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Association Between Body Composition Metrics and Heart Rate Recovery in Female Cricketers: A Cross-Sectional Study

Frajana Akter Boby[1], Borko Katanic[2], Robert Çitozi[3], Karuppasamy Govindasamy[4], Vlad Adrian Geantă[5]

[1]Daffodil International University, Department of Physical Education & Sports Science, Dhaka, Bangladesh, [2]Montenergin Sports Academy, Podgorica, Montenegro, [3]Sports University of Tirana, Faculty of Physical Activity and Recreation, Tiranë, Albania, [4]Symbiosis International (Deemed University), Department of Sports, Recreation and Wellness, Telangana India, [5]Aurel Vlaicu University of Arad, Faculty of Physical Education and Sport, Romania

Abstract

Heart rate recovery (HRR) is a recognized non-invasive marker of cardiovascular fitness and autonomic nervous system function. This study aimed to investigate the association between HRR and anthropometrically derived indicators of body composition in female cricket players, and to identify the most reliable adiposity-related predictor of HRR during field-based fitness screening. A total of 100 female cricketers (aged 16–26 years) were recruited from eight divisions of the Bangladesh National Women's Cricket League (2021–2022). Participants underwent a modified Harvard Step Test, and HRR was recorded at 1 and 2 minutes post-exercise. Anthropometric measures included body mass index (BMI) z-score, waist circumference (WC), waist-to-height ratio (WHtR), and body fat percentage (estimated via skinfolds). Data were analysed using Pearson's correlation and multiple linear regression (SPSS v26). The results revealed that all indicators were negatively correlated with HRR at 1 minute ($r=-0.159$ to -0.223, $p<0.001$), and to a lesser extent with HRR at 2 minutes ($r=-0.098$ to -0.138, $p<0.05$). Body fat percentage emerged as the only significant predictor of HRR at 2 minutes in regression analysis ($\beta=-0.318$, $p=0.009$). In summary, the study reveals a inverse association between body composition indicators (BMI, body fat percentage, waist circumference, and WHtR) and heart rate recovery in female cricketers, with body fat percentage being a key predictor of post-exercise HRR. These findings emphasize the relevance of body composition in evaluating cardiovascular fitness and highlight the value of the Harvard Step Test as a practical assessment tool. Further research is needed to clarify the physiological mechanisms behind these associations and to inform individualized training strategies for female athletes.

Keywords: *heart rate recovery, body composition, female cricketers, cardiovascular fitness, Harvard step test*

Introduction

Cardiovascular fitness and body composition are two interrelated dimensions that influence both athletic performance and health outcomes in sport (Abu Hanifah et al., 2013; Carnethon et al., 2005). In cricket, where intermittent bursts of activity require a balance between endurance and explosive power, these factors are particularly relevant, especially among female players whose physiological responses are understudied (Azam et al., 2022).

Body composition refers to the proportion of fat, lean tissue, bone, and water in the human body (Chao et al., 2008). In applied field settings, anthropometric measurements such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and skinfold-derived body fat percentage are commonly used to estimate adiposity (Pelegrini et al., 2015). Although true body composition is best assessed using advanced laboratory methods such as DEXA, the use of indirect anthropometric estimates is widely accepted and practi-

Correspondence:

Karuppasamy Govindasamy
Symbiosis International (Deemed University), Department of Sports, Recreation and Wellness, Hyderabad Campus, Modallaguda (V), Nandigama (M), Rangareddy, Telangana 509217, India
E-mail: gowthamadnivog@gmail.com

cal for large-scale or field-based studies (Duren et al., 2008; Katanic et al., 2023).

In female cricketers, body composition is pivotal in determining agility, strength, and power (Herridge et al., 2020; Koley et al., 2012). Athletes with a higher lean body mass-to-fat mass ratio often exhibit enhanced athletic performance due to increased muscle power and reduced body fat, which contribute to better endurance and faster recovery (Aikawa et al., 2020).

Heart rate recovery (HRR) is a valuable indicator of cardiovascular fitness and the body's ability to return to a resting state after physical exertion (Faria & Drummond, 1982; Römer & Wolfarth, 2022). Rapid HRR has been consistently associated with favorable cardiovascular outcomes and better endurance performance (Mahon et al., 2003; Radaković et al., 2024; Singh et al., 2007, 2008; Watanabe et al., 2001). For cricketers, especially during prolonged or high-intensity matches, efficient HRR may serve as a critical performance asset (David & Ian, 2017).

Physical fitness is a crucial aspect of performance in any sport, and cricket is no exception (Williams, 1965). As the popularity of women's cricket continues to grow, understanding the relationship between various physiological factors and performance becomes essential. One such factor is the body composition of female cricketers, which can significantly impact their cardiovascular health and overall athletic abilities. Previous research has explored the relationship between heart rate recovery (HRR) and various cardio-metabolic factors, particularly in pediatric and adolescent populations (Laguna et al., 2013; Lin et al., 2008; Singh et al., 2008). According to one study, 39% of the diversity in HRR can be attributed to chronological age, sex, blood pressure, and Body Mass Index (Singh et al., 2008). However, these studies rarely included elite female athletes, and there remains a lack of data on the predictive value of specific anthropometric indicators of body composition on HRR in adult female cricketers.

According to a recent study, boys but not girls showed an unfavorable connection between maximum heart rate, homeostatic model evaluation, waist circumference, and skinfold thickness (Laguna et al., 2013). These findings suggest that HRR is consistently correlated with body composition factors. Optimizing athletic performance and ensuring cardiovascular health are critical priorities in competitive sports (Bermon & Adami, 2019). This quest for excellence often involves the meticulous examination of various physiological and biomechanical factors that contribute to an athlete's capabilities. Within this context, cricket has risen to prominence as a fiercely competitive and physically demanding sport, capturing the hearts of millions around the globe. In Bangladesh, where cricket holds a special place in the national psyche, the commitment to nurturing talent and improving performance among female cricketers has never been more pronounced.

The success and prowess of female cricketers extend beyond the boundaries of skill and technique. To unravel the full potential of these athletes, it is essential to delve into the intricacies of their physiological makeup (Mandoli et al., 2021). One such aspect that has gained increasing attention in sports science is heart rate recovery (HRR), a powerful indicator of cardiovascular fitness and an essential component of an athlete's overall well-being.

This study addresses a gap in the current literature by focusing on female cricketers in Bangladesh a population underrepresented in prior HRR research. While some studies have explored the association between HRR and generalized adiposity indicators, specific anthropometric predictors such as WHtR and field-derived body fat percentage have not been thoroughly examined in this group. Given that impaired autonomic regulation has been linked to adolescent obesity (Baum et al., 2013; Yakinci et al., 2000), a deeper understanding of these relationships in adult female athletes is warranted.

Therefore, the present investigation aimed to examine the relationship between anthropometrically derived indicators of body composition and heart rate recovery following submaximal exercise in female cricket players. It also sought to determine which of these indicators particularly adiposity-related measures exert the strongest predictive influence on HRR performance.

We hypothesized that female cricketers with higher body fat percentage would exhibit slower heart rate recovery, while those with greater lean mass and lower adiposity would recover more efficiently due to superior cardiovascular adaptation.

Methods

Study Design and Participants

A cross-sectional design was employed. A total of 100 female cricketers (mean age =21.8±0.3 years) were randomly selected from participants in the Bangladesh National Women's Cricket League (2021–2022). These athletes represented eight regional divisions and were aged between 16 and 25 years. Prior to enrolment, all participants received a verbal and written explanation of the study's purpose, procedures, and potential risks. Informed written consent was obtained from each participant in accordance with ethical guidelines.

Ethical Consideration

This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and approved by the Research Ethics Committee of the Faculty of Health and Life Science, Daffodil International University (Ref: FHLS-REC/DIU/2024/0013, dated May 6, 2024). All participants provided written informed consent prior to data collection. Anonymity and confidentiality were maintained throughout the research process.

Blood Pressure

With both feet flat on the floor, each participant was seated upright with her right upper arm positioned at heart level. Prior to measuring blood pressure and heart rate, participants were instructed to rest for five minutes. Systolic (SBP) and diastolic (DBP) blood pressure were measured using a stethoscope and a mercurial sphygmomanometer (ALPK2 Blood Pressure Monitor, Tokyo, Japan). Three readings were taken at two-minute intervals, and the average values of SBP and DBP were used for analysis.

Anthropometric Data

Body height was recorded with a portable stadiometer (Seca 213, Seca, Hamburg, Germany), and body weight measured while wearing lightweight clothing was assessed using a digital scale (Equinox Ltd., Gurgaon, Haryana, India). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. The BMI z-score is a statistical measure of how an individual's BMI compares to the average BMI for their age and gender. Body fat percentage was estimated using a skinfold caliper. Waist circumference (WC) was measured with a non-elastic tape (Seca 201, UK), positioned halfway between the lowest rib margin and the hip. The waist-to-height ratio (WHtR) was calculated by dividing each participant's waist circumference (WC) by her body height (BH). These anthropometric indicators have been applied and thoroughly described in numerous previous studies involving athletes (Bjelica et al., 2025; Górnicka et al., 2022; Osayande, Azekhumen, & Obuzor, 2018).

Hart Rate Data

The Harvard Step Test began with each participant stepping on and off a standardized step box for 5 minutes, following a rhythm of 30 cycles per minute, synchronized with a metronome set at 120 beats per minute (bpm; Bunn et al., 2017). A fingertip pulse oximeter (Dr Trust USA Professional Series, Nureca Limited, Mumbai, India) was attached to one of the participant's fingers to continuously monitor heart rate throughout the exercise. Maximum heart rate was recorded during the final minute of the step test. Participants who reached a heart rate exceeding 200 bpm, exhibited respiratory distress, or were unable to continue were immediately withdrawn from the test. Upon completion or early termination, individuals were instructed to sit and rest. The total exercise duration (in seconds) and heart rates at 1 and 2 minutes post-exercise were recorded. Heart rate recovery at 1 minute (HRR1min) and 2 minutes (HRR2min) was calculated as the difference between peak heart rate during exercise and heart rate at each respective recovery time point.

FIGURE 1. Harvard Step Test Method

Statistical Analysis

The collected data were analyzed using descriptive statistics and inferential statistics. The mean and standard deviation were calculated for each group, and the Pearson correlation test was used to determine the correlation between each HRR parameters (HRR1min and HRR2min) with body composition measures (BMI z-score, body fat percentage, WC and WHtR). A p-value of less than 0.05 was considered statistically significant. The data were analyzed using statistical software SPSS version 26 (IBM Corp., Armonk, NY, USA).

Results

Table 1 presents the descriptive statistics for a sample of 100 female cricket players. According to the data analysis, the mean age of the participants was 21.8±0.3 years. On average, the players were 150.6±6.2 cm tall and weighed 48.7±4.5 kg. The average body mass index (BMI) was 20.01±2.4 kg/m², while the mean body fat percentage was 19.7±14.6%.

Table 1. Participants' initial traits and workout specifications.

Variables	Mean	SD
SBP (mmHg)	112.9	10.5
DBP (mmHg)	64.9	10.6
Pulse rate (beats/min)	83.3	11.1
Height (cm)	150.6	6.2
Weight (kg)	48.7	4.5
BMI (kg/m²)	20.0	2.4
BMI z-score	0.2	1.6
Body fat (%)	19.7	14.6
WC(cm)	78.6	12.9
WHtR	0.47	0.1
Peak heart rate (beats/min)	177.6	14.5
Heart rate at 1 min rest (beats/min)	144.7	15.5
Heart Rate at 2 min rest (beats/min)	131.3	14.6
HRR 1 min	41.0	11.9
HRR 2 min	54.5	11.9

The average systolic blood pressure (SBP) was 112.9±10.5 mmHg, and the average diastolic blood pressure (DBP) was 64.9±10.6 mmHg. The resting heart rate was 83.3±11.1 beats per minute (bpm), while the mean maximum heart rate was 177.6±14.5 bpm.

According to the results of the correlation analysis (Table 2), the BMI z-score, body fat %, WC, and WHtR all had a negative connection with HRR 1 min (r=-0.159, -0.195, -0.223, and -0.199 respectively). The table also showed that all body composition measurements were adversely connected with HRR2 min in female crickets (r=-0.113, -0.138, -0.130, and -0.098, respectively).

Table 2. Pearson correlation analysis between HRR parameters and body composition.

Body Composition	HRR 1 min		HRR 2 min	
	r	p	r	p
BMI z-score	-0.159	<0.001	-0.113	0.042
Body Fat (%)	-0.195	<0.001	-0.138	0.012
WC (cm)	-0.223	<0.001	-0.130	0.006
WHtR	-0.199	<0.001	-0.098	0.021

Note. NS—Not significant, BMI—Body mass index, HRR—Heart rate recovery, WC—Waist circumference, WHtR—Waist height ratio.

According to the results of the multiple regression analysis (Table 3), only body fat percentage was found to be adversely correlated with females' HRR 2 min (p=0.009). For BMI z-score, none of the correlations at 1 minute or 2 minutes post-exercise are statistically significant. Waist Circumference and Waist-to-Height Ratio do not show statistically significant correlations with HRR at either 1 minute or 2 minutes post-exercise

Table 3. Standardized coefficients (β) between HRR and body composition (multiple linear regression)

Body Composition	HRR 1 min		HRR 2 min	
	β	p	β	p
BMI z-score	-0.113	NS	-0.008	NS
Body Fat (%)	-0.225	NS	-0.318	0.009
WC (cm)	0.197	NS	0.081	NS
WHtR	-0.071	NS	0.137	NS

Note. NS—Not significant, BMI—Body mass index, HRR—Heart rate recovery, WC—Waist circumference, WHtR—Waist height ratio

Discussion

Heart rate recovery (HRR) after exercise serves as a well-established physiological marker of cardiovascular health, reflecting the body's ability to restore autonomic balance and cardiac efficiency following exertion (Huang et al., 2005).

The present study investigated the relationship between HRR and several anthropometric indicators commonly used to estimate body composition metrics in field settings. It is important to distinguish between body composition as a physiological construct referring to the relative proportions of fat, lean mass, bone, and water in the human body (Chao et al., 2008) and the proxy measures employed to estimate it, such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and skinfold-derived body fat percentage (Pelegrini et al., 2015). These metrics, though indirect, offer practical value in large-scale assessments of adiposity and cardiometabolic risk.

Our findings revealed an inverse association between body composition metrics and HRR, suggesting that increased adiposity may impair autonomic recovery. Body fat percentage emerged as the strongest predictor of HRR at 2 minutes post-exercise in female cricketers. Statistically significant negative correlations were observed between HRR (at both 1 and 2 minutes) and multiple anthropometric measures including BMI z-score, body fat percentage, WC, and WHtR indicating that individuals with higher adiposity values experienced slower recovery. These findings are consistent with previous research emphasizing the detrimental impact of excess fat mass and central obesity on cardiovascular function and recovery capacity (Baruah Hazra, 2023).

At 1 minute post-exercise, all body composition metrics exhibited negative correlations with HRR, indicating that individuals with higher BMI z-scores, greater body fat percentages, larger waist circumferences, or higher WHtR values experienced delayed initial recovery. However, at the 2-minute recovery mark, while body fat percentage and WC maintained negative associations with HRR, the correlations weakened for BMI z-score and WHtR. These nuanced variations in correlations across recovery times suggest potential distinctions in the mechanisms governing immediate and delayed cardiovascular recovery dynamics.

The analysis of beta coefficients provided nuanced insights into the specific predictive capacities of body composition metrics on HRR. Notably, body fat percentage emerged as a significant predictor of delayed HRR, displaying a robust negative association specifically with 2-minute recovery. This distinctive influence of body fat percentage on delayed recovery aligns with established literature emphasizing the pivotal role of adiposity in cardiovascular health outcomes (Heymsfield et al., 2005; Söğüt et al., 2018). However, the non-significant beta coefficients for BMI z-score, WC, and WHtR in predicting HRR suggest potential limitations in their contributions to cardiovascular recovery dynamics.

Our research was contrasted with previously released findings. The European Youth Heart Study evaluated HRR 1 min, HRR 3 min, and HRR 5 min, and found that WC was linked with HRR 3 min in boys but not HRR characteristics in girls (Laguna et al., 2013). The researchers looked at the relationship between HRR and a number of cardio-metabolic risk factors, including measurements of body composition (Laguna et al., 2013; Lin et al., 2008; Singh et al., 2008). Results that were different from ours would have resulted from these factors and the various HRR values used. The HRR 1 min and HRR 2 min were examined in our study. Both HRR parameters have been shown to be accurate and reliable indicators of HRR (Shetler et al., 2001). The different exercise regimes could be another factor. While other investigations, which were carried out in controlled laboratory settings, used active resting periods for treadmills (Lin et al., 2008; Singh et al., 2008) or cycle ergometers (Laguna et al., 2013), this study used mass screening step tests and passive resting recovery. Numerous workout regimes have been proven to affect the results of HRR (Buchheit et al., 2009; Crisafulli et al., 2003). Girls' body fat deposits under the skin and in the total body fat both accumulate (Staiano & Katzmarzyk, 2012). When exercising, the heart rate (HR) increases because the parasympathetic nervous system stops working, and further increases in HR are mediated by the sympathetic nervous system (Buchheit et al., 2007; Drott et al., 1994; Falcone et al., 2005; Hunt, 2001). The first minute of HRR during recovery is caused by vagal reactivation, while the second minute and beyond is caused by a combination of vagal drive, a decrease in the sympathetic pathway, and metabolite clearance (Buchheit et al., 2007; Imai et al., 1994; Laguna et al., 2013; Ohuchi et al., 2000). It has been demonstrated that decreased vagal activity is a predictor of all-cause mortality in both healthy adults and post-myocardial infarction (MI) patients, which has sparked greater interest in HRR in adults and its link with mortality (Cheng et al., 2003; Cole et al., 2000; Nishime et al., 2000; Schwandt et al., 2010; Watanabe et al., 2001). According to a study, there is less parasympathetic drive among MI patients when the sympathetic route is dominant (Rothschild et al., 1988). An increased risk of cardiovascular mortality is indicated by HRRs of less than 12 bpm or 18 bpm during active rest, and less than 43 bpm for HRRs of 1 and 2 minutes, respectively (Cole et al., 2000).

The huge sample size used in this study is its main strength. The modified Harvard Step Test may be utilized as an alternate fitness evaluation tool, according to the research population who used it as a tool. The step test is simple, affordable, portable, and generally safe (Kizilbash et al., 2006; Watanabe et al., 2001b). Due to its portability and need for little equipment, the activity in this study may be completed by five students at once. Furthermore, because it is not a laboratory setting, the atmosphere is more easygoing and requires little specialized training. Each test often took less than 10 minutes to complete, and this short time frame is perfect for on-site mass testing.

The intricate interplay between body composition metrics and HRR holds substantial clinical implications. The significant association between body fat percentage and delayed HRR underscores the importance of integrating adiposity assessments into risk stratification for cardiovascular health post-exercise. Incorporating body fat percentage evaluations in cardiovascular fitness assessments may refine risk assessment strategies and guide targeted interventions aimed at optimizing recovery dynamics (Dewi et al., 2017; Djaafar et al., 2019; Karunasena et al., 2014). However, further research endeavors are imperative to elucidate the underlying mechanisms driving these associations. Exploring potential mediators, such as autonomic nervous system function, inflammatory markers, or hormonal responses, could provide deeper insights into the physiological pathways linking body composition metrics to HRR. Additionally, longitudinal studies encompassing diverse populations, accounting for lifestyle factors, comorbidities, and physical activity levels, are crucial to validate these findings and enhance the generalizability and applicability of results to broader populations.

Limitations and Considerations

This study is subject to several limitations that warrant careful consideration. The cross-sectional nature of the study impedes establishing causality or inferring temporal relationships between body composition metrics and HRR. Additionally, unmeasured confounders, such as fitness levels, medications, or hormonal variations, might influence the observed associations. Thus, cautious interpretation and careful consideration of these limitations are essential when translating these findings into clinical practice or population-level interventions.

In summary, this study unravels the intricate relationship between body composition metrics and cardiovascular recovery dynamics post-exercise. While correlations elucidate associations between body composition and HRR, beta coefficients highlight body fat percentage as a key predictor of delayed recovery. Integrating body composition assessments into cardiovascular fitness evaluations may bolster risk assessment strategies, paving the way for tailored interventions to optimize cardiovascular recovery and promote better health outcomes.

Conclusion

In conclusion, this research highlights the inverse relationship between body composition metrics (such as BMI, body fat percentage, waist circumference, and waist-to-height ratio) and heart rate recovery (HRR) in female cricketers. Body fat percentage emerged as a significant predictor of HRR post-exercise. The study underscores the importance of considering body composition in assessing cardiovascular fitness among female athletes and suggests the practical utility of the Harvard Step Test in evaluating their health. However, further exploration is warranted to understand the complex interplay between body composition and cardiovascular parameters, especially in the context of tailored training and health interventions for women in cricket. Overall, this study provides valuable insights into enhancing performance and well-being among female cricketers.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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