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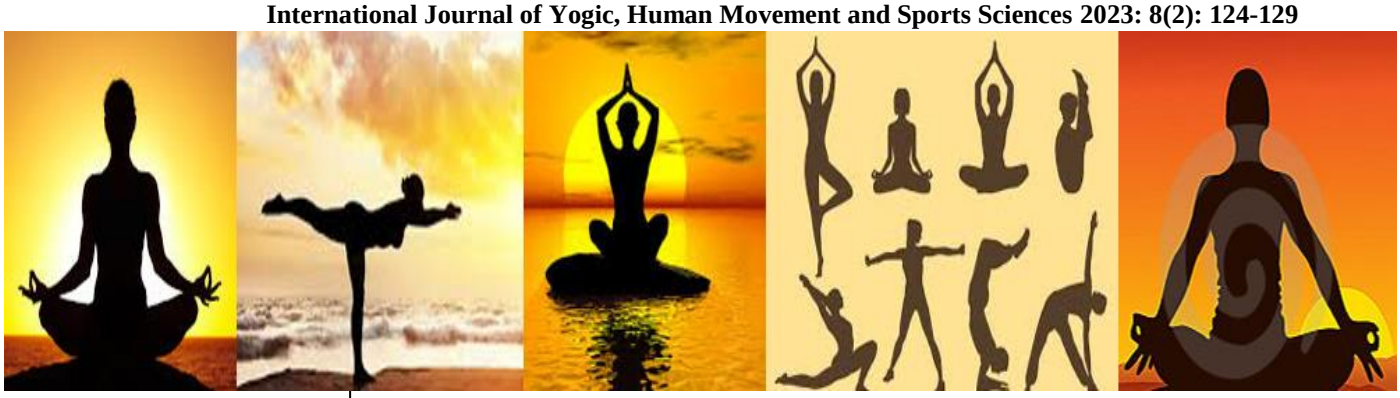

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Dr. Mandeep Singh
Assistant Professor, Government Arts and Sports College, Jalandhar, Punjab, India

Dr. Kanwar Mandeep Singh Dhillon
Assistant Director, Directorate of Sports, Guru Nanak Dev University, Amritsar, Punjab, India

Dr. Parminder Singh
Assistant Professor, Department of Physical Education, Guru Nanak Dev University, Amritsar, Punjab, India

Corresponding Author:
Dr. Kanwar Mandeep Singh Dhillon
Assistant Director, Directorate of Sports, Guru Nanak Dev University, Amritsar, Punjab, India

Physiological parameters as batting performance predictors among elite female softball players

Dr. Mandeep Singh, Dr. Kanwar Mandeep Singh Dhillon and Dr. Parminder Singh

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Abstract
Background and study aim: This study aimed to investigate the relationship of physiological parameters with batting performance among female softball players.
Material and Methods: The participants for this study were 150 female softball players from the various states and universities of India. The vital capacity of the players was assessed with the help of the computerized spirometer. Cooper's 12-minute run/walk test was used to measure the female softball players' aerobic fitness (VO_2max). Speed was measured with the 50 m dash. The explosive strength of the players was determined by using the standing vertical jump. The sit and reach test was used to measure the flexibility of the players. Grip strength was determined with the help of a hand dynamometer. The batting performance of the players was assessed with the help of AAHPERD softball skill test battery.
Results: The results revealed that the physiological parameters i.e. vital capacity ($p<0.05$), explosive strength ($p<0.05$), speed ($p<0.05$), flexibility ($p<0.05$) and grip strength of both right ($p<0.05$) and left ($p<0.05$) hand demonstrated a significant correlation with the batting performance among the female softball players. Regression analysis showed that the grip strength of the right hand was a prime predictor of batting performance among female softball players.
Conclusions: Explosive strength, speed and flexibility were other significant contributors to batting performance.

Keywords: Female, softball, elite, playing ability, physiological parameters, batting performance

Introduction
Physiological characteristics are essential, decisive and powerful factors in the performance of players. The physiological parameters in sports provide opportunities to learn more about the responses of individuals to the demands of exercise and the physiological adaptations to training which underlie improvements in human performance. Awareness of the physiological characteristics of elite-level players in a given sport may be advantageous in terms of optimizing training programs specific to the demands of that particular sport. The knowledge of physiological characteristics may also provide the player with information as to where training may be directed to compensate for areas where he/she may be below average in his/her specific sport [4, 29]. The importance of evaluating sport-specific skills and physiological characteristics in different sports, is vital to understanding sports performance, as high physical fitness qualities improve playing performance [11, 27]. Physiological characteristics have a remarkable effect on the performance level of a player besides personal skill and mental ability.
Physiological parameters are also considered as one of the performance indicators in softball. Softball is a physically demanding sport comprised of several specializations such as hitting, fielding, throwing, pitching, base running, etc. requiring diverse skills and different types of fitness. Physical capacities such as speed, strength, endurance, and flexibility are closely related to complex softball skills, especially during intense and tiring match situations. It requires upper extremity power, hand grip strength, excellent eye-to-hand coordination, and

the coordinated movements of the hips, shoulders, arms, and wrists [25]. Successful participation in softball depends on the player's ability to execute softball skills precisely even at the point of exhaustion which could be the distinguishing instincts between the elite and non-elite sports persons. The elite-level players have the edge over the sub-elite-level players in terms of physical capacities, i.e., speed, strength, agility, and endurance [20]. In softball, players also need a considerable amount of upper-body muscle balance as it plays an integral part in hitting performance [3, 15]. Spaniol [22] has indicated that leg power is significantly associated with batting speed and batted ball velocity among baseball players. Kohmura *et al*. [14] reported that strength, power, and agility were found to have a significant relationship with the subjective evaluation of performance in Japanese college baseball players. In another study on minor and major league baseball players, Hoffman *et al*. [12] reported that lean body mass, lower body power, speed, and grip strength were significantly related to baseball-specific performance variables of total bases, stolen bases, slugging percentage, and home runs. Grip strength is also used as a marker of overall physical strength [9]. The grip strength of the players is evaluated in different sports, and their essential role in success is recognized. The assessment of hand-grip strength is of huge significance in sports like wrestling, badminton, tennis, cricket, basketball, baseball, handball, and softball, as these sports require an adequate level of grip strength to be successful. Several studies associated with the hand-grip strength and anthropometric characteristics of softball players are reported in the literature [28, 15].

In softball, there is little scientific information to suggest which specific components of strength, speed, or power best predict batting performance in softball. There is also very scant information regarding the physiological characteristics as the predictors of performance in softball. As such, the development of performance prediction models as a function of specific tests of physical capacity may provide insight into those factors that relate to hitting performance in softball. This information may also assist in the development and assessment of sport-specific training programs. The present study, therefore, aimed at evaluating the physiological parameters and assessing their association (if any) with the batting performance in elite female softball players from India.

Materials and methods

Participants

A cross-sectional study has been designed to establish the relationship of batting performance with physiological parameters. The subjects of the present study were purposively selected from the university-level and national-level female softball players. 150 female softball players from different universities and states of India were selected to participate in the study. The average age of the female softball players was 20.50±2.10 years. All the players were assessed for physiological parameters vital capacity, aerobic fitness (Vo_{2max}), explosive strength, speed, flexibility and grip strength of both right and left hand. The researcher took verbal consent from the coaches of the team and the participants as well.

Physiological Parameters

Vital Capacity

Vital capacity is the maximum amount of air expelled during forceful expiration from the lungs after a maximum inspiration by a person. It is equivalent to the sum of inspiratory reserve volume (IRV), expiratory reserve volume (ERV) and tidal volume (TV). The vital capacity of the subjects was measured with the help of USB-PC based spirometer. The subject was asked to take a deep breath and then exhale into the sensor forcefully for at least 6 seconds. During the test, soft nose clips were used to prevent air from escaping through the nose.

Aerobic Fitness (Vo_{2max})

The Cooper 12-minute run is a popular running test of aerobic fitness. In this test, the subjects were asked to run/walk for twelve minutes, and the total distance covered in twelve minutes was recorded. The following equation given by Cooper [6] was used to calculate Vo_{2max} (ml/kg/min) from the distance score.

Vo_{2max} = (22.351 x kilometers) - 11.288

Speed (50 m dash)

The purpose of the 50 m dash test is to examine the acceleration and speed of the subject. The test involves running a single maximum sprint over 50 meters, with the time recorded. The subject was asked to stand in a stationary position behind the starting line, and the tester gave the command to the subject set and then go. The subject started from a stationary standing position and had to cross the finish line at the maximum possible speed. The time is taken to complete the 50 m distance was recorded to the nearest two decimal places as the score of the test.

Explosive Strength (standing vertical jump)

Standing vertical jump is used to measure the explosive strength of the subjects. It tests the explosive strength of the legs and the extensibility of hip muscles. The subject was asked to stand side-on with the dominant shoulder facing the wall. The subject then was asked to reach up with the dominant arm and the standing reach height was measured at the point of their fingertips. The subject was then ready to attempt the first jump attempt. The subject was allowed to bend (flex) the knees and swing the arms before the jump. The subject was not allowed a run-up, nor does a shuffle step before the jump. At the highest point of the jump, the subject reached up and touched the wall, making a chalk mark. The subject's vertical jump score was calculated by subtracting the standing reach height from the jump height.

Flexibility (sit and reach test)

The sit and reach test is used to measure the flexibility of the back and legs. Before the measurement, the subject was offered sufficient time for stretching. The subject was asked to sit on the mat without shoes, with both legs extended, so the bottom of the feet was against the modified sit and reach box. The hands were placed on top of the others, with neither set of fingers extending beyond the other. The subject was required to stretch forward maximally and hold the position for 3 seconds. Three trials were given to the subject and the highest score nearest to 0.5 cm was recorded for analysis.

Grip Strength

The grip strength measures the maximum isometric strength of the hand and forearm muscles. It was measured with the help of a hand dynamometer with an adjustable grip. The subject was asked to hold the dynamometer in his right hand, at his side without touching the rest of the body and squeeze it

forcefully. The grip strength of the left hand was measured similarly. The subject was required to squeeze the hand dynamometer gradually and continuously for at least 2 seconds. The best score was recorded in kilograms separately for both the right and left hand.

Batting Performance

The batting performance of the female softball players was assessed as described in the AAHPERD softball skill test battery edited by Dr. Roberta Rikli [1]. This test item evaluates the power and placement of the ball while hitting in softball. Based on the concurrent validity calculated from the relationship between test scores and experts' skill ratings, the validity coefficient ranged from 0.54 to 0.85. The reliability coefficient is found to be 0.69 to 0.91 as calculated from the intra-class test-retest scores' coefficient of correlation. For this test, the softball field was designed, as shown in Fig. 1. Three power zones were created at a distance of 60', 180', and 240' away from the batting site. The softball was placed on a batting tee (adjustable to a proper height), and the subject was required to hit the ball as long and as straight as possible. Each subject was given six trials. The score to the batted ball was assigned as per the landing zone scores shown in fig. 1. The sum of the six balls was the final score.

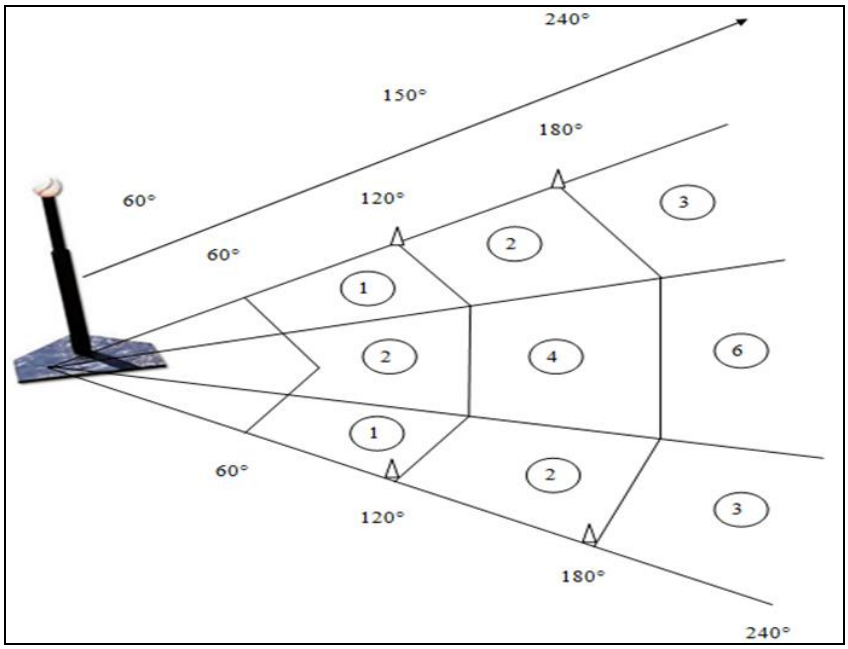

Fig 1: Field marking for batting test

Statistical Analyses

Statistical analyses were performed using SPSS version 16.0 for Windows (SPSS Inc, Chicago, IL, USA). Karl Pearson's product-moment coefficient of correlation was computed to assess the relationship of the physiological parameters with batting performance among female softball players. To predict the batting performance from physiological parameters, stepwise regression analyses were applied. Significance levels were set at $p<0.05$.

Results

Table 1: Relationship of various physiological parameters with the batting performance in female softball players

Variables	N	Pearson Correlation Coefficient (r)	p-value
Vital Capacity (L)	150	0.261	0.001*
Vo_{2max} (ml.kg-1.min-1)	150	0.065	0.432
50 m dash (sec)	150	-0.332	0.000*
Standing Vertical Jump (cm)	150	0.400	0.000*
Flexibility (cm)	150	0.326	0.000*
Grip Strength of Left Hand (kg)	150	0.356	0.000*
Grip Strength of Right Hand (kg)	150	0.413	0.000*

* Indicates $p<0.05$

Table 1 presents the relationship between batting performance and various physiological parameters of female softball players. The vital capacity demonstrated a significant correlation (r=0.261, p<0.001) with the batting performance amongst the female softball players. The statistical results showed that aerobic fitness (Vo_{2max}) did not have a significant relationship with the batting performance in female softball players. The 50m dash test time showed a negative significant correlation (r = -0.332, p<0.001) with the batting performance among female softball players as less time taken to complete 50m means greater speed. The standing vertical jump height (explosive strength) of the female softball players (r=0.400, p<0.001) showed a significant correlation with the batting performance. The flexibility demonstrated a significant correlation (r=0.326, p<0.001) with batting performance among the female softball players. The grip strength of both the right (r=0.413, p<0.001) and left hand (r=0.356, p<0.001) also showed a significant relationship with the batting performance of the female softball players.

The scores obtained from the various physiological parameters of this study were correlated with the batting performance score using the stepwise regression technique.

Table 2: Summary of regression prediction of batting performance with physiological parameters

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1.	0.413a	0.171	0.165	1.85561
2.	0.504b	0.254	0.244	1.76638
3.	0.528c	0.278	0.264	1.74289
4.	0.546d	0.298	0.278	1.72532

a. Predictors: (Constant), Grip strength of right hand
b. Predictors: (Constant), Grip strength of right hand, standing vertical jump
c. Predictors: (Constant), Grip strength of right hand, standing vertical jump, 50 m dash
d. Predictors: (Constant), Grip strength of right hand, standing vertical jump, 50 m dash, Flexibility,

Table 3: Coefficients of regression prediction of batting performance with physiological parameters

Model	Unstandardized Coefficients		Standardized Coefficients	t-value	p-value
	B	Std. Error	Beta		
1. (Constant)	4.811	1.009	0.413	4.768	0.000
Grip strength of right hand	0.204	0.037		5.523	0.000
2. (Constant)	3.539	1.011	0.321	3.502	0.001
Grip strength of right hand	0.158	0.037	0.302	4.297	0.000
Standing vertical jump	0.073	0.018		4.041	0.000
3. (Constant)	8.567	2.462	0.270	3.480	0.001
Grip strength of right hand	0.133	0.038	0.276	3.396	0.001
Standing vertical jump	0.067	0.018	-0.170	3.692	0.000
50 m dash	-0.469	0.210		-2.234	0.027
4. (Constant)	7.710	2.274	0.261	3.116	0.002
Grip strength of right hand	0.128	0.038	0.213	3.400	0.001
Standing vertical jump	0.051	0.019	-0.164	2.641	0.009
50 m dash	-0.454	0.208	0.155	-2.181	0.031
Flexibility	0.080	0.040		1.997	0.048

a. Dependent variable: batting skill

The physiological predictors of softball batting performance were entered into a stepwise regression model. Using the stepwise method, a significant model emerged (F4, 145 =15.370, p<0.0001) as shown in Tables 2 and 3. The adjusted R square value is 0.278, which tells that our model accounts for approximately 28% of the variance in the softball batting performance. For batting performance, 16% of the variance was accounted for by grip strength of the right hand, 8% was explained by standing vertical jump (explosive strength), 2% was explained by 50 m dash (speed) and an approximately additional 2% of the variance was explained by the flexibility. The regression equation for the prediction of batting skill performance based on physiological parameters is as follows:

Batting Performance = 7.710+0.261 (Grip strength of right hand) + 0.213 (Explosive strength) - 0.164 (Speed) + 0.155 (Flexibility)

Discussion

The understanding of the physiological factors of elite-level players in a particular sport may be advantageous for optimizing training programs specific to the requirements of that sport and to accomplish higher performance levels. The female softball players in the present study were assessed for physiological parameters. The results of this study showed that physiological parameters such as vital capacity, speed, explosive strength, flexibility and grip strength were significantly associated with batting performance among female softball players. Batting in softball involves explosive and dynamic action requiring high levels of force to be exerted over a relatively short period [7]. Therefore, strength (explosive strength, grip strength, etc.) plays an important role in batting among softball players. Research in the physiological profiles of softball players confirms the medium-high requirement of strength in batting performance [2, 7, 8, 25]. In softball, grip strength is important for bearing the impact of the ball as well as for imparting force from the body to the slugger to produce maximum velocity while swinging it to hit the ball. Fry *et al.* [10], in a study on collegiate baseball athletes, reported that a relationship exists between grip strength and batted ball velocity. In another study on university-level male softball players, Singh [21] confirmed that among other physiological parameters, grip strength is also contributing to successful participation in softball. On the other side, Hughes *et al.* [13] suggested that the grip strength is not related to bat velocity. Speed is also another important factor in determining batting performance in softball. Batting skills in softball are related to two major components of speed, namely reaction time and movement speed. The reaction time is related to initiating movement to any stimulus. In softball, reaction time is an important factor for the batter to start the swing of the slugger at an appropriate time to hit the ball which is pitched toward him. After the start of the swing, the other factor that influences the batting performance is movement speed which determines the velocity of the bat. Movement speed is also influenced by the explosive strength of the players. Therefore, both speed and explosive strength are the factors that affect the batting performance in softball. Coleman [5] studied the average time, speed, and amount of base running by major league baseball players and reported the importance of speed in fielding, hitting, and base running. Vo_2max did not show a significant association with the batting performance among female softball players. Ellis [7] observed the low-medium importance of endurance in hitting and reported that endurance does not play a major role in the energy requirements of softball. Szymanski [23] also reported that only 5% of the energy used in softball comes from the aerobic system, making endurance of little importance. Softball primarily uses anaerobic energy fitness through the ATP-PC system [5]. The flexibility measured through the sit and reach test showed a significant relationship with batting performance in the current study.

The flexibility is attributed to decreased internal muscular resistance and increased range of motion. A medium amount of flexibility is required for batting in softball as reported in the literature [7]. These findings are in line with other studies that investigated high school and college baseball players [12, 14, 23], youth baseball players [17], and collegiate female softball players [18, 26].

The physiological model for predicting performance on batting skills among female players accounts for 28% of the variance in the batting performance. The grip strength of the right hand was the prime predictor of batting as it accounts for 16% of the variance in batting performance. Explosive strength (8%), flexibility (2%), and speed (2%) were the other significant predictors. These findings agree with those reported by Hoffman *et al.* [12] on professional baseball players. They reported that physiological parameters such as speed, lower body power and agility were the major predictors of baseball-specific performance. Mangine *et al.* [16] studied professional baseball players and found the vertical jump mean power as the single best predictor of fielding performance. Nakata *et al.* [17] examined the youth baseball players and they reported that the body mass index, standing long jump, and back strength as the predictors of the hit ball kinetic energy. Kohmura *et al.* [14] studied the relationship between physical fitness and performance evaluated by coaches and found the association of physical fitness variables with performance among college baseball players. The results of the present study conform to those reported by Szymanski *et al.* [24] on high-school baseball players. They studied the relationship of physiological variables with the bat swing velocity and found strength as the predictor of the bat swing velocity. Till, *et al.* [26] determined the relationship of performance variables with bat swing and throwing velocity of female college softball players. They found that the peak power and 1RM hang clean were associated with bat swing velocity. On the other hand, the results of the present study are not in line with those reported by Rao and Kumar [19] on under-15 softball players. They studied the relationship between physiological parameters and performance and reported that the physiological parameters were not significant predictors of performance among softball players. It is concluded from the above discussion that there was significant variation in the contribution of different physiological parameters in the batting performance among the female players. Grip strength of the right hand was a prime predictor of performance in batting skill among female softball players.

Conclusion

The physiological parameters *viz.* vital capacity, explosive strength, speed, flexibility and grip strength of both right and left hand showed a significant relationship with the batting performance among the female softball players. The grip strength of the right hand was reported as a prime predictor of batting performance among female softball players. Explosive strength, speed, and flexibility were other significant predictors of batting performance.

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