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RESEARCH ARTICLE

Intelligent Prediction of Suitable Physical Characteristics Toward Archery Performance Using Multivariate Techniques

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Abstract

The present study aims to explore different physical characteristics towards a successful performance of archery and to predict the most vital attributes that contribute to the achievement of high archery scores. 32 archers drawn from different archery programmes participated in the study. Standard physical characteristics tests were conducted, and archers' shooting scores of one end were recorded. Multivariate techniques of principal component analysis (PCA), hierarchical agglomerative cluster analysis (HACA) and discriminant analysis (DA) were used to achieve the aims of the study. The PCA after varimax rotation indicates two variables containing 12 and 2 varifacators (VF). The First VF revealing high positive loadings from weight (0.94), calf circumference (cc) (0.89), abdomen cc (0.97), hip cc (0.97), thigh cc (0.95), triceps thickness (0.76), biceps thickness (0.75), subscapular thickness (0.83), suprailiac thickness (0.85), abdominal thickness (0.85), front thigh thickness (0.76) and medial calf thickness (0.80) revealing that endomorphic body positively affect the performance of the sport. The second VF discloses high negative loadings from height (-0.88) and arm length (-0.90) describing that body height, and arm length negatively affects the performance of the sport. HACA classified the archers into three classes based on the PCA outputs namely; High-performance class, Medium-performance class and Low-performance class. Standard, backward and forward stepwise DA discriminate the classes from the 14 predicted variables with accuracies of 74.19%, 96.77% and 93.55% respectively. The findings from the current study can be helpful in mapping out potential athletes in archery based on their physical characteristics.

Keywords: *Intelligent prediction, Archery, Physical characteristics, Multivariate techniques.*

Introduction

Various evident have indicated that body size and strength contribute to motor performance. The escalation in strength is associated to rise in total muscle mass [1].

There exist evidence showing the significant positive relationship between strength and performance specifying that stronger individuals are the individuals who accomplished better [2].

Nevertheless, the style of enhancement of strength and physical performance is not identical in all tasks. Strength and body size may be essential to the successful performance of some specific motor performances but not as imperative to others. It is probable that performances associated with resistance activities would display a parallel tendency to that of power. Physique and body composition have commonly been discovered to have a significant connection with physical performance [3].

However, it has been reported that body physique does not predict performance in many instances [4].

Nonetheless, a high level of endomorph is

bound to restrict physical performance volume, whereas a high degree of mesomorphy is more inclined to motor performance [4]. Moreover, associations between physique, strength and performance are usually considered moderate and not necessarily high for predictive bases [5,6].

Despite limited available data related to archer's body physique and its association with their performance, previous researchers revealed that the sum of the body shape and physical function of Xibo ethnic archers have distinct variations on their performances for the females their physique features require strength endurance, and the male require the training of strength endurance, and the training standard should not necessarily be a contact and endurance type [7]. This evidence has shown that there is still the need for more literature to elucidate the relationship of body composition and physique with the shooting performance in youth archery.

Despite the attempt of the previous researchers to offer insight into the physical characteristics of their archers, to date, there has been little or no effort to investigate in-depth different physical attributes and to predict the most crucial physical variables that could play a role in the successful performance of the sport.

The current study hypothesized that certain physical characteristics could influence successful archery performance. In view of this background, the current study aims to explore different physical characteristics towards a successful performance of archery and to predict the most vital attributes that contribute to the achievement of high archery scores.

Material and Methods

Participants: A total number of 32 archers were recruited to participate in this study. The participants were 24 males and 8 female youth archers between the ages range of 13-24 with a mean and standard deviation of (17.0 ± 3.4) drawn from Terengganu sports council, Malaysia. The archers are under development program for training both at university and the state level and subsequently, targeted to be promoted to state and national archers respectively. Some of the archers have represented their respective university and state for inter-state archery championship within Malaysia.

The coaches and the stakeholders of the council were informed about the purpose of the research. Written approval was obtained, and all the archers signed consent forms.

All the procedures, protocol and apparatus for this study were permitted by the Research Ethics Board of the Terengganu Sports Institute (ISNT) with a reference number 04-04/T-01/Jid 2.

Physical Characteristics Test: Standard anthropometric testing was conducted which include weight and height. Standing height was measured with a wall-mounted wooden stadiometer to the nearest 0.5 cm. Body weight was taken with a standardized electronic digital scale to the nearest 0.01 kg.

Skinfold calipers were used to measure the triceps, biceps, subscapular, suprailiac, abdominal, front thigh and medial calf to the nearest 0.1 mm, whereas medial upper arm circumference (muac), abdominal circumference, hip circumference, thigh circumference, arm span and calf circumference (cc) were measured via measuring tape. All the measurements were implemented in accordance with ISAK protocol [8].

The measurements were obtained twice, and the mean value was generated as the final score.

Archery Shooting Score Test: A simulated shooting competition area was set up, and all the archers' shoot six arrows (one end) over 50 meters. All the archers were given trials of four arrows shot before recording the final six arrows scores.

Data Analysis: In the present study, PCA was used to give insights into the an essential variables due to its ability in lessening huge variables with a considerably limited loss of the original data [9].

Hierarchical agglomerative cluster analysis (HACA) was applied to isolate the classes of the relevant performance variables measured. Discriminant analysis (DA) was employed using the standard, forward stepwise, and backward stepwise methods.

These methods were used to construct degree of freedoms (DFs) to evaluate relative performance variations in the physical characteristics and the archery shooting performance.

The relative performances of the archers were the accumulated (dependent) variables whereas all the assessed components constitute the independent variables. Similarly, in the forward stepwise mode, the variables were counted step by step beginning with the highest significant variable until no significant changes were obtained.

In the backward stepwise mode, variables were eliminated step by step starting with the less important variable until no significant changes were obtained. All the statistical analysis was performed at $p \leq 0.05$ alpha level of confidence using XLSTAT 2014 add-in software USA.

Results

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is shown in Table 1. The test was implemented to determine the adequacy of the sampling to quantify as well as to make a reasonable interpretation based on the data gathered [10,11]. Similarly, the test was conducted to ensure that the variables are not related to each other.

The KMO value from the table shows 0.83 which contributed for 83% sampling adequacy. Therefore, based on results it is apparent that there is no multicollinearity observed among the original variables and that enabled us to proceed further with the PCA analysis having satisfied the measure of the sampling adequacy.

The scree plot of the eigenvalue for the initial PCA is displayed in Figure 1. From the figure, it can be observed that the PCA identified two components as the most essential due to their higher eigenvalues greater than 1(>1). These components were retained and used as an input variable for further analysis.

Table 1: Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy

Variables	Values
Weight(Kg)	0.79
Height(cm)	0.48
Calf circumference(cm)	0.87
Abdomen cc(cm)	0.84
Hip cc(cm)	0.83
Thigh cc(cm)	0.88
Arm span(cm)	0.51
Triceps(mm)	0.85
Biceps(mm)	0.94
Subscapular(mm)	0.87
Suprailiac(mm)	0.95
Abdominal(mm)	0.82
Front thigh(mm)	0.81
Medial Calf(mm)	0.84
KMO	0.83

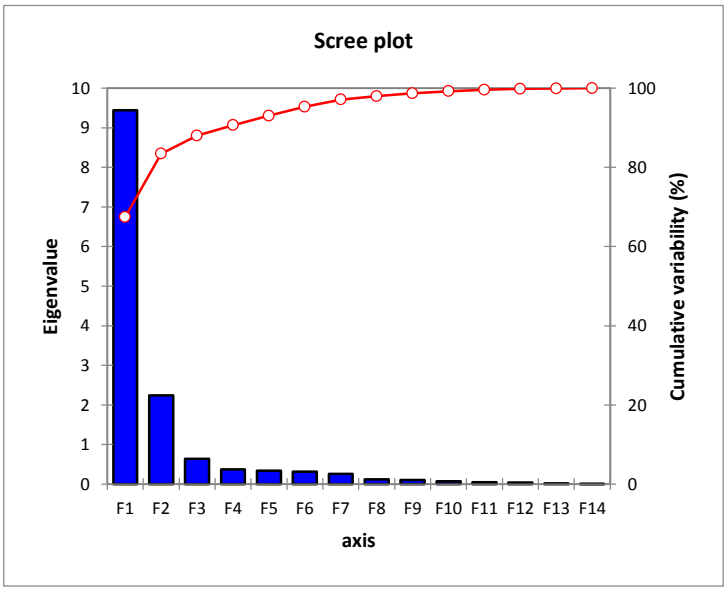

Figure 1: Scree Plot for PCA

The PCA after varimax rotation is demonstrated in Table 2. It can be seen from the table that from VF1 12 variables fulfilled the 0.75-factor loading threshold. The VF2 identifies two variables with negative higher factor loading although, the height and arm span show negative factor loadings, it means that the attributes are inversely associated with archery physical characteristics related performance components. The most significant components after varimax rotation, the contribution of each varifactor within the components as well their variability is shown in Figure 2. It can be observed from the figure that VF1 and VF2 contributed to about 83.44% of the total data set and the variability of 64.07% and 19.37 % respectively.

Table 2: PCA Factor loading after varimax rotation

Variables	VF1	VF2
Weight(Kg)	**0.94**	-0.23
Height(cm)	-0.07	**-0.88**
Calf circumference(cm)	**0.89**	-0.18
Abdomen cc(cm)	**0.97**	0.06
Hip cc(cm)	**0.97**	0.08
Thigh cc(cm)	**0.95**	0.00
Arm span(cm)	0.03	**-0.90**
Triceps(mm)	**0.76**	0.52
Biceps(mm)	**0.75**	0.33
Subscapular(mm)	**0.83**	0.38
Suprailiac(mm)	**0.85**	0.10
Abdominal(mm)	**0.85**	0.31
Front thigh(mm)	**0.76**	0.51
Medial Calf(mm)	**0.80**	0.36
Eigenvalue	9.44	2.24
Variability %	67.45	15.98
Cumulative %	67.45	83.44

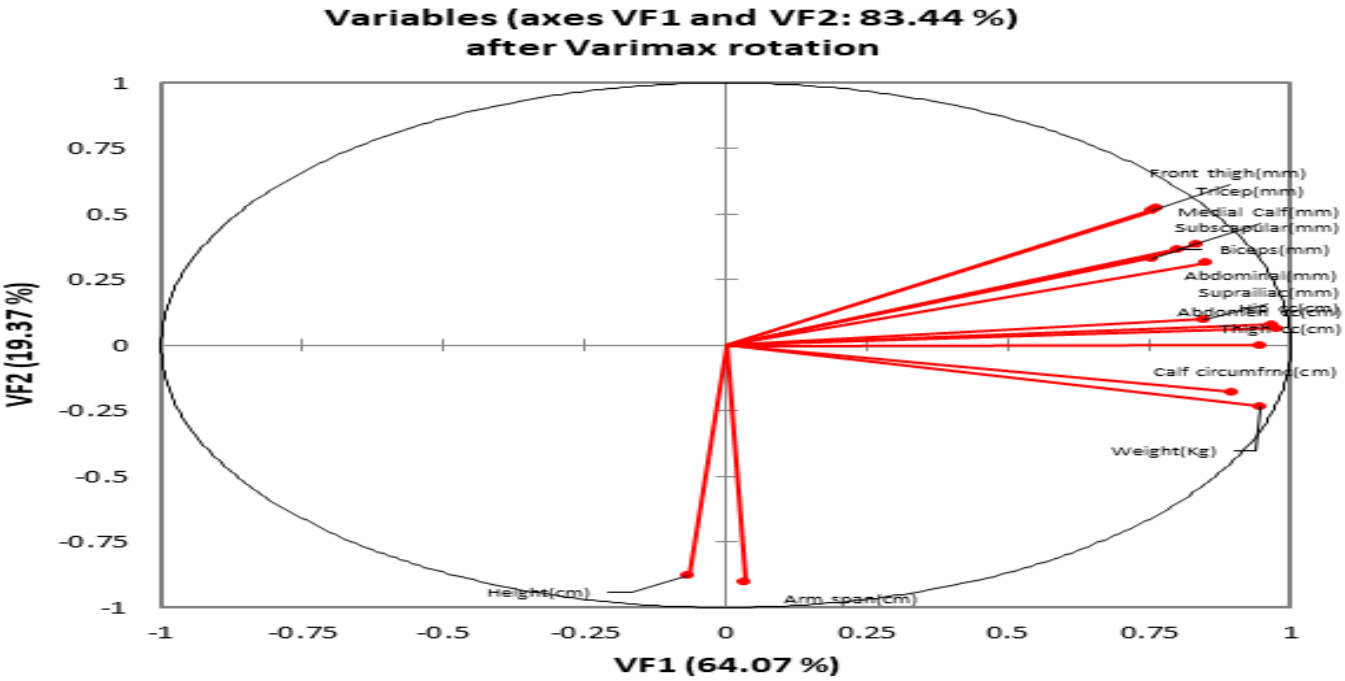

Figure 2: Factor loading plot after vari max rotation

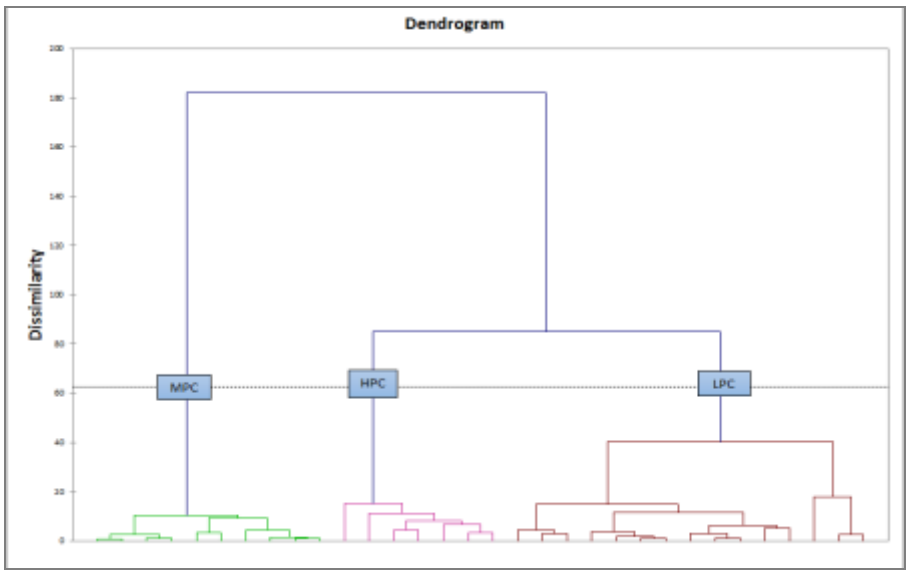

Figure 3: Dendogram of the three classes assigned by the Cluster Analysis

The grouping of the athletes in relation to their performance classes determined by HACA, which is based on the similarity level of the relative performance variables evaluated is projected in Figure 3. The group's profile plot of each cluster of relative performances is revealed in Figure 4. The figure describes the performances of the archers based on the variables examined. From the figure, it can be detected that the HPC (green color), has the highest performance across 12 variables tested (weight, calf cc, abdomen cc, hip cc, thigh cc, triceps, biceps, subscapular, suprailiac, abdominal, front thigh, medial calf, and archery shooting scores). Similarly, the MPC (blue color) has the moderate performance based on the 12 variables examined while the LPC (red color) has the lowest performance across the 12 variables tested and recorded higher performances on two variables(height and arm span). These grouping enabled the classification and assignation of the performance related variables to the athletes and consequently lead us to the further analysis for confirmation and differentiating the athletes.

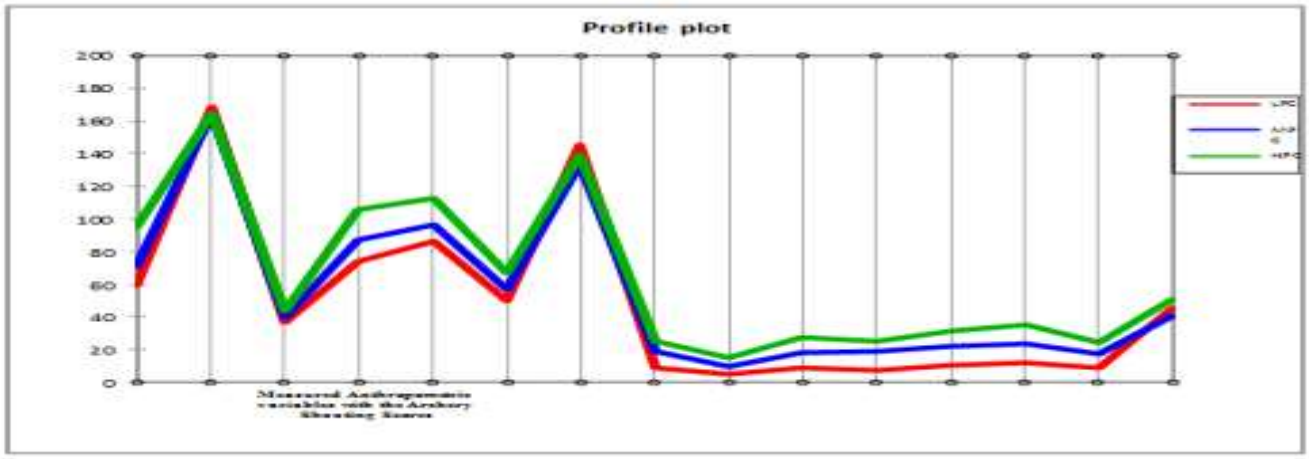

Figure 4: Profile plot of the three classes in relation to their performances on the measured variables.

The discriminant analysis conducted for the further analysis is illustrated in Table 3. The DA was applied on clusters defined by HACA in order to view through variation of relative performance. The clusters act as the dependent variable, while the physical characteristics and the archery shooting scores were treated as independent variables. Standard, backward stepwise and forward stepwise mode methods were selected to perform the DA.

The precision of classification using standard, backward stepwise and forward stepwise was 74.19% (14 independent variables), 96.77% (14 independent variables) and 93.55% (14 independent variables), respectively. Also, we found that 7 archers are classified to HPC, 14 archers into MPC and 10 archers in LPC. However, one archer did not fit into any of the defined classes and therefore was automatically eliminated from the classification. The box and whisker plots of the 14 physical characteristics performance variables from the three identified classes differentiated by the DA via backward stepwise is displayed Figure 5.

It can be observed from the figure that the mean performances of HPC are higher in the variables measured except arm span and height in which the LPC performed higher. This indicated that the LPC are more attributed to height and longer arms when compared to the o HPC class.

Table 3: Classification Matrix of the Discriminant Analysis on the three classes in relation to their performances on the variables measured.

Assigned Classes	% Correct	Classification Matrix assigned by DA		
		HPC	MPC	LPC
Standard mode (14 independent variables)				
HPC	28.57%	2	0	12
MPC	90.00%	0	1	0
LPC	85.71%	2	9	2
Total	74.19%	7	10	14
Backward stepwise (14 independent variables)				
HPC	100.00%	0	0	0
MPC	100.00%	0	10	13
LPC	92.86%	7	0	1
Total	96.77%	7	10	14
Forward stepwise (14 independent variables)				
HPC	100.00%	7	0	1
MPC	100.00%	0	0	12
LPC	85.71%	0	10	1
Total	93.55%	7	10	14

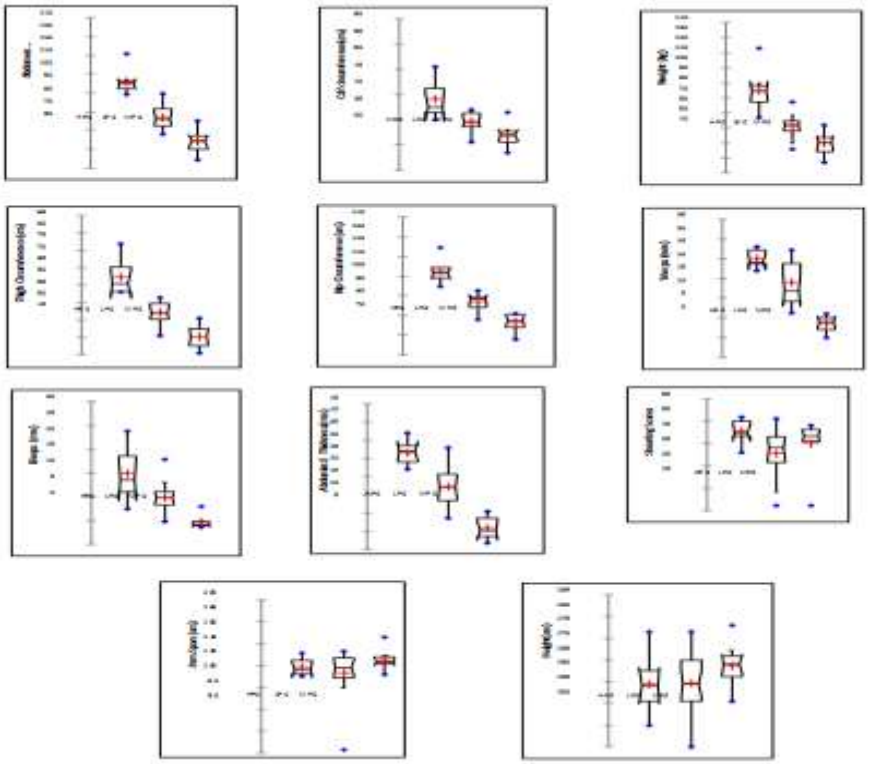

Figure 5: Box and whisker plots created from the backward stepwise in DA

Discussion

The present study intended to explore different physical characteristics towards a successful performance of archery and to predict the most vital physical attributes that contribute to the achievement of high archery scores. To achieve the aim of this study, Research project employed 32 archers from different archery programs in Terengganu Malaysia. The study subjected the archers to standard anthropometric tests, and their archery shooting scores were recorded.

The current study utilized PCA, HACA, as well DA as statistical analysis to determine the clusters of the archers, identify the distinguishing features of the clusters and predict the most crucial variables pertinent to the requirement of the sport. HACA has indicated clusters of the performance groups (figure 3 and 4) and DA has discriminated the clusters based on their performances in the predicted variables (see Table 3 and Figure 5).

However, in the current study, VFs with absolute values greater than 0.75 for the PCA were standardised as the selection threshold due to the fact that these values are considerably solid and stable, which indicates moderate to strong loadings on the extracted factors. It has been revealed that 14 variables satisfied the 0.75-factor loading threshold (Table 2 and Figure 2). These variables are then classified as the essential physical characteristics that are mainly required for the performance in archery. However, each of these variables contained varifactors associated to it.

The VF1 contributes for about 67.45% of the variation in the physical characteristics performance variables data. It has high positive factor loadings from 12 variables, which are weight (0.94), calf circumference (cc) (0.89), abdomen cc (0.97), hip cc (0.97), thigh cc (0.95), triceps thickness (0.76), biceps thickness (0.75), subscapular thickness (0.83), suprailiac thickness (0.85), abdominal thickness (0.85), front thigh thickness (0.76) and medial calf thickness (0.80) (Table 2).

Considering the nature of these 12 variables, they can be interpreted as endomorphy or otherwise plump body type. Nonetheless, the finding has stressed the importance of bigger body mass in the sport. Endomorphs body type is associated with a pear shaped body, fat on the body, and lower upper arms and thighs and legs. Archery is a sport that requires a high static balance. For an archer

to achieve a higher score, he or she must be able to achieve a greater level of postural stability. However, previous researchers have investigated the relationship between some physical characteristics parameters with static balance in both athletes and non-athletes. They reported a significant relationship between weight, body fat, body mass index, pelvis, thigh and lower leg with static balance, stressing that lower leg and shorter individuals are more stable when compared to their counterparts [12].

This result is in agreement with the previous researchers who explained that adaptation of the balance control is multifactorial. They indicated further that height and less weight were related to the body sway during stability testing, and suggested that body size and other physical characteristics factors should be considered in the assessment of athletes in various sports [13]. Our study has revealed that body size is a factor in the performance of archery sport.

The VF2 from Table 4 accounted for about 15.98% of the variability in the physical fitness performance variables data. It demonstrates negative higher factor loadings from height (-0.88) and arm span (-0.90). These variables can be interpreted as height and long arm. However, due to the negative signs associated with the variables, it has indicated an inverse association between these variables and archery performance. The muscular makeup of an

individual is obviously a key factor when looking at the suitability of athletes. Evidently, a marathon runner or swimmer, for example, needs to be physically light. However, some sports don't require a particular shape. The results from the current study have revealed that taller archers recorded considerably lower scores compared to the shorter ones.

This is not surprising due to the fact that the sport of archery is static in nature, for an athlete to achieve a maximum score in the sport the archer must be able to control any movement to hit a given target precisely. This finding can be supported by the findings of the previous researchers who reported lower stability among taller athletes in comparisons to the shorter ones [14,15].

Conclusion

The current study has successfully identified the most needed physical variables in the productive performance of archery sport. The findings from the study have revealed that endomorph body type positively affects the performance of the sport and body height and arm length hamper the performance of the sport. This research discoveries proposed the investigation of physical characteristics variables that are essential in the performance of archery which might be of help to the coaches, team managers and other stakeholders in assessing the impacts of a preparatory program. Moreover, the findings from the current study can be helpful in mapping out suitable athletes in the sports in view to their physical characteristics (Talent Identification).

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