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Research paper

Postural Balance for Selection of Martial Artists Using Machine Learning Techniques

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Abstract

Due to differences in power and different pressures applied to joints and muscles, both athletes in different kinds of sports and non-athletes may have different grades in balance tests. There isn't enough information on specific or non-specific balance in sports. The purpose of this study was to classify participants, according to balance test scores, and to detect martial art athletes. Fifty healthy volunteers participated in this experiment. Measures of static and dynamic balance indices were obtained from 4 balance tests. Balance test scores were used for inputs of classifiers where the applied methods included the support vector machine, k-nearest neighbor's algorithm, and artificial neural network. Only by the result of 4 tests, detection accuracy of 90.5% was achieved. Balance indices are useful features for the detection of martial art athletes. This may also be helpful for talent identification in martial arts.

Keywords*:* Artificial Neural Network, Balance, Classification, K-Nearest Neighbors, Martial Arts, Support Vector Machine

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Introduction

Balance during physical activities is a critical element in the control of dynamic movements. It denotes one's ability to maintain the body's center within the base of support [1]. Substantial data suggest that physical exercise can help improve one's balance, walking, and muscular strength [2]. Although maintaining postural control is significant and necessary for all activities, this factor is the main feature in activities performed with high intensity and speed [3], and to achieve success and avoid injuries, it should be of the highest quality. Any disruption causing the person's matter in maintaining the control of stature increases the risk of falls and injuries [3]. The main role and importance of keeping balance in physical performance and gesture cannot be ignored. One's ability to maintain postural control can determine his/her success in physical activities [4]. The capacity for balance maintenance depends on different elements, including muscular power and anaerobic capacity [4]. Considering all key characteristics, factors, the needs of the discipline, and the type of training and skills, each sport needs a different level of balance [5]. Athletic performances that affect balance are different in any sport. [6-7- 8-9, 10].

The proposed aim of our study was based on a supervised learning model to predict the correct label for newly presented input data. The function used to connect input features to a predicted output was created by the machine learning model during training.

Methods

The aim of the present study is to classifying the participants according to the balance test scores and to detect athletes in martial arts. As it mentioned before, participants were tested by the 4 balanced tests. These balance tests are mentioned in Table 1.

Table 1- List of features extracted for classification.

Index	Descriptions
#1	Stork balance stand test (open eyes) in seconds
#2	Stork balance stand test (closed eyes) in seconds
#3	Y test (lower quarter) score
#4	Y test (upper quarter) score

Fifty secondary school male students (mean age ± SD = 16 ± 01 years), with no physical problems and known disorders, participated in this study. Since most secondary school athletes are multisport, we asked if each of the 50 participants have competed more than one sport. Also, these sports were after school/weekend sports teams. Twenty-five of the participants were martial art athletes although the other twenty-five were not martial art athletes. In both groups, there were participants with different stature and mass characteristics; however, all participants, except for 3 martial artists, had a normal body mass index. Martial arts exercises included Taekwondo (n=4), Wrestling (n=8), kickboxing (n=1), Karate (n=4), Kung Fu (n=3), Ninjutsu (n=2), and Boxing (n=3). The non-martial artist group included Swimming (n=1), Football (n=3), Futsal (n=1), Volleyball (n=2), and Fitness (n=3), as well as non-athletes (n=15). It should be noted that 15 of the subjects were not professional athletes. However, in every respect, they were healthy and strong than they had regularly exercised in the form of non-professional. Those that were in the martial arts group had a few years of martial arts exercise experience and had regular practices in the last 6 months. Further, participants who were in the non-martial artist group and were active in other sports, had the same amount of experience and practice in their sports activities. Those who did not have these conditions, were labeled as non-athletes.

In response to the question of why these balance tests were selected, it should be mentioned that this work aims to study the relationship between balance and martial arts, and the detection of martial artists from balance test scores. The performance, reliability, and validity of selected balance tests in balance assessment have been proved in numerous studies [7, 11- 12-13-14-15-16-17-18-19-20-21-22]. Stork test assesses static balance. Measure from the Y-Balance Test lower quarter is an appropriate measure of dynamic balance. The upper quarter screen seeks to assess scapular stability, scapular mobility, thoracic rotation, and core stability. It seems these factors are important in martial arts [23]. Thus, these tests are selected. Descriptions of the balance tests are provided subsequently.

A: Stork Balance Test

In this test, after positioning the hands on the hips, the participant is asked to rest the free foot against the inner knee of the opposite leg; the participant has 1 minute to reach the balance. Afterward, he is asked to lift the heel to reach balance on the ball of the foot. In the present study, the watch is stopped in case one of the following conditions were encountered: (1) movement of the supporting foot in any direction, (2) loss of contact between the free foot and the knee, and (3) positioning the heel of the involved foot on the floor. To rate the participants' performance, the total time is reported in seconds, and the best performance among the 3 trials is scored [1]. This test is done with both open and closed eyes.

Fig 1- Stork Balance Test – starting position [28]

B: Y Test (Lower Quarter)

Before the test, the participants watched a video of standard guidelines, which showed the evaluator's presentation of the designated positions. In general, the Y balance test is a dynamic tool, which is applied while the participant stands on 1 single leg; this stance demands muscular endurance, flexibility, core control, as well as proprioception. Physical performance and functional symmetry can be evaluated by this test. Additionally, athletes who are at a higher risk of severe damage in the lower extremities, can be distinguished by this measure [12-13]. The purpose is assessment of active balance and core control. Before implementing the test, it is essential to assess the length of the right limb for further calculations. In this test, the goal is to keep one's balance on a single leg, while reaching as far as possible with the opposite leg positioned in 3 different directions (anterior, posteromedial, and poster lateral directions). In total, six tests should be applied: 1. Right anterior reach. 2. Left anterior reach. 3. Right posteromedial reach. 4. Left posteromedial reach. 5. Right poster lateral reach, and (6) Left poster lateral reach.

First, the participant is asked to stand on a single leg at the stance plate with toes placed on the red line, then, the participant slowly positions the opposite leg right behind the plate. The non-supporting foot is stretched in the desired direction to press the indicator as far as possible while keeping balance. The participant should place the non-supporting foot in the initial position while maintaining balance. However, one might not be able to put the free leg down during the movement to keep balance. Also, one might place his foot on the indicator to have stance support and might not be able to touch the indicator.

In this test, all calculations are obtained from the red line of the stance plate and are scored to the closest 0.5-cm increment; the test device is used to measure the distance. Besides, every test is performed in triplicates, and the maximum reach is recorded in each direction. To determine a "composite reach distance", the results are calculated considering limb length. Moreover, the measurements from each leg can be compared to assess asymmetry. In general, the Y balance test is derived from the Star Excursion Balance Test [12].

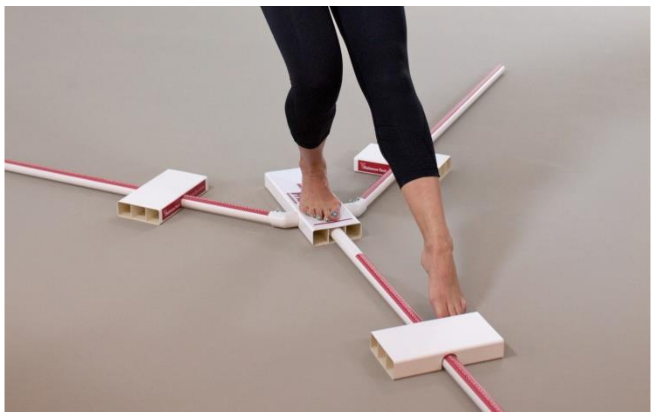

Fig 2- Y Test (Lower Quarter) [29]

C: Y Test (Upper Quarter)

Before implementation of the test, the participants watch a video of standard guidelines, which includes the evaluator's presentation of the designated positions. To implement YBT-UQ, the participant first places one hand on the stance platform. The thumb is drawn inward and aligned behind the red line. The initial position of the reaching hand is determined by placing it on the medial reach indicator, which is situated shoulder-width from the stance plate. The participant assumes three different directions with the freehand; meanwhile, he remains in a pushup position with feet placed shoulder-width apart. The test is repeated if the following conditions are encountered: (1) failure to keep the one-hand stance on the platform (touching the floor with the reaching hand or falling off the platform); (2) failure to maintain contact between the hand and the indicator on the intended area during movement (shoving the indicator); (3) use of the indicator as stance support (positioning the fingers or hand on the indicator); (4) failure to move the reaching hand to the initial position under control; and (5) raising one of the feet off the floor. This process is carried out in triplicate in every direction for every hand. Also, it should be mentioned that the participants are free to leave the study if they desire.

A standard arrangement is developed to promote test reproducibility and introduce a reliable protocol. The arrangement includes placing the right hand on the stance plate so that the left hand can reach the medial direction (right medial reach). Then, the participant reaches under the trunk in infer lateral direction (right infer lateral reach) and then the super lateral direction (right super lateral reach); finally, the participant returns to the initial position while maintaining control. The mentioned procedure is repeated two more times on the right limb. Following 3 trials on the right limb, the same process is carried out for the left limb. To reduce the influence of test novelty and to prevent the participants' exhaustion (considering the test's demanding nature), a practice trial is performed on every side before the trials. The farthest distance the participant can reach is calculated using tape on the edge of the indicator (where the most distal part of the hand can reach). The calculations are graded concerning the nearest 0.5-cm increment [14]. The gathered information has been randomly categorized into two datasets for training and evaluation, respectively. The cross-validation technique is used to assess the participant’s final performance. All the study samples (n=50) are classified into two groups for training and testing, respectively.

Fig-3 Y Test (Upper Quarter) [29]

Our tools for analysis of the data in association with the test of the athletes include Multi-layer Perceptron (MLP) Artificial Neural Network (ANN), Support Vector Machine (SVM) and K-Nearest Neighbors (K-NN) classifiers. In this section, we are going to mainly explain how these ANNs and classifiers are employed to deal with our data.

I: Multi-layer Perceptron Artificial Neural Network

Multi-layer Perceptron Artificial Neural Network is recently introduced as computational system used for machine-based learning, information presentation, and knowledge application for the prediction of the response of a complex system. They are mainly based on the performance of the nervous system in processing information for learning and knowledge development. The introduction of novel configurations for data processing is a major component of ANNs. Artificial Neural Networks act in conjunction with different processing elements, known as neurons, to resolve different problems. In this network, if a neuron is damaged, the rest of the neurons can compensate and reconstruct the loss. These networks are capable of learning.

II: Support Vector Machine

The SVM is regarded as a controlled learning method [24] that is used for classification [25] and regression [26]. This is a relatively new method, which has shown good performance in recent years. The SVM classifier works on the linear classification of data, and in the linear division of data, it tries to choose a line, which has a more confident margin.

III: K-Nearest Neighbors

In pattern recognition, the k-NN algorithm is regarded as a nonparametric method of categorization and regression [27]. The input of this algorithm includes the k-nearest neighbors in the feature space. On the other hand, the output of categorization includes class membership. An object is categorized concerning the majority of its neighbors and is allocated to a class, which is the most common among its k-closest neighbors (k is a positive integer). In this algorithm, if k is equal to 1, the object will be categorized in the class of the closest neighbor.

IV: Evaluation of Classifiers

In a 2-class problem, consisting of positive and negative samples, TP and TN denote positive and negative samples, respectively, which are accurately categorized. On the other hand, FP and FN denote positive and negative samples, which are mistakenly categorized, respectively. Overall, different functions can be used for quantitative assessments.

$$\text{Sensitivity (recall)} = \frac{\text{TP}}{\text{TP+FN}} \qquad (1)$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN+FP}} \qquad (2)$$

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+FN+TN+FP}} \qquad (3)$$

In the present study, in ANN, using a multilayer perceptron (MLP), the number of nodes in the hidden layer is empirically set at 5 for better outcomes. The training process ends as soon as the participant's performance ceases to change over a long period (> 400 iterations). Performance is analyzed in terms of sensitivity, specificity, and accuracy.

In SVM, the radial basis function kernel is used as it can produce particularly favorable outcomes. Other significant parameters for SVM consisting of γ of the Gaussian kernel as well as the soft-margin parameter C are assigned through the

cross-validation technique by choosing different classifications of parameter values. The group providing the highest total accuracy is selected as the most favorable.
Finally, for the K-NN classifier, the K parameter is empirically set as 1 for better results.

rEESULT AND DISCUSSION

Data on 50 high school male students (mean age ± SD = 16 ± 1 years) are included in our study. Among these participants, 50% are martial artists. There is a significant difference between the balance of martial artists and non-martial artists. The current study is able to detect martial artists with an accuracy of 90.5%, and sensitivity and specificity of 91% (Table II). The findings of this study suggest that martial art athletes have specific balance (as measured by the stork, Y lower and upper quarter tests) and the balance is a good sign for the detection of martial artists.
In addition, need for specific balance for any sport is demonstrated in this study, which is consistent with previous reports [5, 6, 7, 8, 9, and 10].
It is important to note the limitations of this study. The first limitation is that it has been conducted on a small population. Secondly, all participants are male. Finally, the experiment is conducted on a specific age group. Regardless, it may be beneficial to prove specific balance in martial arts and detect martial artists from balance test scores. Future research should include females and larger sample sizes and other age ranges.
The results demonstrated the appropriate detection of machine learning techniques on the data. There is a significant relationship between balance and being a martial artist Furthermore, the results indicated the need for a specific balance in martial arts. The experimental results of ANN, SVM, and K-NN classifiers are discussed in the next section for categorizing and identifying martial arts athletes, using balance parameters. To confirm the results of the present study, quantitative assessments were performed. In our study, the training ratio is set at 80% (80%, training; 20%, testing).
Table 2 presents the quantitative comparison of ANN, SVM, and K-NN. The SVM outperforms ANN and K-NN in sensitivity and accuracy. The sensitivity of 0.91 and accuracy of 0.905 from SVM is much larger than those of ANN and K-NN at 0.82 and 0.84, and 0.82 and 0.86, respectively. This refers to significantly superior performance. In the specificity, K-NN generates slightly better results than ANN and SVM.

Table 2- List of Different Applied Classifiers and Their evaluation parameters

		Classifiers		
		ANN (MLP)	**SVM**	**K-NN**
Evaluation Parameters	Sensitivity	0.82	0.91	0.82
	Specificity	0.86	0.90	0.91
	Accuracy	0.84	0.905	0.86

Conclusion

Data on 50 high school male students (mean age ± SD = 16 ± 1 years) are included in our study. Among these participants, 50% are martial artists. There is a significant difference between the balance of martial artists and non-martial artists. The present study proposed to detect martial artists with an accuracy of 90.5%, and sensitivity and specificity of 91% (Table II). The findings of this study suggest that martial art athletes have specific balance (as measured by the stork, Y lower and upper quarter tests) and the balance is a good sign for the detection of martial artists.

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