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DISCRIMINANT ANALYSIS OF ANTHROPOMETRIC AND BIOMOTOR VARIABLES AMONG GROUPS OF MALE UNIVERSITY ATHLETES IN THREE SPORTS

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Abstract:
The aim of this study was to identify anthropometric and bio-motor variables that discriminated among groups of university male athletes aged 21.4 ± 2.1 years (mean ± s) from three different sports (soccer, *n = 53*; rugby, *n = 27*; basketball, *n = 31*). Anthropometric parameters included body mass, height and body fat percentage. The bio-motor variables included blood pressure and maximal aerobic power (VO2max) measured using 40meter dash test. Using a cross-sectional design, discriminant analysis was used to determine field tests identifying male university athletes. Young men (n = 111) who were to participate in the East Africa Inter-university games volunteered as subjects (mean ± SD age = 21.4 ± 2.1 years). Discriminant analysis revealed two significant functions ($P < 0.05$). After validation, the resulting regression equations correctly classified 83.8% of the soccer, rugby and basketball athletes. Six variables significantly contributed to the discriminant analysis (*Wilks A = 0.231*, $x^2 = 153.95$, $df = 14$, $p < 0.0001$, *adjusted* $R^2 = 0.788$). The interpretation of the obtained discriminant functions was also based on examination of the structure coefficients greater than 0.30. The athletes were discriminated mainly on height (structure coefficient, *SC=0.319*), percentage body fat (*SC=0.401*), Cooper test (*SC=0.482*), upper body strength (*SC=0.404*) and abdominal strength (SC=0.253). Our model confirms that university male athletes show physical and bio-motor differences that clearly distinguish them according to their particular sport. Generally, the athletes' anthropometric and bio-motor variables varied according to sport, probably because of the different training regimens in the different sports that conditioned the athletes differently. In conclusion, these discriminant models could help in player recruitment and improve training programs.

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Keywords: talent identification, strength, power, body composition, linear discriminant analysis (LDA), anthropometric, bio-motor, kinanthropometry, multivariate analysis

1. Introduction

Anthropometric and bio-motor characteristics in relation to performance in different sports has been reported by studies in the past; basketball players (Jakovljevic *et al.*, 2011), volleyball players from colleges and universities of North India (Gaurav & Singh, 2014), wrestlers from Colombia (Ramirez, 2014), Indian elite male hockey players (Koley & Vashisth, 2014), track and field athletes (Singh, 2015), volleyball players (Mielgo et al., 2015), baseball players (Mangine *et al.*, 2015), softball players (Wentzel & Travill, 2015) water sports athletes (Akca, 2014), football players (Brahim, Bougatfa & Mohamed, 2013), handball players (Zapartidis, 2009) and gymnastic players (Douda, 2008). Over the past few years, attention has been focused on the description of bio-motor and anthropometric variables that distinguish between elite athletes from different sports (Smith & Thomas, 1991; Gualdi-Russo *et al.*, 1992; Loko *et al.*, 2000). The significant role of anthropometric characteristics in sport performance besides other factors is well known. Body composition and somatotype of a sportsman has a significant role in sports performance besides other factors like physiological and physical fitness, psychological aspects, skills etc. Requirement of specific physique for good performance in particular sports had been supported by different studies (Carter & Heath, 1990).

Available research on this subject has put too much focus on the identification of the most discriminant statistics between winning and losing teams (Akers, Wolff, & Buttross, 1991; Ibanez, Sampaio, Saenz-Lopez, Gimenez, & Janeira, 2003; Sampaio & Janeira, 2003). However, few attempts have been made to identify and quantify the variables that distinguish university athletes from various sports. This study could serve as a guide for coaches as well as for researchers looking for a reference model for the three sports investigated. To get this model, discriminant analysis can be used. Discriminant analysis to some extent, could orient training programs by identifying the variables that affect the anthropometric and bio-motor profile of players in specific sports by use of an established model. A previous study done by Pollock et al. (1980) for runners, showed that modifications to training that induced anthropometric or bio-motor changes could be quantified by means of discriminant scores; these could then be used to indicate whether the modifications helped to classify each individual correctly. The aim of this study therefore was to develop a multivariate model that would allow the identification and quantification of the individual contributions of a series of anthropometric and bio-motor variables to the classification and prediction of university athletes according to their sport.

2. Methods

One hundred and eleven university athletes aged between 17 and 28 years (mean age 21.4 ± 2.1, CI 21.0-21.8 years) participated in this study. The sample included subjects from three different sports; soccer (n=53), rugby (n=27), basketball (n=31). The investigation took place among participants in the selection of athletes to participate in East Africa Inter University games. Written consent was obtained from all subjects. Variables in our study were of two categories: Anthropometric and bio-motor variables. Anthropometric parameters: body mass, height and body fat percentage. All measurements were taken according to standardized procedures (Callaway *et al., 1988*). Body weight (kg) was determined with a certified digital scale used for official weigh-ins for each competition. Height (cm) was determined using a wall scale and a Broca plane with the head held in the Frankfort plane. The bio-motor variables included blood pressure and maximal aerobic power (VO2max) measured using Cooper test. Muscular strength was assessed by two tests; push-ups for upper body strength and sit-ups for abdominal strength (Leone & Léger, 1985). All variables were chosen from a battery of tests, and came from the wide variety which has previously been used to describe athletic populations (MacDougall *et al.,* 1988; Carter & Ackland, 1994).

Although most of the tests administered are very standardized and well recognized assessments, test-retest re- liability on the specific subject pool used in the present study could not be obtained. To counter this potential problem, all testers were thoroughly trained and familiarized with proper test administration prior to actual data collection. Additionally, all tests were administered by the same tester to avoid intertester errors. The discriminant analysis is considered to be robust with these variables (Norusis, 1993).

Multivariate analysis of variance (MANOVA) was first used to determine if the groups were different. To avoid unacceptable shared variances, common zero-order correlation coefficients (r^2) were determined for each separate variable group. Seven easily obtained variables with low shared variances were included in the analysis. Discriminant analysis was then employed on 7 variables measured, which included anthropometric and bio-motor parameters, to develop a model to predict membership of each athlete in the four different sports. A discriminant analysis using the Wilks A was performed to deter mine the ability to discriminate between the four sports using the 7 selected variables ($p < 0.05$). The interpretation of the obtained discriminant functions was based on examination of the structure coefficients greater than 0.30, meaning that variables with higher absolute values have a powerful contribution to discriminate between groups (Tabachnick & Fidell, 2000). Validation of discriminant models was conducted using the leave-one-out method of cross-validation (Norusis, 1993). Cross-validation analysis takes subsets of data for training and testing and is needed in order to understand the usefulness of discriminant functions when classifying new data. This method involves generating the discriminant function on all but one of the participants (n-1) and then testing for group membership on that participant. The process is repeated for each participant (n times) and the percentage of correct classifications generated through averaging for the n trials.

Data analysis was done using the statistical program for social sciences (SPSS) version 25. In this study the study variables were assessed by a two-tailed probability value of p<0.05 for significance. Schlomer *et al*. (2010) outlined guidelines for best practices regarding the handling and reporting of missing data within research. Visual inspection of the data illustrated that missing data appeared to be missing at random. Their guidelines were considered when reviewing the missing data for the current research study. Homogeneity of between groups variance covariance matrix was checked using the Box M test. All assumption for conducting the discriminant analysis were met before undertaking the test. Alpha level for all the computations was considered p <0.05.

3. Results

Means and standard deviations for the four groups of athletes are presented in Table 1. The global test for equality of the mean vectors for the four groups was significant (Hotelling's *T, P<0.01*), which showed that the groups were different in all variables except in systolic blood pressure which yielded a statistically non-significant result (see table 2). The Box's M test was not significant (approximate value of *F=140.5, P=0.205*), which indicated homogeneous variance-covariance matrices for each group (Norusis, 1993).

Table 1: Descriptive results from the anthropometric and bio-motor variables for the three sports (values are mean, ±SD)

Variable	Soccer	Rugby	Basketball
Height	170.1±9.25	175.25±7.1	178.61±6.86
Weight	65.65±16.67	78.46±5.41	67.24±9.82
Systolic	118.85±17.09	120.78±17.34	118.77±17.25
Abdominal strength	41.96±8.78	51.81±11.36	47.90±12.17
Upper body strength	38.69±10.61	57.85±14.95	50.06±14.07
% body fat	20.01±5.49	27.32±6.51	20.97±4.65
Cooper test	39.82±1.79	42.3±0.84	39.2±2.09

Table 2: Test of equality of group means

Variable	Wilks' Lambda	F	df1	df2	Sig.
Height	.827	11.275	2	108	.000
Weight	.854	9.254	2	108	.000
Systolic	.997	.145	2	108	**.865***
Abs Strength	.862	8.636	2	108	.000
UBS	.713	21.756	2	108	.000
% body fat	.768	16.354	2	108	.000
Cooper test	.669	26.675	2	108	.000

* statistically non-significant.

The 7 variables selected for inclusion in the discriminant analysis exhibited low shared variances, as exhibited by their common zero-order correlation coefficients (see Table 3). The only exception to this was the shared variance for systolic blood pressure and diastolic blood pressure ($r^2 = 0.27$), systolic blood pressure and pulse ($r^2 = 0.41$). Hence, pulse and diastolic blood pressure were excluded from the discriminant analysis.

Table 3: Common zero-order correlation coefficients (r) of variables selected for inclusion in the discriminant analysis

	Height	Weight	Diastolic	Systolic	Pulse	ABS	UBS	% Body fat	40m Dash
Height	1								
Weight	.251	1							
Diastolic	-.137	-.087	1						
Systolic	.026	.087	.518**	1					
Pulse	-.122	-.094	.668**	.641	1				
ABS	.107	.091	.033	.067	-.085	1			
UBS	.111	.145	.100	.107	-.065	.297*	1		
% Body fat	-.185	.116	.120	-.038	.004	.219	.167	1	
Cooper test	.179	.147	-.031	.063	-.306**	.100	.139	-.117	1

ABS- Abdominal strength; UBS-Upper body strength; *-statistically significant

The structure coefficients quantify the potential of each variable to maximize differences between means amongst the soccer, rugby and basketball player. The larger the magnitude of the coefficients, the greater the contribution of that variable to the discriminant function. Multiple discriminant analysis revealed two significant functions (Table 5). Based on values of Wilk's lambda, discriminant function 1 accounted for 78.8% of the variance, while discriminant functions 2 explained 21.2% of the remaining variance between groups respectively. Unstandardized coefficients allow the derivation of discriminant scores for each individual.

Based on these scores, group membership could be predicted according to the proximity of the respective group centroid values (mean group values) (see Table 4). It is then possible to determine correct classifications. The more correct classifications, the more efficient the model.

Table 4: Functions at group centroids

	Function 1	Function 2
Soccer	-.912	-.561
Rugby	2.366	-.157
Basketball	-.502	1.095

The structure coefficients of majority of the variables was above .3 which shows high ability to discriminate among groups. Function 1 reflect an emphasis on 40-meter dash, percentage body fat, weight and upper body strength (Table 5).

Table 5: Discriminant function coefficients and tests of statistical significance

	Structure matric coefficient		**Unstandardized discriminant functions**	
	Function 1	**Function 2**	**Function 1**	**Function 2**
Cooper test	.482*	-.337	.026	.097
% body fat	.401*	.005	.015	-.002
Weight	.302*	-.001	.001	-.004
Systolic	.037*	-.012	-.001	.013
Height	.319	.601*	.027	.046
UBS	.404	.438*	.171	-.012
ABS	.353	.281*	.482	-.395
Wilks' Lambda	.231	.665		
Chi-square	153.9	42.9		
P	<0.01	<0.01		
Eigenvalue	1.880	.505		
% of variance	78.8	21.2		
Canonical correlation	.808	.579		

UBS- Upper body strength; ABS- Abdominal strength; *P*- alpha value

The original classification summary shows 84.7% of the cases correctly classified in their respective sports (Table 6). This is significant when compared to the proportional chance ($p < 0.05$). The leave-one-out test summarizes the ability of the discriminant functions to correctly classify the players in their respective sports (see Table 6). This analysis provided an overall percentage of successful classification of 86.8% for the soccer players, 92.6%% for the rugby players and 71% for the basketball players. Notably, almost all soccer and rugby players were correctly classified on the basis of their anthropometric and bio-motor scores.

Table 6: Classification matrix for the sports according to anthropometric and bio-motor variables of the discriminant functions

			Soccer	**Rugby**	**Basketball**	**Total**
Original	%	Soccer (n=53)	**88.7**	3.8	7.5	100.0
		Rugby (n=27)	7.4	**92.6**	.0	100.0
		Basketball (n=31)	25.8	3.2	**71.0**	100.0
Cross-validated	%	Soccer (n=53)	**86.8**	5.7	7.5	100.0
		Rugby (n=27)	7.4	**92.6**	.0	100.0
		Basketball (n=31)	22.6	6.5	**71.0**	100.0

84.7% of original grouped cases correctly classified; 83.8% of cross-validated grouped cases correctly classified

4. Discussion

The aim of this investigation was to study the discriminating power of selected anthropometric and bio-motor variables among university athletes in three different sports (soccer *n=53,* basketball *n=31 and* rugby *n=27)* in Kenya. From the findings, most of the variability among groups (78.8%) was accounted for by the first discriminant function; this reflected differences in anthropometric and bio-motor variables between soccer players and the other groups of athletes. The results in Table 1 show that soccer players obtained the lowest values for all anthropometric variables. This was particularly true for body mass (65.65±16.67) and height (170.1±9.25). Basketball players had the highest mean in height (178.61±6.86). At the moderate to high levels of basketball competition, success can be mostly dependent on the recruitment of players with complementary skills who are capable of performing according to the demands of the game (Ige & Kleiner, 1998). Studies reveal that height can play a significant role in contributing to success in some sports by offering certain natural advantages. For those sports where this could be a contributing factor, height can be useful (although certainly not in all cases and is not the only factor) since in general it affects the leverage between muscle volume and bone towards greater speed of movement and power, depending on overall build, fitness and individual ability. (Carter, 1984)

Studies done on basketball players, have shown differences between anthropometric and physiological measures of individuals especially height (Ackland, Schreiner, & Kerr, 1997; Bale, 1991; Smith & Thomas, 1991). Height is a significant contributor in the model with a structure coefficient of .319 and .601 in function 1 and function 2 respectively and plays an important role in discriminating basketball players from soccer and rugby players. The results of this study are new insights to the understanding of ball games. In fact, the results describe precisely the actions that distinguish players by their sport and allow us to better understand how team performance depends upon players with complementary skills. This study did not factor female athletes but studies concerning female basketball players have shown they have different anthropometric and physiological measures (Ackland, Schreiner, & Kerr, 1997; Bale, 1991; Smith & Thomas, 1991). The findings of this study also show that weight is a significant contributor to the discriminant model with a structure coefficient of .302 in function 1. Recent studies showed that body mass index (BMI), reflecting greater muscle mass rather than greater adiposity, is the important factor associated with best performance for the world-class sprinters. The study also revealed that in track and field athletes, the reciprocal ponderal index (RPI) was an important indicator of best performance with tall and lean body type (Watts, Coleman & Nevill, 2011). However a recent study by Anup, Nahida, Nazrul Islam, & Kitab, (2014) supported the decade long hypothesis for encouraging the ectomorphic mesomorph body type for the sprinting athletes with higher reciprocal Ponderal index. Percentage body fat was the second largest discriminator with a structure coefficient of .401 in function 1. Negative relationship between sports performance especially sprinting events and adiposity in terms of body fat percentage were revealed by different studies though some of the studies showed less relationship of body fat percentage with endurance activity in terms of maximum oxygen consumption (Sporis *et al.*, 2011).

Considering basketball involves sprinting the same rule of thumb may also apply. A study by showed a body fat percentage range between 3.3% and 18.4% for male athletes in soccer, basketball, football, ice hockey, body building, wrestling, baseball, tennis and powerlifting. However track and field athletes possessed as low as 3.3% body fat for the marathon runners whereas the male sprinters and discus throwers reported to be with a higher value of 16.4%(Anup et al., 2014). Previously reported talent identification test batteries of sports like weightlifting have included or suggested tests for relative fat (Richter,1983), height and weight (Smalcerz, 1994), However as noted by (Fry *et al.*, 2006) many of the characteristics measured may be important contributors for high-level performance in a variety of sports like rugby. From the findings anthropometric variables had more discriminating abilities compared to bio-motor variables.

A study done by Leone, Lariviere, & Comtois, (2002) revealed that in the discriminant analysis, the anthropometric variables contributed more to the model than the bio-motor variables. When the discriminant analysis was repeated without the bio-motor variables, 78% of the athletes were correctly classified, whereas 60% were when the anthropometric variables were excluded from the analysis. (Leone et al., 2002). These results actually confirm that each sport is characterized by athletes with particular anthropometric and bio-motor profiles, conforming previous observations (Housh *et al.*, 1984; Watson, 1988). In general, it would be helpful to develop talent identification test batteries that would provide the most information using the fewest number of simply-administered field tests. If the identification of variables that characterize athletes of different sports is of interest to understand what distinguishes them, their relative contribution is also important (Leone, Lariviere, & Comtois, 2002). There are clear training effects between sports. Thus, the training specific to a particular sport may play an important role in defining certain inter-sport bio-motor difference (Leone, Lariviere, & Comtois, 2002).

Success in many different sporting activities would most likely be dependent in part on strength, power, body type and composition. As a consequence, those responsible for talent identification for other sports might also be interested in these characteristics (Fry, Ciroslan, & Schilling, 2006). In summary, the findings of this study confirm that anthropometric and bio-motor variables are able to correctly classify and predict the sports players can participate to maximize performance. The results showed that after cross validation 83.8% of cases were correctly classified, with 86.8% being correctly classified in soccer, 92.6% being correctly classified in rugby and 71% being correctly classified in basketball. These findings corroborate with findings from a previous study done by Leone, Lariviere, & Comtois, (2002) where 88% of the athletes were correctly classified in their respective sports. The model confirmed that elite adolescent female athletes showed physical and bio-motor differences that clearly distinguish them according to their particular sport (Leone, Lariviere, & Comtois, 2002).

5. Conclusions

In this study, we present a model that could be used to predict the sports of an athlete from a number of anthropometric and bio-motor variables. This could be employed to orientate the training of athletes towards a specific sport, but could also be of use in improving performance in deficit areas. Further studies are required to construct models that include sprinters and long-distance runners (marathon). Hence, it could be concluded that anthropometrical characteristics were one of most influential factors in determining good athletic performances in specific sports besides other physiological characteristics.

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