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Correlation of body composition and aerobic capacity with heart rate variability in Indian elite soccer players

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***Abstract*---**Objective: This study aimed to investigate the relationship between Heart Rate Variability (HRV) indexes with body composition and aerobic capacity (VO2max) in Indian Elite soccer players. Methods: 115 male soccer players were recruited and all the subjects were measured for age: 16.8 ± 3.11; height: 167.85 ± 8.27; weight: 57.05 ± 10.66; BMI: 20.16 ± 3.02; body fat %, lean body mass and anthropometry profiling. The aerobic performance was measured using a 20-meter shuttle run test (20 MSRT) for $VO2_{max}$. Heart Rate Variability (HRV) was recorded (RMSSD, pNN50%, LF, HF, LH/HF ratio) at a resting state (~5 minutes) using the Heartware Shimmer ECG device. The Pearson correlation coefficient for % BF and $VO2_{max}$ with heart rate variability was calculated. Result: The result revealed a highly significant negative correlation between VO2max with Body fat% (4-site skinfold) at ($p<0.01$; r = -.280), while Body fat %(4-fold) showed strong significant positive correlation with BMI ($p<0.01$; r= .631). Resting heart rate showed strong significant negative correlation with SDNN and positive correlation with Body fat % (4-fold) with their r- values at -.318 and .258 respectively ($p<0.01$). Lean body mass (4-fold) showed highly significant positive correlation ($p<0.01$) with BMI and LFnu(r= .670 and .295) respectively. Lean body mass (4-fold) and LF/HF ratio ($p<0.05$; r= .215). Conclusion: The findings suggest that there is a relationship between body fat percentage and VO2max and BMI in young adolescent soccer players, while no correlation was found between LF, HF, LF/HF ratio with Body fat % and aerobic capacity ($VO2_{max}$).

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***Keywords*---**body composition, soccer players, heart rate variability, VO2max.

Introduction

Soccer is the most known game in the world. Soccer players' average intensity of work during a match is generally between 80% -90% of HR_{max} which consist of walking (25% of total work), jogging (37%), sprinting (11%), backing (6%), and cruising (20%)(Prajapat et al. 2018). Efficient training provides sufficient exercise stimuli to enhance athletes' performance capacities while avoiding sustained non-functional overreaching or under-recovery. Continuous athlete monitoring may provide information that can be used to balance stress and recovery, ultimately increasing the performance readiness of the athlete and minimizing the risk of illness and injury (Schneider et al. 2019)**.** Neural adaptations to aerobic physical exercise, such as decreased cardiac sympathetic and increased parasympathetic modulation in rest, are important cardio protective factors as sympathetic hyperactivity is an integral part of the pathophysiology of various cardiac diseases field field(Abreu et al. 2019).

Indeed, significant advancements in the field of strength and conditioning and nutritional sciences have occurred concurrent with changes in body composition over recent decades, as evidenced by the increase in body mass not only being associated with an increase in fat mass, which has health implications, but also with gains in lean mass. The changes in lean mass are considered relatively positive given the improvements observed in performance, even over a short period field field(Anding and Oliver 2015). Athlete body composition should be assessed over the course of a season coincident with performance measures to evaluate the efficacy of training and nutrition program implementation. Body composition is an important component, of physical fitness and in creating athlete's profiles and conditioning programs field field(Anwar and Noohu 2016). In the study by Daniela Zanini 2019 to verify the relationship between body composition and physical capacities in young soccer players. Results showed significantly correlation in agility ($p=0.000$; $\rho=0.530$) and vertical jump tests ($p=0.003$; $\rho=-0.437$) with body fat percentage. It was concluded that there is a relationship between body fat percentage and agility and explosive power of lower limbs. (Zanini et al. 2020)

In soccer, the importance of body composition on performance remains unclear; however, it is a Primary concern in conditioning programs throughout a season at all levels of the competition field field(Hailu et al. 2016). A football athlete's body composition is of particular importance for performance. It has been suggested that an increase in body mass or height is associated with increased playing time as well as greater rates of pay. Since performance is so strongly dependent on body morphology and composition, the ability to measure these changes in an athlete over time is essential to both coaches and players. In addition to performance, there is growing interest in the body composition of football athletes because of its impact on health. Studies using body mass index (BMI) as a measure of obesity suggest that up to 56% of football players, including high school players, are obese. Therefore, there is a need for monitoring body composition in football athletes from both a performance and health perspective field field(Anding and Oliver 2015)· Therefore, BMI and body mass alone can be used as a screening tool but not to determine ideal performance mass. Anthropometric measures (e.g., skinfolds and circumferences) aimed at estimating body fat percentages are, in principle, technically simple to perform. Lower relative body fat is desirable for successful competition in most ball games. The study by Esayas Hailu (2016)found that the mean anthropometric measurement of southwest Ethiopian youth soccer players was slightly lower than that of top world-class players of similar age group players. It is also obtained that the lack of significant differences among playing positions reflect on BMI, lean mass and body fat% indicate as coaches are not given playing position-specific training for players(Hailu et al. 2016). Another study by Francesco Campa (2018) aimed to evaluate the associations of anthropometry, functional movement patterns (FMP) and physical performance characteristics with the repeated-sprint ability (RSA) in male youth soccer players. Results showed that measures of physical performance derived from horizontal plane in 10-m and 20-m sprints were more strongly associated ($p<0.05$)(Campa et al. 2019).

Heart rate variability (HRV) is widely used as a marker of the cardiac autonomic nervous system activity (CANA)(Herzig et al. 2018). Heart rate variability (HRV) is a relevant marker reflecting cardiac modulation by sympathetic and vagal components of the autonomic nervous system (ANS). Although the clinical application of HRV is mainly associated with the prediction of sudden cardiac death and assessing cardiovascular and metabolic illness progression, recent observations have suggested its applicability to physical exercise training. HRV is becoming one of the most useful tools for tracking the time course of training adaptation/maladaptation of athletes and in setting the optimal training loads leading to improved performances. However, little is known regarding the role of HRV and the internal effects of physical exercise on an athlete held(Dong 2016). Monitoring the status of the autonomic nervous system (ANS) with HR-based measures [HR and HR variability (HRV) indices] is an attractive option for testing due to its noninvasiveness and time-efficiency when performed for an entire training group or team field field(Schneider et al. 2019). Therefore, interventions to increase HRV, that is, increment of parasympathetic modulation at rest, should be investigated field field(Abreu et al. 2019). Individuals' HR(V) responses likely differ with training context (i.e., training phase and history, exercise modality and intensity, and the time course of response)(Schneider et al. 2019). This technique allows you to quickly and clearly show the adaptive picture of each athlete.

Physiological measures are often considered to correlate with athletic performance, it is unclear to what extent physiological measures correlate with enhanced athletic performance across the spectrum of different sports(Girard, Feng, and Chapman 2018). Higher resting HRV is usually related to greater adaptability and better recovery of the ANS when responding to stressors(de Sousa et al. 2018). Nevertheless, the competitive sports context puts senior athletes under special physiological and psychological constraints with the impacts of training, competition, professional obligations and various other stress factors (family etc.). The practice of sports in competition requires a perfect balance between a day of rest, training and competition and other good management of the various constraints field field(Leti and Bricout 2013). A study by Jan Helgerud (2001) on Aerobic endurance training improves soccer performance 2001. The present study aimed to study the effects of aerobic training on performance during a soccer match and soccer-specific tests. Enhanced aerobic endurance in soccer players improved soccer performance by increasing the distance covered, enhancing work intensity, and increasing the number of sprints and involvements with the ball during a match. (Helgerud et al. 2001)

For the determination of cardiorespiratory endurance, the gold standard has been maximum oxygen consumption (VO2max), which corresponds to the maximum transport capacity and use of oxygen during high-intensity exercise field field(León-Ariza, Botero-Rosas, and Zea-Robles 2017). In youth soccer, aerobic fitness has been reported to be a relevant component of the physiological make-up of the elite-level young soccer player. Indeed, scientific evidence has shown that aerobic fitness parallels the competitive development of youth soccer players field field(Castagna et al. 2010). Aerobic endurance fitness is important for soccer players. The standard test for assessing aerobic endurance fitness is the direct measurement of the player's maximal oxygen uptake (VO2max) whilst running to exhaustion. Field-based tests may serve as convenient surrogates to directly measure VO2max when assessing aerobic endurance performance in soccer players. Multistage shuttle run test (MST) involves running at variable speeds across a 20 m distance, interspersed with frequent dynamic twisting and changing of direction that is deemed to be specific to soccer movements. MST was deemed a valid field-based test of maximal aerobic exertion and power in soccer players field field(Aziz, Tan, and Kong 2005).

Both anthropometry and body composition have a relationship with soccer performance. But still, more clarification is required on anthropometric and body composition associated with changes in a cardiac adaptation by heart rate variability in young adolescent soccer players. The research will contribute to the examination of the associations between body composition, VO2max and HRV, the analysis of which would allow the assessment of the correct interaction between these parameters.

Methodology

Subjects

The priori sample size was calculated using G* power 3.1.9.7 using α= 0.05 with 90% power and a correlation coefficient of 0.30 and the estimated sample size was 112. 115 Indian Elite soccer players from Hoops Soccer Academy (Najafgarh), Village Soccer Academy (Vaishali) and Manthan Foundation Soccer Academy (Rohini), New Delhi, India. participated in the study. Ethical clearance was taken from the Institutional Ethical Committee of Indian spinal injuries Centre Institute of rehabilitation science, Vasant Kunj, New Delhi, India. Male soccer players between the age of 12-25 years with BMI (body mass index) ranging from 18-24.9 kg/m^2, indulging in soccer-specific training for at least the last 3 months (5 - 6 days/week), and having participated in the university-level competition, were included in the study. Those with a history of cardiac or respiratory pathology, taking medications that alter cardiac response or recovery, diagnosed with a chronic health condition, caffeine addict, smokers and alcoholics, were excluded. The mean (±SD) age (years) 16.8 ± 3.11, height (cm) 167.85 ± 8.27, weight (kg) 57.05 ± 10.66 and BMI (kg/m^2) 20.16 ± 3.02.

Procedure

Before the commencement of data collection, subjects were explained the purpose, methodology, and possible risks of the study. Subject and parental written informed consent were obtained. An observational study design was performed on 115 Indian elite male soccer players to take part in the study, the players be involved in the sport for at least 2 years, and be free from any injury at the time of testing. The assessments were divided into 2 sessions: an introductory session and a formal assessment. After a detailed general history of symptoms, an introductory session was performed to assess anthropometric profile, body composition analysis and practice trial of a 20-meter shuttle run test.

The assessments were scheduled in the morning hours between 7-11 am. Vitals (heart rate, blood pressure, spo2, and temperature) of the subjects were measured before the commencement of the assessment. Heart rate variability (HRV) was measured under controlled circumstances. Subjects were pre-informed about not eating or drinking caffeinated beverages at least two hours before the testing and to avoid any physical activity to prevent alteration in the heart rate.

Anthropometric assessment

All the measurement was taken while the player was dressed in minimal clothing (Durandt J. et al. 2009). Subjects were instructed to stay hydrated. Height was measured using a stadiometer to the nearest 0.1cm. Body mass was recorded on the calibrated scale to the nearest 0.1kg (Oone J. et al. 2012, Sharma A. et al. 2012). The procedure outlined by ISAK (international society for Kinanthropometry) was followed in recording girth, and SKF (Sharma H. et al. 2017). Body circumference was measured using an anthropometric tape Lufkin (W606PM) with an accuracy of ±1mm (Santos D.A. et al. 2014). SKF Was recorded on the right side of the body through Harpenden Skinfold Caliper to the nearest 0.1mm (Oone J. et al. 2012, Poris G.O. et al. 2009). Body density was calculated using 4 -site SKF equations (Manna I. et al. 2012). BF% was obtained by converting body density into BF% using the Siri equation. Also, BF% was calculated using the BMI equation (Womersley & Durnin, 1977) (Sharma A. et al. 2012).

Formal assessment

The formal assessment was performed within one week of the introductory session.

Measurement of Heart Rate Variability

The HRV measurement was performed using a Heart wear Shimmer ECG device by EsMedTek, Consensys software for recording and sinus or the analysis of the HRV. The procedure followed the recommendations of the Task Force(Nunan, Sandercock, and Brodie 2010). The HRV was recorded in the resting state in a sitting position. All the subjects were instructed to maintain calm and normal breathing patterns and the temperature of the room was maintained. To maintain the quality of the HRV recording and to minimise the likelihood of signals interference from electrodes falling off or sporadic contact caused by hairs or dirt particles, it was ensured that all the participants shaved off their chest hair for the good electrode-to-skin contact. Also, the skin was cleaned to remove oils and sweat so that interferences of the signals can be avoided. The 5 electrodes were taken in which the two electrodes were placed at 2cm below the clavicle (midclavicular line) on the right and left sides. Rest two electrodes were placed two finger breadths above the ASIS on the right and left sides. The remaining electrode was placed over the 4-5th intercostal space. The machine was simultaneously connected to consensys software via Bluetooth on the laptop and HRV was recorded. The First 2 Minutes of ECG were recorded to lookup for observation and then the actual ECG was recorded for 5 minutes. While the participants were seated, parameters of HRV analysed were mean RR intervals (RMSSD), the standard deviation of NN interval (SDNN), low frequency spectral (LF) component; high-frequency spectral component (HF); low frequency/high frequency (LF/HF).

Measurement of Vo2max/aerobic fitness

The players were tested in groups of 4-5 at one time. On the day of the formal assessment, a practice trial of a 20-meter shuttle run test was performed. The participants were told to perform a routine warm-up before performing the tests to prevent injury. And, an appropriate recovery time had been given in between the tests to avoid fatigue. 20-meter shuttle run test (20msrt): the 20-MSRT is widely used for cardiovascular assessment, also known as the "multistage fitness test" or pacer test. The equation suggested by leger et al. 1984, 1988 is used for the calculation of VO2max. The 20-MSRT consisted of one-minute stages, paced by beeps from the audiotape. 20-ms is continuous, incremental speed-running. According to the original protocol, the athletes started at a speed of 8.5 km/h, with increments of 0.5 km/h each minute (Bandyopadhyay A. et al. 2019). The participants need to run continuously between two lines 20-m apart while keeping pace as signalled by the pre-recorded audiotape. The test was terminated when the athlete could not reach the line with the audio signals on two consecutive occasions (Przysucha E. et al. 2019).

Statistical Analysis

All statistical analyses were performed using SPSS version 25.0. Data normality was confirmed with the Shapiro wilk test. Pearson correlations were used to examine the correlation between resting heart rate, body composition, and VO2max and HRV indices of all the subjects. Data were expressed as mean values and included the standard error of the mean (SEM; ±). The statistical significance was set at $p<0.05$.

Result

Table: I Descriptive data of Indian elite soccer players for demographic, anthropometric characteristics and heart rate variability parameters

Variable	Mean ± Sd
Age.(yrs)	16.79±3.16
Exp.(yrs)	4.13±2.85
Height (cm)	167.85±8.27
Weight (kg)	57.05±10.66
BMI (kg.m-2)	20.16±3.02
BCABF	16.14±5.65
BF_BMI	14.55±4.05
AGE_A	16.8±3.11
BF_4_SITE_SKF	13.57±4.92
BF_7_SITE_SKF	6.23±4.14
LBM_BMI	48.39±7.05
LBM_4_SITE_SKF	49.12±8.44
LBM_7_SITE_SKF	53.22±8.48
MSFT_LAPS	82.5±21.68
VO2MAX	45.94±6.75
RMSSD ms	115.84±88.9
SDNN ms	107.86±64.18
pNN50	40.56±25.22
NN50	169.34±148.48
Mean HR(bpm)	80.15±20.12
VLFms2	2324.35±4205.13
LFms2	3100.61±8614.67
HFms2	5670.74±19289.09
LFHF	1.13±1.34
LF nu	44.71±17.25
HF nu	55.29±17.25

EXP.= experience,HT = height, WT = Weight, BMI = Body mass index,
P<0.005*, P<0.001**

Table: II shows a correlation between BF%, FFM, physical fitness and HRV in elite soccer play

Variables	RMSSDms		SDNNms		PNN50		NN50		LFnu		HFnu		LF/HF ratio	
	R value	P value	R value	P value	R value	P value	R value	P value	R value	P value	R value	P value	R value	P value
BMI	-0.06	0.53	-0.03	0.73	-0.11	0.26	-0.11	0.23	0.18	0.05	-0.18	0.05	0.10	0.27
BF_BMI	-0.06	0.53	-0.03	0.73	-0.11	0.26	-0.11	0.23	0.18	0.05	-0.18	0.05	0.10	0.27
LBM_BMI	0.04	0.71	0.07	0.47	-0.06	0.50	-0.05	0.57	.278**	0.00	-.278**	0.00	.200*	0.03
LBM_7_SITE_SK	0.04	0.65	0.08	0.42	-0.07	0.44	-0.06	0.54	.294**	0.00	-.294**	0.00	.213*	0.02

F														
BF_7 _SITE _SKF	-0.10	0.31	-0.08	0.38	-0.06	0.51	-0.09	0.35	0.05	0.60	-0.05	0.60	0.00	0.98
BCA BF	-0.07	0.48	-0.05	0.63	-0.06	0.51	-0.10	0.30	0.12	0.20	-0.12	0.20	0.07	0.44
VO2 MAX	0.16	0.09	0.15	0.10	0.07	0.48	0.13	0.15	0.04	0.63	-0.04	0.63	0.06	0.52
Mean HRbp m	.395**	0.00	.196*	0.04	0.17	0.07	.590**	0.00	-0.08	0.38	0.08	0.38	0.07	0.45

Table: II shows a correlation between Fat %, FFM, physical fitness and HRV in elite soccer players.

Pearson Correlation analysis revealed a highly significant negative correlation of VO2max with Body fat% (4-site skinfold) at ($p<0.01$) and $r = -0.280$ while Body fat %(4-fold) showed a strong significant positive correlation with BMI ($p<0.01$) and r= 0.631 A highly significant negative correlation was seen between experience in years with Resting HR and LFnu ($p<0.01$) with their r- values at -0.302 and -0.448 respectively while a highly significant positive correlation was indicated with BMI (4-fold) and SDNN with their r- values at 0.247 and 0.270 respectively ($p<0.01$).

Resting heart rate showed a strong significant negative correlation with SDNN and a positive correlation with Body fat % (4-fold) with their r- values at -0.318 and 0.258 respectively ($p<0.01$). HRV Frequency domain: LF/HF ratio showed a strong significant negative correlation with RMSSD and SDNN ($p<0.01$) with their r- values at -0.382 and -0.347 respectively, while a statistically significant positive correlation was seen with the height of the soccer players ($p<0.05$; r= 184) while no correlation was found with Body fat %(4-fold) or aerobic capacity (VO2max). Statistically, a negative correlation was seen between LF and resting heart rate (r= -0.191; $p<0.05$)

HRV Time domain: SDNN showed a highly significant negative correlation with LF/HF ratio and LFnu ($p<0.01$) with their r- values at -0.347 and -0.476 respectively, while e strong positive correlation was seen between RMSSD with HF and HFnu ($p<0.01$) with their r- values at 0.533 and 0.542 respectively. A statistically significant negative correlation was seen between RMSSD with Resting heartrate ($p<0.05$), r= -.214

Lean body mass (4-fold) showed d highly significant positive correlation ($p<0.01$) with the height of the players, their body mass or weight, BMI and with LFnu (HRV Frequency domain) with each of their r-values-values at 0.763, 0.937, 0.670 and 0.295 respectively. While it showed strong negative correlation with HFnu (r= -0.295; $p<0.05$). A statistically significant positive correlation was seen between Lean body mass (4-fold) and LF/HF ratio ($p<0.05$; r= .215).

Discussion

The study aimed to investigate the relationship between body composition and aerobic capacity, with heart rate variability in young adolescent soccer players.

Spectral analysis indices showed A statistically highly significant negative correlation of VO2max seen with Body fat% (4-site skinfold) while Ba body fat % showed a strong significant positive correlation with BMI. No correlation was found between LF/HF ratio with Body fat % and aerobic capacity (VO2max). Accordance with a previous study by Safa Anwar (2016) to determine the correlation of percentage body fat (%BF) and muscle mass (MM) with aerobic and anaerobic performance in collegiate soccer players suggest that there is a significant weak negative correlation between body fat percentage with vertical jump height and moderate positive correlation of body fat percentage with 30 m sprint time and a moderate negative correlation of VO2peak and physical fitness index with percentage body fat with no significant correlation of muscle mass with both VO2peak and physical fitness index. (Anwar and Noohu 2016).

The more years of experience showed a highly significant negative correlation between resting heart rate and LFnu. Furthermore, a study by G.Rave (2019) on heart rate variability is correlated with sympathetic components (i.e. LF and LFnu), which were correlated with perceived physical fitness in elite soccer players (Ravé et al. 2020). In the present study resting heart rate showed strong significant negative correlation with SDNN between and a positive correlation with Body fat % (4-fold). Our results are consistent with those reported by Francesco Campa (2019) who highlighted the associations of anthropometry, functional movement patterns (FMP) and physical performance characteristics s with the repeated-sprint ability (RSA) in males youth soccer players suggesting that low body fat is related to better RSA performance. In addition, a negative correlation between Countermovement jump and the best time of sprint ability was found in the athlete's (Campa et al. 2019).

The present study revealed a strong significant positive correlation between Lean body mass (4-fold) with the height of the players, their body mass or weight, BMI and with LFnu (HRV Frequency domain), it also showed a strong strong negative correlation with HFnu, while e statistically significant positive correlation was seen with LF/HF ratio. By, a previous study by Safa Anwar (2016) to determine the correlation of percentage body fat (%BF) and muscle mass (MM) with aerobic and anaerobic performance in collegiate soccer players the results of the present study suggest that muscle mass has a significant moderate positive correlation with vertical jump height and a significant weak negative correlation with 30 m sprint time [5].

LF/HF ratio a showed a strong significant negative correlation with RMSSD and SDNN. This study also revealed a statistically significant result with height of the soccer players. An r   previous study by Riccardo Proietti (2017) on heart rate variability discrimination competitive levels in professional soccer players shows interclass the correlation coefficient values of the HRV indices varied from 0.78 (very large) to 0.90 (near perfect)). The coefficient of variation (CV) values for RMSSD and SDNN were all <5.00%, although the CV for stress score was 6.13% and for the sympathetic and parasympathetic ratio was 21.33%(Proietti et al. 2017). While a strong positive correlation was seen between RMSSD with HF and Hindu. A statistically significant negative correlation was seen between RMSSD with resting heart rate.

Conclusion

In conclusion, the present study analysed a significant relationship between body composition, aerobic capacity, and heart rate variability in young adolescent soccer players. The results indicate the relationship between VO2max and Body fat%. No correlation was found between LF/HF ratio with Body fat % and aerobic capacity (VO2max). HRV has great potential as a useful marker of physical fitness readiness in team sports. The more years of experience showed a highly significant negative correlation between resting heart rate and LFnu.

Study Limitations

- Athletes included in this study were under 25 years of age.
- Only males were included in the study.

Practical implications

HRV in the morning may represent a valid marker of physical fitness readiness in soccer players.
HRV in sports taxing simultaneously different physical capacities.

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