI with 0.028 cm and for any 1 m increase of body height there is a 3.103 cm decrease of SI.

Table 9. Beta coefficients for Sway Index (SI) dependent variable in 1L_EC test

Coefficients[a]					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1. (Constant)	**.801**	.343		2.335	0.29
v(COP)	**.021**	.003	.857	7.973	.000
2. (Constant)	**1.001**	.331		3.025	.006
v(COP)	**.015**	.004	-.623	4.256	.000
SA	**.024**	.011	-.320	2.189	.040
3. (Constant)	**6.159**	2.193		2.808	.011
v(COP)	**.014**	.003	.600	4.504	.000
SA	**.028**	.010	.365	2.720	.013
Height (H)	**-3.103**	1.307	-.217	-2.375	.027
a. Dependent Variable: Sway Index (SI)					

The application of the linear regression analysis method in the 1L_EO balance test for predicting the parameters of EQ(AP) and SI, revealed that the variables entered in the regression equation statistically significantly predicted equilibrium and sway index: $F(8; 16) = 6.712$; $p < 0.001$. In accordance with the results of the explanatory analysis, it is confirmed that only one of these variables contributes statistically significantly to the prediction of the regression equation for the equilibrium: sway area (SA), for which $p < 0.001$, therefore it will be taken as the best predictor of the model for the 1L_EO balance test.

From the application of the regression method in 1L_EC test, for the main balance parameters EQ(AP) and SI, the variables entered in the regression equation predicted statistically significantly equations of these parameters: F (8; 16) = 12.999; $p < 0.001$. According to the results of the explanatory analysis, it is shown that only three of these variables contribute statistically significantly in the prediction of the regression equation for EQ(AP) and SI: which are respectively: v(COP), SA and body height, for which $p < 0.001$, therefore they will be taken as the best predictors of the regression model for 1L_EC balance test, in predicting the equilibrium of the volleyball female team.

The application of regression equations is extended in many fields. Some studies have shown that a predictive model of injury occurrence may help to prevent future injury of sportspersons with a higher risk of developing injury (Nelson et al., 2019). It can inform the subject about the risk level of probability of occurrence of injury and can help in taking appropriate preventive actions (Hemantajit et al., 2021). The majority of these studies assume that the same kinematic factors are related to various running injuries (Bramah et al., 2018). Progressive fatigue sets in, prominently impacting dynamic balance and overall functional performance among players. In response to the demands of ankle injury prevention and instability management, the application of ankle taping has become a prevalent strategy in the world of sports, because the fatigue impairs dynamic balance, which may increase sports injury risk (Azhar et al., 2023).

A previous study has confirmed the correlation between leg strength and various physical attributes, particularly gender and quadriceps muscle thickness, which are significant predictors of leg strength in individual aged 19-25 years old (Sukkho et al., 2024). Another study applied in the rehabilitation program on balance showed that people who have a low stability limit have an increased risk of injury caused by falling, when they shift their bodyweight forward, backward or sideways, and the prevalence of ankle sprains, associated with high recurrence rates, persistent impairments, and the deterioration of the ankle's functional ability (Culea et al., 2023).

Balance is one of the less studied and quantified skills in the school environment (Garcia et al., 2020). Some balance assessments are usually based on qualitative methods, which are inefficient and have low reliability (Hahn & Chou, 2023). On the contrary, numerous studies have been performed to assess equilibrium about the global behaviour of the individual and not specifically their COG, (Rogers et al., 2003). To maintain standing balance, the location of an individual's, COG must remain vertically projected within the boundaries of the base of support, and although the predictive power of each variable differed across the balance conditions, the findings indicate that COP sway-area rate, a clinically meaningful standing balance variable can be estimated from wearable accelerometers across balance conditions (Carzoli & Enoka, 2023).

One study revealed that 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 (Bendo et al., 2023a), whereas another study showed that three main sway parameters: SA and SI are statistically decreased due to the balance training in yoga exercises, while EQ scores are statistically increased (Bendo & Haxholli, 2017), confirming that proprioception training and yoga exercises have resulted overall in the improvement of the body equilibrium system. The results of this study are in line with the previous study, which reported that MLR for CMJ and SJ jump test on a football club emerged the maximal velocity and body mass parameters as the best predictor of the main variable maximal height in CMJ test, as well as the body mass and Pmax/kg parameters as the best predictor for Fmax in SJ test (Bendo & Mara, 2020). There are many possibilities for quantifying the COP path of body sway, and combinations of anthropometric and biomechanical parameters may explain the behavior of balance in different conditions more completely.

Conclusions

The main objective of MLR analysis is to predict the relationship of a respondent variable in terms of predictor variables in a linear function or multiple linear functions. The regression method applied on 1L_EO and 1L_EC balance tests for a volleyball team, allows us to determine the overall fit of the model and the relative contribution of each predictor to the total variance explained. In both tests, was found that much of the variation in the test performance of the dependent variable can be explained by anthropometric and biomechanical parameters as well as the relative contribution of each independent variable in explaining the variance. The equations of regression for this team emerged these parameters as the best predictor of the main variables for each test: for EQ(AP) and SI in 1L_EO test: sway area (SA); and for EQ(AP) and SI in 1L_EC test: (COP), SA and body height, for which $p < 0.001$. Considering the objectives of the research and presenting the results of the research study, the following can be concluded:

The multiple regression analysis point out significant relationship of a respondent variable in terms of predictor variables in a multiple linear function. The results have identified the significant variables that affect equilibrium and sway index by using MLR model. The application or MLR model to Volleyball player's data have allowed to estimate the performance and to select the best model of this method by comparing the predictors between them.

This study has estimated and selected the best model on the variables that affect the balance.

Clearly, the training technique strongly affects the mechanical output muscles, as the motors that generate explosion maximal force and also improving equilibrium. Application of this statistical model in a sport team such as volleyball, has confirmed that MLR method is very effective and it is highly recommended to estimate and to select the best model on the variables that affect the balance or equilibrium. Finally, all strength exercises in this volleyball team, have improved the biomechanical parameters, including the balance ability.

Recommendations

The results of this study are expected to be useful for coaches of different disciplines for predicting the responsible variables that affect the balance. Similar studies and MLR methods should be performed for the estimation of other interest variables in many sports disciplines. The application of methods of machine learning or data mining tools could be useful in further research work on the human body balance.

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Conflict of interest

The authors declare no conflict of interest.

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