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Physiological and psychological variables among elite female athletes from three categories of sports and non-athletes

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***Abstract*---**Background: The aim of the study was to categorize various body composition, physiological and psychological variables among Indian elite female athletes participating in endurance sports (Group A, n= 22, age= 17.01±0.99 years), combat sports (Group B, n= 20, age= 19.15±3.63 years) and skill sports (Group C, n= 25, age= 18.80±2.21 years) and non- athletic control group (Group D, N= 23, years= 18.34±1.87 years). Methodology: Physical parameters included body fat percent, lean body mass, muscle content and total water content. Physiological parameters included time domain and frequency domain parameters of heart rate variability and maximal aerobic power (VO_2 max) measured using Astrand protocol. Various psychological parameters were evaluated using Big Five Inventory and State-Trait Anxiety Inventory questionnaires. Results: Discriminant analysis revealed three significant functions (P<0.05) contributing 78.2%, 13.2% and 8.7% respectively to the model. After cross validation, the resulting equation correctly classified 68.3% of endurance, combat, skill athletes and control group. Total eighteen variables significantly (P<0.05) contributed to the discriminant analysis. The interpretation of the acquired discriminant functions was also based on examination of the structure coefficients greater than 0.30. The athletes and control were discriminated mainly on VO_2 max (structure coefficient, SC=0.679) in Function 1, body weight

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(SC=0.527), fat percent (SC=0.497) and total body water (SC=-0.619) in Function 2. Conclusion: Elite female athletes were observed to have physical and physiological differences emphasizing the fact that different training regimens of different sports condition athletes differently. These discriminant models could help in athlete's induction, talent identification process and improving training programs.

***Keywords*---**maximal aerobic power, linear discriminant analysis, endurance sports, combat sports, skill sports, personality.

Introduction

Many sports are based on multidimensional performance profile determined by various physical, physiological and psychological variables. Body composition assessment is of value in determining potential effects of training programs and health of young athletes.[1] In certain sports which require movement of body through space such as running, jumping; or projection of objects such as javelin, discus increased body fat can have negative influence on performance.[2] The American College of Sports Medicine recommended that (1) young wrestlers have their body composition assessed prior to the season using "valid methods for this population" and (2) medical clearance be obtained for competition in male wrestlers 16 years and younger with <7% fat and in male wrestlers older than 16 years and <5% fat. Minimal fatness of 12-14 % is recommended for female wrestlers.[3,4]

Good aerobic capacity which is accepted as a major component of assessing physical capacity of an athlete is indispensable for achieving success in many sports.[5] Along with physical capacity, psychological factors also play a very important role in athletic success. It has been found that more successful athletes are significantly more agreeable, more conscientious, and more emotionally stable than less successful athletes.[6] Research also suggests that elite players exhibit lower state anxiety.[7] A statistically significant difference was reported to be found between the trait anxiety of athletes participating in different sports such as taekwondo and wrestling.[8]

Heart rate variability (HRV) is an indicator of cardiovascular autonomic regulation and is an important in determining adaptations to training.[9] In one study, comparison between sedentary subjects and athletes demonstrated that athletes exhibit a different HRV profile as compared to sedentary subjects, showing an overall increase in parasympathetic cardiac modulation and HRV.[10] In athletes, the autonomic balance is altered in response to varied intensities and duration of training, as measured by changes in HRV variables. Well trained athletes have an elevated parasympathetic dominance as compared to non-athletes; confirming that athletic conditioning improves the autonomic control of the cardiovascular system.[11]

Many researchers have tried investigating the discriminative value of different performance prerequisites in different sports disciplines. In a study conducted on

81 active athletes aged 9-11 years, a correct classification of 85.2% was obtained including five groups of sports; ball sports, dance, gymnastics, martial arts, raquet sports, and swimming.[12] In a study conducted in 2002, 88% of athletes from four different sports (figure skating, swimming, tennis, and volleyball) were differentiated by means of a discriminant analysis including anthropometric and motor characteristics.[13] In 2015, Pion et al. could assign 96.4% of 141 adolescent Flemish athletes into nine sports disciplines.[14] Even more promising were the findings of Pion, Fransen, Lenoir & Segere (2014) in elite male U18 athletes, as the investigators found a 100% correct classification within the more interconnected martial arts disciplines judo, karate, and taekwondo.[15]

However, there is a lack of research exploring the discriminative value of different performance fundamentals for female elite athletes over a variety of different sport disciplines. Thus, the aim of this study was to investigate whether Indian female athletes participating in three different types of sports (endurance, combat and skill) illustrate a sport specific physical, physiological and psychological profile which is in line with the specific necessities of each sport that might serve as scientific knowledge backdrop for sports specific talent identification purposes.

Materials and Methods

Participants

The sample consisted of 90 female participants, divided into 4 groups. Group A (n=22) included elite female athletes belonging to endurance sports such as middle and long distance athletics, swimming and cycling, Group B (n=20) included elite female athletes belonging to combat sports such as wrestling and judo, Group C (n=25) elite female athletes belonging to skill games such as archery and Group D (n=23) included non-athletic population. Athletes were all selected from various schemes of Sports Authority of India (SAI), Northern Region and control group was composed of healthy university students who didn't participate in any sports. The athletes had a history of participation in at least national level competitive events with minimum of 2 years formal training and were in pre- competitive phase during the conduction of the test.Subjects, who were healthy, with no history of any hereditary or cardio-respiratory diseases, were selected for the study. Prior to that, a full explanation of the purposes, procedures and potential risks and benefits of the assessments were offered to all players, and their written consents were acquired. The present study was conducted following guidelines as laid down in the Declaration of Helsinki, and ethical clearance was also obtained from the Institutional Ethical Committee before performance of any tests on human subjects.

Procedure

All subjects were assessed for various physical, physiological and psychological variables at Human Performance Laboratory, SAI and conducted during morning hours on similar day. They underwent heart rate variability assessment first and then physical and questionnaire based psychological assessments were done followed by sub- maximal exercise testing with the help of bicycle ergometer after familiarizing them with the exercise protocol. The training was relatively common to all the athletes of the study besides the skill training. Their medical history and training duration was evaluated by a preset questionnaire.

The height and weight were measured using digital measuring station (SECA 284; SECA, Hamburg, Germany). Heart Rate Variability (HRV) was measured using Physiological Monitoring System (Zephyr Technology Corporation, Annapolis, MD, US).[16] The chest strap was tied across the chest of the subject such that the centre of the electrode was directly beneath the subject's armpit. The subject was seated in a comfortable arm-chair located in a quiet laboratory, and was asked to remain as still as possible for the duration of the recording. The readings were taken for duration of 10 min, out of which last 5 min readings were considered for analysis. The values of the RR intervals were analysed using Kubios Software (Version 2.2, Kuopio, Finland).[17] Body composition analysis was done using Body Composition Analyser (BCA) (Model mBCA 515, SECA, Hamburg, Germany).[18] The subjects were instructed to come for the test fasting and with empty bladder, and all metal accessories, coins and mobile phones removed from the body. The subjects were made to stand on the platform with electrodes such that, their heels were placed central to the smaller posterior electrode, and forefoot was placed central to larger anterior electrode. The subjects were asked to touch the electrodes in such a way that the electrode separator was located between middle and ring fingers. Aerobic capacity of the subjects was measured using the Astrand protocol on bicycle ergometer (Monark LC7). The subject cycled for 6 minutes at a workload chosen to try and elicit a steady-state heart rate between 125 and 170 bpm. Recording of the heart rate was done every minute during the test. If the heart rate at 5 and 6 minutes was not within 5 beats/min, the test was continued for one extra minute. The steady-state heart rate and workload recorded were put in the equation to determine an estimation of VO_2max.[19] For the characterisation of the personality type Big Five Inventory was used, which is a 44-item inventory that measures an individual on the dimensions of personality namely, extraversion, agreeableness, openness, neuroticism and conscientiousness.[20] The State-Trait Anxiety Inventory (STAI) was used for the measurement of trait and state anxiety levels.[21]

Although most of the tests administered are very standardized and well documented assessments, test-retest reliability on the specific subject pool utilized in the present study could not be acquired. To counteract this possible problem, all testers were methodically trained and familiarized with proper test administration prior to actual data collection. All tests were done by the same tester to keep away from inter-tester errors. The discriminant analysis is considered to be robust with these variables.[22]

Statistical Analysis

Data analysis was done using the statistical program for social sciences (SPSS) version 25 SPSS (Inc., Chicago, IL, USA). In this study, the study variables were assessed by a two-tailed probability value of $p<0.05$ for significance. The data were tested for assumptions of normality using the Shapiro Wilk test. Homogeneity of between groups variance-covariance matrix was checked using the Box M test. Discriminant analysis was employed on 18 variables measured, which included various physical, physiological and psychological parameters, to develop a model to predict membership of each athlete and non- athlete in the four groups (sports and non-sports). A discriminant analysis using the Wilks Λ was performed to determine the ability to discriminate between the four groups using the 18 selected variables ($p < 0.05$). The interpretation of the acquired discriminant functions was based on assessment of the structure coefficients greater than 0.30, meaning that variables with higher absolute values have a foremost contribution to discriminate among groups.[23] Validation of discriminant models was carried out using the leave-one-out method of cross-validation.[22] Cross-validation analysis is required in order to comprehend the usefulness of discriminant functions when classifying new data. This method involves producing the discriminant function on all but one of the participants (n-1) and then testing for the group membership of that contributor. The process is repeated for each participant (n times) and the percentage of correct classifications created through averaging for the n trials.

Results

Means and standard deviations for the four groups of athletes and control are presented in Table 1. The global test for equality of the mean vectors for the four groups was significant (Wilk's Lambda, P<0.01), which showed that the groups were different in all variables except in age (years), height (cm), LF/HF measure of HRV, open mindedness, state anxiety and trait anxiety which yielded a statistically non- significant result (Table 2).

Table 1: Descriptive results from the physical, physiological and psychological variables of elite female athletes (n=90) of different sports (values are mean± SD)

Variables	Group A Endurance (n=22)	Group B Combat (n=20)	Group C Skill (n=25)	Group D Control (n=23)
Age (years)	17.07±0.99	19.15±3.63	18.80±2.21	18.34±1.87
Training (years)	6.00±2.67	7.15±1.89	5.3±2.17	NA
Height (cm)	160.11±4.84	159.51±6.36	162.27±4.27	159.49±6.39
Weight (kg)	54.10±7.34	54.50±8.17	60.44±8.59	50.24±7.14
Fat (%)	18.06±4.63	21.04±6.10	28.95±6.00	22.21±8.26
Lean body mass (kg)	44.13±5.33	42.63±3.77	42.65±3.55	38.70±3.95
Muscle content (kg)	18.48±1.89	19.83±2.15	19.26±1.99	17.90±2.81
Total body water (%)	61.60±5.26	56.91±4.13	52.19±4.24	57.54±4.79
VO2 max (ml/min/kg)	52.44±4.97	53.61±6.08	36.72±4.26	37.38±5.31
SDNN	99.76±47.01	129.70±73.28	65.34±20.14	75.77±37.35
pNN50 (%)	36.09±17.05	31.06±24.82	10.90±13.09	26.36±18.26
LF/HF	1.29±0.96	3.29±4.58	1.83±1.97	1.86±1.01
Extraversion	30.42±3.15	29.35±3.71	29.92±4.94	26.21±3.83
Conscientiousness	36.92±4.92	34.25±5.58	35.24±4.66	31.60±4.66
Agreeableness	38.00±3.28	36.70±4.81	36.88±4.00	34.21±4.23
Neuroticism	20.14±6.31	26.80±7.35	24.96±5.59	25.91±6.20

Open mindedness	38.71±3.14	39.05±3.48	38.72±3.37	36.47±3.51
State anxiety	31.00±8.39	37.85±8.72	37.32±9.16	37.43±8.63
Trait anxiety	38.50±8.91	44.60±8.98	43.16±8.59	43.56±7.46

* - significant at the level of <0.05
** - Significant at the level of <0.01
SDNN – Standard Deviation of NN intervals
pNN50 – Percentage of consecutive NN interval difference greater than 50 msec
LF – Low Frequency
HF – High Frequency
LF/HF – Ratio of Low Frequency over High Frequency
NA=Not applicable

Table 2: Test of equality of group means

Variables	Wilk's Lambda	F	df1	df2	Sig.
Age (years)	0.920	2.250	3	78	0.089*
Height (cm)	0.951	1.331	3	78	0.270*
Weight (kg)	0.792	6.820	3	78	0.000
Fat (%)	0.719	10.160	3	78	0.000
Lean body mass (kg)	0.797	6.638	3	78	0.000
Total body water (%)	0.655	13.715	3	78	0.000
Muscle content (kg)	0.898	2.950	3	78	0.038
VO_2 max (ml/min/kg)	0.287	64.530	3	78	0.000
SDNN	0.765	8.004	3	78	0.000
pNN50 (%)	0.783	7.185	3	78	0.000
LF/HF	0.929	2.002	3	78	0.121*
Extraversion	0.851	4.545	3	78	0.005
Conscientiousness	0.870	3.887	3	78	0.012
Agreeableness	0.900	2.905	3	78	0.040
Neuroticism	0.884	3.412	3	78	0.022
Open mindedness	0.907	2.674	3	78	0.053*
State anxiety	0.924	2.143	3	78	0.102*
Trait anxiety	0.942	1.590	3	78	0.199*

*statistically non-significant.
SDNN – Standard Deviation of NN intervals
pNN50 – Percentage of consecutive NN interval difference greater than 50 msec
LF – Low Frequency
HF – High Frequency
LF/HF – Ratio of Low Frequency over High Frequency

The structure coefficients enumerate the potential of each variable to maximize differences between means amongst the endurance (Group A), combat (Group B), skill (Group C) athletes and control (Group D). The larger the enormity of the coefficients, the greater is the contribution of that variable to the discriminant function. Multiple discriminant analysis revealed three significant functions

(Table 3). Function 1 reflect an emphasis on VO_2 max, function 2 on height, weight, fat percent, lean body mass, total body water, muscle mass, SDNN, pNN50, extraversion, agreeableness and open mindedness; while function 3 on age, SDNN, LF/HF, conscientiousness, neuroticism, state anxiety and trait anxiety (Table 3). Based on values of Wilk's Lambda, discriminant function 1 accounted for 78.2% of the variance, discriminant function 2 accounted for 13.2% of the variance, while discriminant function 3 accounted for 8.7% of the remaining variance among groups respectively.

Table 3 also provides standardized discriminant function coefficient, an index of the importance of each predictor like the standardized regression coefficient (beta's) did in multiple regression. The sign indicates the direction of the relationship. The interpretation of the obtained discriminant functions was based on examination of the structure coefficients greater than 0.30. VO_2 max and total body water is the strongest predictors of Function 1 and 2 respectively.

Table 3: Discriminant function coefficients and tests of statistical significance

Variables	Structure matrix coefficient			Standardized discriminant functions		
	Function 1	Function 2	Function 3	Function 1	Function 2	Function 3
Age (years)	-0.037	0.175	-0.306*	-0.140	0.203	0.001
Height (cm)	-0.035	0.196*	0.144	-0.347	-0.044	-0.058
Weight (kg)	-0.009	0.527*	0.199	0.802	-0.515	0.062
Fat (%)	-0.185	0.497*	0.066	-0.377	0.691	0.460
Lean body mass (kg)	0.160	0.323*	0.244	-0.068	0.353	0.876
Total body water (%)	0.190	-0.619*	0.144	-0.025	-0.432	0.547
Muscle content (kg)	0.066	0.293*	-0.173	-0.307	0.076	-0.650
VO2 max (ml/min/kg)	0.679*	-0.151	-0.414	1.280	0.199	-0.134
SDNN	0.206	-0.058*	-0.391*	-0.238	-0.083	-0.445
pNN50 (%)	0.163	-0.394*	-0.100	0.052	-0.428	0.153
LF/HF	0.040	0.070	-0.336*	0.207	0.040	-0.439
Extraversion	0.111	0.316*	0.211	0.333	0.383	0.125
Conscientiousness	0.106	0.217	0.299*	-0.029	0.313	-0.139
Agreeableness	0.104	0.204*	0.189	-0.008	0.229	0.175
Neuroticism	-0.067	0.065	-0.428*	-0.550	0.139	-0.328
Open mindedness	0.093	0.259*	0.028	0.369	0.283	0.109
State anxiety	-0.072	0.092	-0.292*	-0.290	0.247	-0.079
Trait anxiety	-0.046	0.067	-0.286*	0.144	-0.098	-0.051
Wilk's Lambda	0.056	0.342	0.637			
Chi square	201.933	75.082	31.559			
P	0.000	0.000	0.011			
Eigenvalue	5.124	0.862	0.570			
% of Variance	78.2	13.2	8.7			
Canonical	0.915	0.680	0.602			

correlation

SDNN – Standard Deviation of NN intervals
pNN50 – Percentage of consecutive NN interval difference greater than 50 msec
LF – Low Frequency
HF – High Frequency
LF/HF – Ratio of Low Frequency over High Frequency

Based on these scores, group membership could be predicted according to the closeness of these respective group centroid values (mean group values) (Table 4). It is then possible to determine correct classifications. In our study, endurance group has a mean of 3.056; combat group has 2.261, skill group has -1.512 while control group has -2.182 in Function 1 while endurance group has a mean of -0.614; combat group has 0.294, skill group has 1.130 while control group has -1.110 in Function 2 (Figure 1). Cases with scores near to a centroid are predicted as belonging to that group.

Table 4: Functions at group centroids

Groups	Function		
	1	2	3
Endurance (A)	3.056	-0.614	1.159
Combat (B)	2.261	0.294	-1.027
Skill (C)	-1.512	1.130	0.371
Control (D)	-2.182	-1.110	-0.217

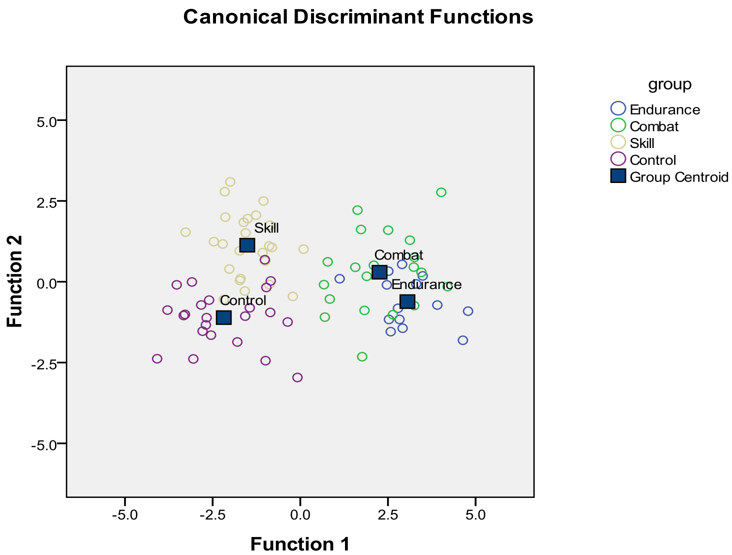

Figure 1: Plot of the individual and group differences between elite female athletes of different sports and control group resulting from different physical, physiological and psychological tests.

The original classification summary shows 86.6% of the cases correctly classified in their respective sports (table 5). The leave-one-out test summarizes the ability of the discriminant functions to correctly classify the athletes in their respective sports (see Table 5). This analysis provided an overall percentage of successful classification of 71.4% for the endurance players, 70.0% for the combat players, 68.0% for the skill players and 65.2 % for the control group. Notably, almost all players were correctly classified on the basis of their physiological and psychological variables.

Table 5: Classification matrix for the sports according to physical, physiological and psychological variables of the discriminant functions

Classification Results[b,c]							
			Predicted Group Membership				
		Group	Endurance	Combat	Skill	Control	Total
Original	%	Endurance	78.6	21.4	0	.0	100.0
		Combat	10.0	90.0	0	0	100.0
		Skill	.0	.0	84.0	16.0	100.0
		Control	.0	.0	8.7	91.3	100.0
Cross-validated[a]	%	Endurance	71.4	28.6	0	.0	100.0
		Combat	20.0	70.0	10.0	0	100.0
		Skill	.0	4.0	68.0	28.0	100.0
		Control	8.7	.0	26.1	65.2	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 86.6% of original grouped cases correctly classified.

c. 68.3% of cross-validated grouped cases correctly classified.

Discussion

The aim of this study was to explore the discriminating power of selected physiological, physical and psychological variables among 90 Indian female participants of different sports. Endurance (n=22), Combat (n=20), Skill games (n=25) and control group (n=23). Most of the variability among groups was reported for by the first discriminant function (78.2%) which reflected variations in physical, physiological and psychological variables between combat and other groups of athletes as well as control group. Combat sport athletes obtained the highest mean value of maximum aerobic capacity (VO_2 max) (53.61±6.08 ml/kg/min) among four groups, signifying that aerobic capacity is an important parameter for success in combat sports. VO_2 maxis a significant contributor in the model with a structure coefficient of 0.679 in Function 1 and plays an important role in discriminating combat and endurance players from skill players and control group. In 2015, Tonnesen et al. reported aerobic capacity for women participating in cross country skiing to be 72 ml/kg/min and 67 ml/kg/min for cross country sprint skiing.[24] The mean valueof $vO_{2max}$for the female combat sport athletes in this study was found to be 53.6 ± 6.1 ml/kg/min which is higher than the results obtained for the Polish National Wrestling team (49.7 ml/kg/min) evaluated using graded exercise test on treadmill[25] and from women boxers (44.5 ml/kg/min).[26] VO2max in female archers in age range of 20-30 years has been reported to be 39.8 ml/kg/min [27] which is higher than observed in our study (36.7 ml/kg/min).

The results in Table 1 revealed that the athletes of skill sports (archery) had comparable amount of muscle content (19.3 ± 2.0 kg) to combat (19.8 ± 2.2 kg) and endurance players (18.5 ± 1.9 kg). This signifies the importance of development of muscle mass for archers who need to shoot arrows for hours requiring great muscular strength of upper body.[28] The findings of this study also showed that weight, lean body mass and muscle content are significant contributors to the discriminant model with a structure coefficient of 0.527, 0.323 and 0.293 in function 2 respectively (Table 3). The results of this study are new insights to the understanding of characteristics of females in skill sports such as archery and combat sports such as wrestling, judo. Several studies have examined the body composition of elite wrestlers and proved that international-level wrestlers had greater fat free mass (FFM) and less fat tissue.[29] As in all weight category sports, body weight, and body composition play a major role in judo and reducing substantial amounts of weight within short time is a usual part of the competition. It has also been proven that the anaerobic power of judo athletes is influenced by an increase in lean body mass while maintaining the initial level of adipose tissue.[30]

Skill games like archery and combat sports have completely different characteristics. Greater parasympathetic activity and a balance between both systems of autonomic nervous system are beneficial to the performance of archers.[31] In a comparative study conducted on archers and boxers, it was found that boxers showed sympathetic dominance whereas parasympathetic dominance was found in archers.[32] In the present study, we have found significant differences in LF/HF ratio ($p<0.05$) between combat group and remaining three groups (endurance, skill and control). Different sports activities have different effects on HRV, likely due to different demands of training — such as strength versus endurance, continuous versus interval and ratio of training to competition. In this study, highest HRV values were found in cyclists and canoe and kayak paddlers, while the lowest in runners.[33]

The general profile of sportsmen in terms of personality is low neuroticism, high extraversion, and conscientiousness, as well as average openness to experience and agreeableness.[34] Similar findings were obtained in the present study; however, highest value of neuroticism was seen in combat sport athletes. In case of state anxiety and trait anxiety, lowest values were found in athletes involved in endurance sports. Research suggests that elite players exhibit lower state anxiety.[7] For future research it is suggested to involve a greater number of athletes for every discipline to understand the differences in the psychological process to a greater extent.

A study done by Leone et al (2002) revealed that in the discriminant analysis, the anthropometric variables contributed more to the model than the bio-motor variables.[13] This study is in agreement of the fact that physical and maximal aerobic capacity contributed more than the heart rate variability and psychological factors to characterize and distinguish female athletes participating in different sports. There are clear training effects between sports. Success in many different sporting activities would most likely be reliant in part on aerobic power and body composition. In summary, the results showed that after cross validation 68.3% of cases were correctly classified, with 71.4% being correctly classified for the endurance players, 70% being correctly classified for the combat players, 68% being correctly classified for the skill players and 65.2% being correctly classified for the control group.

Conclusions

In this study, we present a model that could be used to predict the sports of an athlete from a number of physical and physiological variables. This information might be employed to familiarize the training of athletes towards a specific sport and could also be of use in improving performance in deficit areas. Our interpretation of the findings is bound by the fact that it was only focused on elite female athletes. The sample size taken for the present study was small and was drawn from only one region of the country and therefore generalizability is doubtful.

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