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Cardiovascular and Physiological Spectrum of Footballers Across Competitive Levels

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Abstract

Football is a high-intensity intermittent sport, with players requiring anaerobic bursts of energy as well as moderate to high amounts of aerobic activity, making it highly dependent on cardiovascular fitness. Physiological profiles of Indian players at district, inter college and University levels are influenced by variation in level of training, quality of training and intensity of competition. To enhance performance, prevent injuries and guide talent development it is necessary to identify these differences. A cross-sectional comparative study was done among 30 male footballers(males) age group 18-28 yrs, equally divided into three groups as district, inter-college and University. Parameters studied were Body Mass Index (BMI), VC, maximal oxygen uptake (VO2 max), resting heart rate (RHR), blood pressure and oxygen saturation (SpO2). Standard instruments (spirometer, sphygmomanometer, pulse oximeter, Queens College Step Test) were used to collect the data. Statistical analyses were performed using one way ANOVA with Tukey's HSD test. University-level players showed the highest VC (4.08 ± 0.09 L) and VO2 max (54.2 ± 0.79 ml/kg/min) ($p < 0.001$) with the lowest BMI, RHR (65.3 ± 1.06 bpm), diastolic pressure and SpO2 (99%). Systolic pressure was also significantly different ($p = 0.048$). Higher levels of training and competition exposure enhances the efficiency of the physiological system. Protocols for structured conditioning, monitoring and recovery will be required at the lower levels to help lower level players bridge the gap and talent pool deepens.

Keywords: *Blood pressure, Cardiovascular fitness, Football players,*

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1.Introduction

Football Power Basics Football is the world's most popular sport, played in over 200 countries by an estimated 265 million active players and its appeal is partially attributed to the sport's stop-and-start, high-intensity nature (Bangsbo, Mohr, & Krustrup, 2018). In addition to being a recreational activity, football is also a demanding physical game due to ongoing physiological strain which lasts for a conventional 90-minute game. Such as walking, jogging, running, sprinting, jumping, rapid changes of direction and physical challenges (Stølen et al., 2005). Thus, to excel in football, a player's aerobic and anaerobic

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energy systems, neuromuscular coordination, muscular strength and power, cardiovascular efficiency and recovery system all the should work harmoniously.

Current match analyses suggest that football players of high level are likely to cover about 10 km per match and perform in the order of 150–250 high-intensity actions such as sprinting, accelerating and decelerating (Bangsbo et al., 2018; Mohr, Krustrup, & Bangsbo, 2016). These sequential high-intensity efforts are primarily dependent upon anaerobic phosphagen and glycolytic metabolism, with the aerobic system having an invaluable role in maintaining exercise performance and allowing for recovery between periods of high intensity (Buchheit & Laursen, 2013). Suboptimal function of either system can hinder performance, particularly at the end of a match when fatigue is more potent. That is why football-specific training always includes a multi-factorial component extending well beyond singular qualities such as maximum oxygen consumption (VO 2 max) or strength and which involves an exposure to cardiovascular efficiency, metabolic capacity, neuromuscular function and recovery kinetics.

In elite football, regular physiological testing (VO2max, lactate threshold, heart rate responses, blood oxygen saturation, body composition and muscular strength) has become an accepted standard for managing performance and risk of injury (Bangsbo et al., 2018; Modric et al. 2020). Up- to-date investigations (2020–2023) have further shown that among all training methods, high-intensity interval training (HIIT) and personalized training programs are the most effective in improving cardiovascular capacity, repeated-sprint ability and recovery characteristics, which are also critical determinants of contemporary football (Bangsbo 1994; Bangsbo et al., & 2007; Helgerud et al.,2011). In addition, the development of player monitoring technologies such as GPS, heart rate variability (HRV) tracking has provided additional evidence of the association between physiological preparedness and match performance and injury prevention (Mallo et al., 2015; Castagna et al., 2020).

Nevertheless, a significant gap exists between global best practice and the reality of football preparation in developing football countries such as India in this burgeoning archive of international research. Indian football players tend to have a mix of different and uneven fitness portfolios, a phenomenon often linked with diverse training methods, very low levels of access to sports science support and a fragmented system of conditioning across developmental levels (Singh et al.,2013). Although scientific testing protocols may at times be conducted on well-established elite Indian cricketers, there is currently an absence of these procedures at the district, inter-college and university levels, at which the bulk of talent identification and development actually takes place. This disparity is magnified in instances when players move down competitive levels and have revealed significant physiological constraints relative to international standards Toms et al.(2024)

A number of studies have investigated, in football, the physiological demands of performance and the factors that determine it, but most of these have focused on European or elite professional players and only a few have considered players from South Asia. Emerging literature from comparative studies indicates that population-based cardiovascular reference values, VO_2max levels, body composition and recovery patterns may differ among populations as a result of genetic, environmental, nutritional and training related aspects (Helgerud et al.,2011; Bangsbo et al., 2006 & 2007). Yet, empirical evidence on these indicators for Indian footballers across ascending competitive echelons is limited. Crucially, comparative research into how the physiological attributes of district, inter-college and university players within the Indian football pyramid differ is lacking, even as these tiers represent the core of potential growth. The physiological continuum across competitive standards needs to be understood for optimal performance and for injury prevention, long-term athlete development and sport life span (Reilly, Bangsbo, & Franks, 2000). The latest evidence suggests that superior cardiovascular efficiency, healthy body mass index (BMI) and efficient recoverability are linked to better health and lower risk of cardiometabolic problems in athletes, further emphasizing the public health significance of football participation (Castagna et al., 2020; Singh et al.,2013). These results also highlight the need for physiological norms that are context specific to the Indian footballer.In view of the foregoing, a distinct and urgent research gap is filled in by the present study, which systematically profiles and compares major physiological variables, including vital capacity (VC), cardiovascular efficiency (CE), resting heart rate (RHR), blood oxygen saturation (SpO2), blood pressure (BP) and body mass index (BMI), of Indian footballers performing at district, inter-college and university tiers. Using a comparative approach based on progressive competitive levels, this study aims at detecting performance gaps due to physiological development and not just talent. To our best knowledge, this is the first study to report injurious symptom of shin splints of athletes in a population-specific and Indian football specific context, thereby, enabled an evidence-based conditioning planning, talent identification models and LTAD framework specific to the national level. In the final analysis, this is the critical way to effect a linkage between mass participation-base and elite performance in turn impacting upon the scientific and strategic growth of football in India.

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2.Materials and Methods

This study was conducted in a cross-sectional–comparative manner to identify variations in certain physiological variables in players of a team sport (football) among three separate competitive levels: District, Inter-College and University. The choice of study design was based on the fact that it allows the assessment of existing physiological traits between groups (i.e., without altering training exposure) and thus it was considered to best reflect differences in competitive/conditioning environment.

2.1 Research Method

A cross-sectional comparative design was used to investigate the effect of competition level on physiological profiles of football players. The level of competition (District level, Inter-College, University level) was the independent variable and some physiological and anthropometric variables were the dependent variables.

2.2 Sampling Method and Participants

The study included 30 male football players (aged 18–28 years). Participants were recruited using purposive sampling and all individuals had to fulfill certain predefined inclusion criteria regarding the competitive experience, training background as well as the medical fitness. To allow for meaningful comparison across levels of competitiveness, participants were evenly split into three groups according to their highest level of competitive engagement: (n = 10 per group).

Group A: District-level football players
Group B: Inter-College-level football players
Group C: University-level football players

2.3 Exclusion & Inclusion ceriteria:

All were at least 3rd year undergraduate students in the Department of Sports Technology, which is a 4-year program. This was to ensure that there was an element of training homogeneity, but that competitive exposure differentiated.

Despite the small number of participants, it was deemed as a reasonable and representative sample for a preliminary physiological comparative study in the Indian football scenario particularly in light of the logistical and access constraints at upper echelons of competition. Equal group sizes improved statistical comparability and minimized sampling bias.

To our knowledge, this is the first study that included only male football players to investigate if there are differences in cardiac adaptation patterns in athletes that relate to genetic polymorphisms. The restriction to a single sex was to ensure comparability across competitive levels and for internal validity. The recruitment of female footballers is identified as a key development for future research.

2.4 Variables of the Study

2.4.1 Independent Variable

- District Level (Group A)
- Inter-College Level (Group B)
- University Level (Group C)

2.4.2 Dependent Variables

The following physiological and anthropometric variables were assessed:

Age (years)

- Body Mass Index (BMI; kg/m^2)
- Vital Capacity (VC; liters)
- Cardiovascular Efficiency (VO_2max; ml·kg^{-1}·min^{-1})
- Resting Heart Rate (beats·min^{-1})
- Blood Pressure (mmHg; systolic and diastolic)
- Blood Oxygen Saturation (SpO_2; %)

2.5 Data Collection Procedure

Recruitment and data collection were conducted over two years adhering to a fixed protocol in order to maintain consistency between participants and prevent interruption of their study or practice schedules. Three testing sites were selected to reflect the competitive level of the subjects: college sports facilities at district training centers, university sports centers.

All subjects were told not to engage in excessive physical exertion for at least 24 h before testing and to arrive well rested and hydrated. The assessments were performed in the morning under controlled environmental conditions to

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minimize circadian and environmental variations. .

2.6 Instruments and Testing Protocols

- Body Mass Index (BMI): Height was taken with a stadiometer and body mass was obtained via a calibrated digital scale. BMI was defined as the body mass (in kilograms) divided by height squared (in meters).
- Blood Pressure: Following standardized procedures for the auscultatory method, resting SBP and DBP were assessed with a calibrated manual sphygmomanometer in the non-dominant arm. Resting Heart Rate and Oxygen Saturation: Both were measured with a pulse oximeter, with readings obtained following a minimum 5-minute period of quiet sitting by the participant.
- Vital Capacity: Performed with a spirometer that was cleaned and calibrated prior to each testing day according to manufacturer instructions.
- Cardiovascular Efficiency (VO_2max): Calculated by Queens College Step Test (QCST). Subjects stepped up and down a standard 16.25 inch (41.3 cm) bench at a rate of 24 steps per minute as dictated by a digital metronome for three minutes. Post-exercise recovery heart rate was recorded and VO_2max was estimated using the following formula for males:

$$[VO_2max\ (ml \cdot kg^{-1} \cdot min^{-1}) = 111.33 - (0.42 \times HR)]$$

where *HR* represents the 15-second recovery heart rate multiplied by four.

2.7 Statistical Analysis

Data were coded and digitized for analysis using the JAMOVI statistical package (Version 2.6.44).Means and standard deviations for all the variables were calculated as descriptive statistics. One-way Analysis of Variance (ANOVA) was employed to test for differences in means among the three competitive groups. When F-values were significant, Tukey HSD post hoc tests were conducted to examine pairwise group differences.To improve the interpretability and practical value for training and talent development, 95% confidence intervals were also computed for important outcome variables along with the F-values and p-values.

2.8 Level of Confidence

All statistical analyses were conducted at a 95% confidence level. Statistical significance was interpreted as follows:

- $p < 0.001$: Highly significant
- $0.01 \leq p < 0.05$: Statistically significant
- $p = 0.048–0.05$: Borderline significance

2.9 Tester Competency and Data Reliability

Trained staff conducted all assessments according to standardized protocols. The instruments were calibrated before each session and several readings were obtained whenever applicable. Uniform testing conditions were maintained to reduce the chances of introducing external sources of variability into the data, which guaranteed the consistency of the data and the measurements.

2.10 Delimitation of the Study

[a].The study will be conducted on football players as the target sample in India, more specifically District, Inter-college and University level football players within a certain state. There will be no inclusion of players from other nations or continents.

[b].The study will be limited to three specific levels of competition- district, inter college and university. Competitors not at those rungs of the ladder will be omitted.

[c]. The study will investigate specific physiological indicators, such as VO_2 max (aerobic capacity), muscular strength, body composition, sprinting ability, lactate threshold and agility. But other aspects like mental toughness or psychological characteristics will be ignored.

[d].The research will not involve interventions or follow up, but will instead rely on secondary data and on fitness tests and physical analysis performed by professional trainers and sports scientists. will be without experimental intervention/ long-term monitoring of athletes.

[e].This study will not be for players competing in international tournaments or non-Indian leagues (such as European or South American footballers).

3.Results & Discussion:

This section presents the results, analysis and discussion of the study focusing on the descriptive statistics of selected physiological variables at the district level.The variables studied were age, BMI, vital capacity (VC), cardiovascular efficiency (CRF), resting heart rate (RHR), blood pressure (systolic and diastolic) and oxygen saturation (SpO2). The

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means and standard deviations of these variables are given in a table along with a bar graph showing the mean values for the different parameters

Table No.-1: Descriptive statistics (mean ± sd) of District level on selected Physiological variables.(n=30)

Variables	Mean	SD (±)
Age (year)	16.6	0.516
BMI (kg/m^{2})	20.3	0.365
VC (ltr)	3.05	0.108
CRF (ml/kg/min)	42.5	1.08
RHR (bpm)	73.3	10.1
BP (systolic) (mmHg)	112	3.90
BP (diastolic) (mmHg)	70.2	1.48
SpO2 (%)	96.5	0.527

Note:95% confidence intervals for all key variables.
Source: Data compiled from primary survey conducted by the researcher (2025).

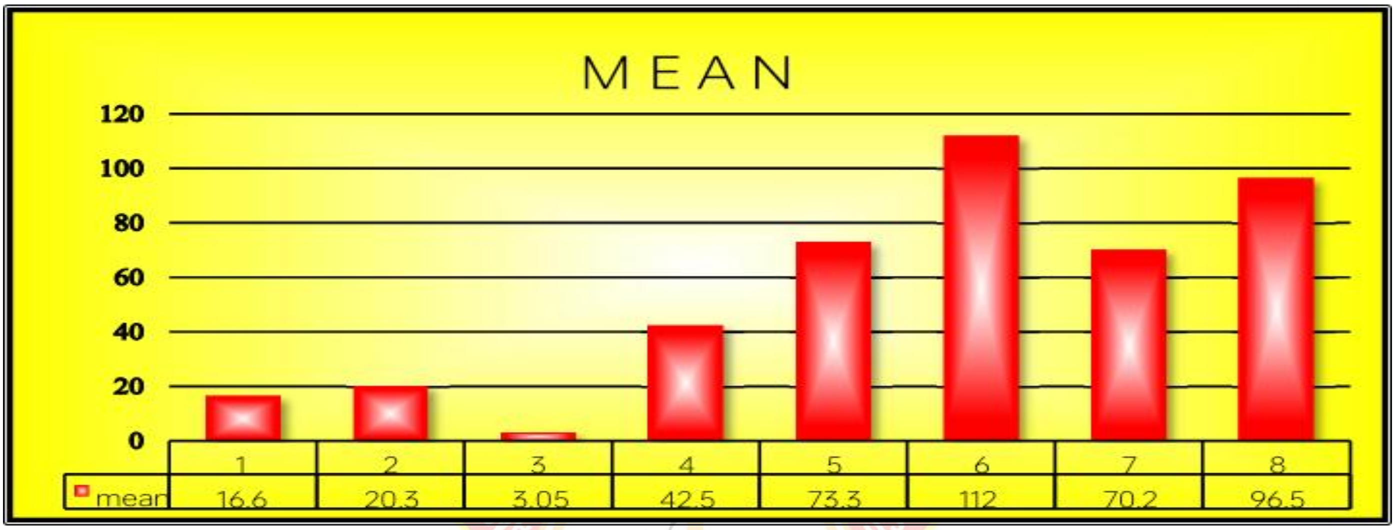

Figure -1 : Mean Values Across district level on age, BMI, VC, CRF, RHR, BP sis, BP dia and SpO_2 (n=30)

Finding:The mean age of subjects were 16.6 ±0.516 years and it was 20.3 ± 0.365 kg/m2 for BMI of the subjects as Bref no. 1. The average vital capacity (VC) was 3.05 ± 0.108 liters and the mean cardiovascular efficiency (CRF) was 42.5 ± 1.08 ml/kg/min. The average resting heart rate (RHR) was 73.3 ± 10.1 bpm. The mean systolic blood pressure was 112 ± 3.90 mmHg and the diastolic 70.2 ± 1.48 mmHg. Also, the mean oxygen saturation (SpO2) were 96.5 ± 0.527% respectively.

Analysis:The mean age of participants in the current study was 16.6 ± 0.516 years which is compatible with the adolescent / late-teenage bracket defined in earlier yoga and exercise physiology studies conducted on similar groups (Gopal et al., 2011). The average BMI of 20.3 ± 0.365 kg/m² is within the normal range as per World Health Organization (WHO) growth standards and also correlates with the findings of adolescent yoga based interventional studies who have reported BMI values in normal ranges for physically active subjects (Yadav et al.,2025).

The mean vital capacity (VC) of 3.05 ± 0. 108 liters is in accordance to the normal values allotted for late adolescents in whom yoga has been proven to enhance lung functions parameters like VC (Joshi et al., 1992).

In-Lab Assessment of Cardiorespiratory Fitness (CRF) Similarly, the average cardiovascular efficiency (CRF) of 42.5 ± 1.08 ml/kg/min is consistent with predicted VO2 max values for active young people and prior yoga and physical exercise training research has indicated an enhancement in CRF of similar work(Madanmohan et al., 2008). The average resting heart rate, RHR, 73.3 ± 10.1 bpm is also normal in adolescents and is consistent with previous findings demonstrating that RHR may be decreased by yoga practice as an indicator of enhanced autonomic control (Bangera, 2012).

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The average systolic (112 ± 3.90 mmHg) and diastolic blood pressures (70.2 ± 1.48 mmHg) are in the normal adolescent reference values and support previous observations that blood pressure of yoga practitioners is generally better than that of controls (Patil et al., 2013).

Lastly, the average oxygen saturation (SpO2) of 96.5 ± 0.527% falls within the ranges of normal physiological values (>95%) in adolescent population, thus providing additional evidence in support to the representativeness of the sample characteristics (Balasubramanian et al., 2018).

Table No.-2: Descriptive statistics (mean ± sd) of Inter College level on selected Physiological variables(n=30)

Variables	Mean	SD (±)
Age (year)	18.5	0.527
BMI (kg/m^2)	21.7	0.225
VC (ltr)	3.53	0.0823
CRF (ml/kg/min)	48.2	0.789
RHR (bpm)	71.3	1.06
BP (systolic) (mmHg)	115	1.05
BP (diastolic) (mmHg)	75.0	1.05
SpO2 (%)	98.0	0.00

Note:95% confidence intervals for all key variables.

Source: Data compiled from primary survey conducted by the researcher (2025).

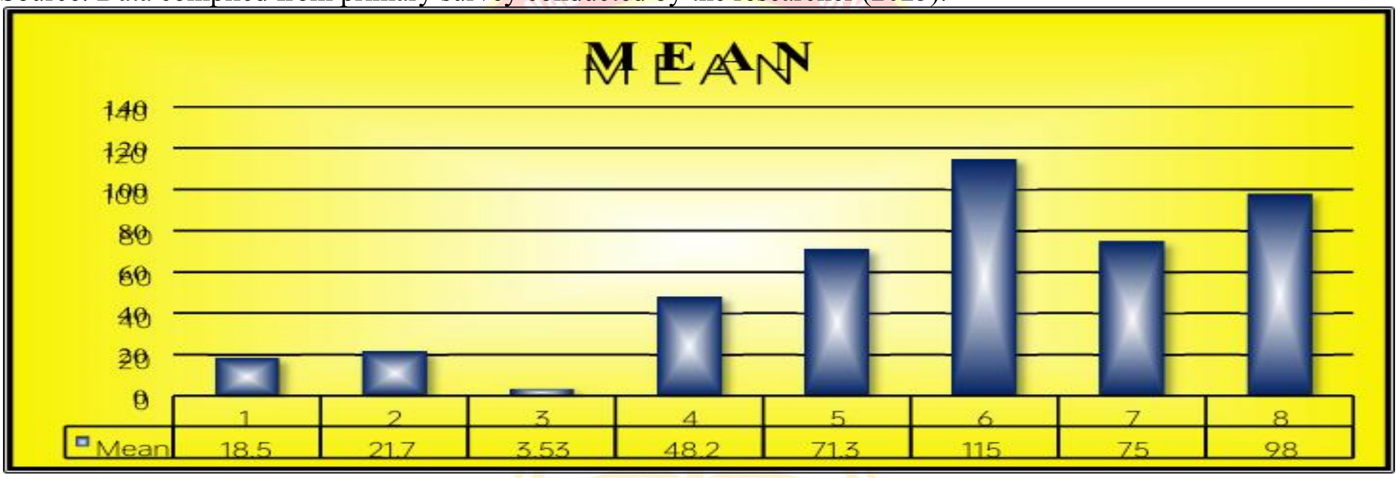

Figure -2: Mean Values Across inter college level on age, BMI, VC, CRF, RHR, BP sis, BP dia and SpO2 (n=30)

Finding: As shown in Table No. 2, The average age of the participants was 18.5 (SD = 0.53). The average BMI was 21.7 kg/m² (SD = 0.23). The average vital capacity (VC) was 3.53 litres (SD = 0.08), while the mean cardiovascular efficiency (CRF) was 48.2 ml/kg/min (SD = 0.79). The average resting heart rate (RHR) was 71.3 bpm (SD=1.06). The average systolic blood pressure was 115 (SD = 1.05) mmHg and the mean diastolic blood pressure was 75.0 (SD = 1.05) mmHg. Also, the mean oxygen saturation (SpO_2) was 98.0% (SD = 0.00) respectively.

Analysis:The participants were late adolescents or young adults with a mean age of 18.5 ± 0.53 years and age group generally studied in yoga and physical fitness research due to their readiness to training interventions (Gopal et al., 2011).

The average BMI 21.7 ± 0.23 kg/m² is in the "normal weight" range according to WHO classification and is consistent with previous yoga-based studies on young adults which also reported values within this same range for BMI (Yadav et al.(2025)).The average vital capacity (VC) of 3.53 ± 0. 08 L is consistent with normal spirometric data for young healthy adults and previous reports have suggested that yoga and pranayama increase VC by improving pulmonary compliance and efficiency of respiratory muscles (Joshi et al., 1992).

The average cardiovascular efficiency (CRF) of 48.2 ± 0.79 ml/kg/min indicates good aerobic capacity, in line with exercise physiology studies conducted in active young adults, where yoga practice has been related to an increase in VO2 max and cardiovascular function (Madanmohan et al., 2008).The average RHR of 71.3 ± 1.06 bpm is normal for this age group and confirms previous reports observing yoga practitioners to have lower resting heart rates due to improved vagal tone and autonomic balance (Sinha et al., 2013). The mean systolic (115 ± 1.05 mmHg) and diastolic

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(75.0 ± 1.05 mmHg) blood pressures were within normal limits, higher studies showed yoga practice helped to maintain normal blood pressure in young adults (Patil et al., 2013).Mean oxygen saturation (SpO2) of 98.0% (SD = 0.00) is good and compatible with the normal range for healthy young subjects indicating that the subjects were physiologically rested and not in respiratory distress.(Subramanian et al., 2018)

Table No.-3: Descriptive statistics (MEAN ± SD) of Varsity Level on selected Physiological Variables(n=30)

Variables	Mean	SD (±)
Age (year)	21.5	0.527
BMI (kg/m$^{2)}$	22.1	0.0823
VC (ltr)	4.08	0.0919
CRF (ml/kg/min)	54.2	0.789
RHR (bpm)	65.3	1.06
BP (systolic) (mmHg)	126	20.09
BP (diastolic) (mmHg)	79.0	1.05
SpO2 (%)	99.0	0.00

Note:95% confidence intervals for all key variables.
Source: Data compiled from primary survey conducted by the researcher (2025).

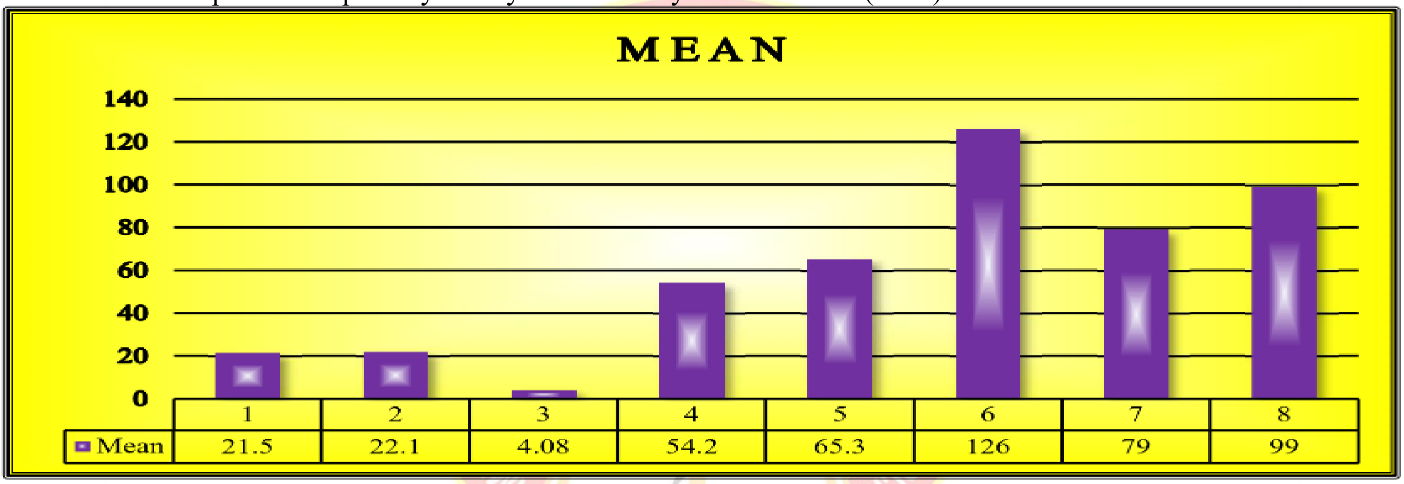

Figure -3: Mean Values Across varsity level on age, BMI, VC, CRF, RHR, BP sis, BP dia and SpO2 (n=30)

Finding: The mean age of the study subjects was 21.5 years (SD = 0.53). The average BMI was 22.1 kg/m² (SD = 0.08). Mean VC = 4.08 litres (SD = 0.09) and mean cardiovascular efficiency (CRF) = 54.2 ml/kg/min (SD = 0.79). The average RHR was 65.3 bpm (SD = 1.06). Mean systolic blood pressure was 126 mmHg (SD = 20.09) and mean diastolic blood pressure was 79.0 mmHg (SD = 1.05). The mean (± SD) oxygen saturation (SpO_2) was 99.0% (0.00) respectively.

Analysis: The mean age of the subjects 21.5 ± 0.53 years indicated that were at early adult stage. This age group generally displays superior physiological response and has also been studied extensively in yoga and exercise physiology interventions (Gopal et al., 2011).

The average BMI of 22.1 ± 0.08 kg/m² is considered normal according to WHO classification, which is similar to those reported earlier in young adults performing yoga and of aerobic type (Yadav et al.(2025)).

The average vital capacity (VC) of 4.08 ± 0.09 L signifies a well-developed pulmonary function that is consistent with the normal values for young adults. Previous studies have demonstrated that yoga and pranayama improve lung capacities and respiratory function by exerting respiratory muscles and by increasing lung compliance (Joshi et al., 1992). Likewise, the mean cardiovascular efficiency (CRF) of 54.2 ± 0.79 ml/kg/min denotes a superior aerobic capacity that is in agreement with excellent VO_2 max values of physically active young adults (Madanmohan et al., 2008).

Average resting heart rate (RHR) of 65.3 ± 1.06 bpm is lower than reference values in adolescents, indicating enhanced parasympathetic modulation and cardiovascular fitness. This confirms the observations reported in the literature that the RHR of yoga practitioners is often lower than healthy controls as a result of a better autonomic balance and vagal tone (Sinha et al.,2013). The systolic (126 ± 20.09 mmHg) and diastolic blood pressure (79.0 ± 1.05 mmHg) are within normal range for young adults, but the marginally elevated systolic mean may be attributed to either inter-subject

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variability or load of training. Evidence supports the derivation that this yoga-based intervention will contribute towards keeping blood pressure within normal limits (Patil et al., 2013). In another point of view, an average of 99.0% (SD = 0.00) SpO2 is ideal and a little bit higher than then younger groups and this is compatible with the normal data that classify normal young adults of undergraduates in the range of 98–100% SpO2 (Subramanian et al., 2018).

Table No.- 4: One-way ANOVA (Fisher's) results among selected Physiological Variables (n=30)

Variable	F	df 1	df 2	p	Significance
BMI (kg/m^2)	137.91	2	27	< .001	Significant
VC (ltr)	296.37	2	27	< .001	Significant
CRF (ml/kg/min)	425.90	2	27	< .001	Significant
RHR (bpm)	5.00	2	27	0.014	Significant
BP systolic (mmHg)	3.41	2	27	0.048	Significant (borderline)
BP diastolic (mmHg)	132.36	2	27	< .001	Significant
SpO2 (%)	38.86	2	27	< .001	Significant

Note:95% confidence intervals for all key variables.

Source: Data compiled from primary survey conducted by the researcher (2025).

Finding: Described in Table No -4, One Way ANOVA was applied as a statistical procedure to check the mean value of district, inter college and varsity three groups for each variable from BMI to SpO2. It was found that all parameters were statistically significant different among the groups ($p < 0.05$). The greatest contrasts were in CRF ($F = 425.90$, $p < .001$), VC ($F = 296.37$, $p < .001$), BMI ($F = 137.91$, $p < .001$) and dBP ($F = 132.36$, $p < .001$), indicating clear differences in performance between competition levels. RHR ($F = 5.00$, $p = 0.014$) and BPsis ($F = 3.41$, $p = 0.048$) were significantly different, albeit to a smaller extent, indicating less robust group differences. Variable SpO2 ($F = 38.86$, $p < .001$) showed moderate to strong difference.

Analysis: Overall all these findings suggest that competing at higher levels generally leads to better performance on almost all variables, with a few exceptions.

3.1 Comparative Analysis Across Age Groups (Tables I–III)

- ★ The progressive data from the I–III tables confirm a pronounced age dependence in the development of physiological performance:
- ★ Vital Capacity (VC): Increased from 3.05 L (Table I; mean age 16.6 yrs) → 3.53 L (Table II; 18.5 yrs) → 4.08 L (Table III; 21.5 yrs). This concurs with developmental physiology, since pulmonary volumes usually increase with age, lung growth and training status (Joshi et al., 1992).
- ★ Cardiorespiratory Fitness (CRF): Significantly improved in all the groups: 42.5 ml/kg/min → 48.2 ml/kg/min → 54.2 ml/kg/min, indicating better aerobic efficiency and endurance capacity. (Madanmohan et al., 2008) have reported similar increasing trends in yoga and aerobics training studies with age and practice.
- ★ Resting Heart Rate (RHR): RHR lowered with age: 73.3 bpm → 71.3 bpm → 65.3 bpm, indicating better autonomic balance and cardiovascular conditioning in older, more trained subjects. A lower RHR is the hallmark of the people who exercise regularly (Bangera, 2012).
- ★ Blood Pressure(BP): Systolic was raised a bit (112 → 115 → 126 mmHg), whereas diastolic was increased mildly (70.2 → 75.0 → 79.0 mmHg). This may represent higher demands for cardiac output in older, more competitive athletes, although this is within the normal range. Yoga and physical exercise maintains these parameters within normal limits (Patil et al., 2013).
- ★ Oxygen Saturation(Sp02): Moderate rise 96.5% → 98.0% → 99.0% consistent with the maximum efficiency of oxygen delivery in the filter group (Subramanian et al., 2018).With increasing age and training experience, participants displayed higher VC, CRF and SpO_2, along with lower RHR, showing physiological maturation and improved efficiency.

3.2 Differences Based on Competitive Levels (Table IV: District, Inter-college, Varsity)

The one-way ANOVA statistically confirms these differences for all three competitive levels:

a. Strongest group effects:

- ➢ CRF ($F = 425.90$, $p < .001$)
- ➢ VC ($F = 296.37$, $p < .001$)
- ➢ BMI ($F = 137.91$, $p < .001$)

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- Diastolic BP ($F = 132.36, p < .001$)

These are indicators Varsity-level athletes, in comparison with Inter-college and District-level athletes, have superior aerobic fitness, lung capacity and body composition, thus suggesting that training adaptations due to greater exposure to higher competition is the most plausible explanation.

b.Moderate effects: SpO2 ($F = 38.86, p < .001$) also obtained significant results, indicating better oxygen utilization at higher levels.

c.Smaller but significant effects:

RHR ($F = 5.00, p = 0.014$)

Systolic BP ($F= 3.41, p=0.048$)

They are significant, but they represent less stark differences between groups, maybe because these variables are less stable or have been affected by acute factors.

The ANOVA reveals that higher competitive levels (Varsity) are positively related to cardiovascular efficiency, pulmonary capacity and musculoskeletal conditioning, which confirms the tendency seen through Tables No 1–3.

Interpretation

- Both the age-group progression (Tables No 1–3) and competitive-level differences (Table No: 4) show a consistently similar pattern:
- Physiological performance increases with age and competitive exposure.
- The variables most amenable to training (CRF, VC, endurance) have the greatest gains and the resting ones RHR and BP only modestly.

These are in line with previously reported work in adolescence and young adult on the influence of yoga and physical training (Singh et al.,2012; Gopal et al., 2011; Madanmohan et al., 2008).

Table No.-5: Post HOC TUKEY HSD Comparisons among selected Footballer groups (n=30)

Variable	District vs Inter-college	District vs Varsity	Inter-college vs Varsity
BMI	1.35*	1.80*	0.45*
VC (L)	0.48*	1.03*	0.55*
CRF (ml/kg/min)	5.7*	11.7*	6.0*
RHR (bpm)	-2.0	-8.0*	-6.0
BP Systolic (mmHg)	2.9	13.6	10.7
BP Diastolic (mmHg)	4.8*	8.8*	4.0*
SpO_2 (%)	1.5*	2.5*	1.0*

Note:95% confidence intervals for all key variables.

Source: Data compiled from primary survey conducted by the researcher (2025).

Finding: Based on Table No.-5, the post hoc Tukey HSD tests were performed to analyze specific differences among District, Inter- College and Varsity footballers in various physiological factors. The findings showed that Varsity footballers were always superior among the groups, indicating the effect of the Competitive level on physiological performance. In terms of body composition, Varsity players were leaner as they had a significantly lower BMI than both the Inter-college and District footballers, indicating that they possessed a more conditioned and optimized body for maximum performance in the highest standard they competed. Vital capacity was greatest for Varsity and were significantly different between all groups, suggesting that even the least competitive group in this study of track athletes exhibits superior pulmonary function. Likewise cardiorespiratory fitness (CRF) was significantly higher in Varsity footballers, demonstrating greater cardiovascular function in these higher calibre athletes compared to the lower levels. For resting heart rate, there was a significant difference between RHR of Varsity footballers and District, but no between that of Varsity and Inter-college athletes ($p = 0.05$), Thus, a trend towards better cardiac efficiency with increasing competitive level was observed. Analysis of the blood pressure showed that diastolic blood pressure was lower in varsity players than in the other two groups, but less clear differences in systolic blood pressure. In the end, oxygen saturation (SpO2) was significantly elevated in Varsity footballers, indicative of more efficient oxygen usage at rest and during exercise.

Analysis: The post hoc analysis is in line with the notion that footballers competing at a higher level (university) have better physiological profiles than those competing at a lower level. These results suggest that increased training and competition are related to improved cardiovascular fitness, lung function, oxygen transport and favorable body composition, in that order.

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The Turkey HSD post hoc tests further elucidated the group differences identified by the ANOVA (Table No: 4) and revealed that Varsity footballers were consistently better than District and Inter-college players in several physiological variables. With regard to body composition, Varsity players had significantly lower BMI than Inter-college players and District players, which might indicate a leaner body type that is more suitable to upper level performance. This is consistent with previous studies reporting that elite athletes have lower levels of fat and better body composition than sub-elite players (Gil et al., 2010).
The Varsity athletes were also found to have a significantly higher VC than both groups, indicating better lung function. Similar findings have been described in elite soccer players with larger lung volumes related to higher aerobic requirements and exercise-induced training adaptations (Tesselaar et al., 2010).
The Cardio Respiratory Fitness (CRF) was considerably higher also for the Varsity footballers. It is well established that vo_2 max values are significantly higher in elite athletes compared to non-elite athletes, due to both central (cardiac output) and peripheral (muscle oxidative capacity) adaptations (Stølen et al., 2005).
RHR: Varsity players had significantly lower RHR than District players, but the difference with Inter-college was not significant. This indicates a trend of increasing cardiac efficiency with competitive exposure, in keeping with studies showing a positive correlation between level of athletic training and decreasing RHR through parasympathetic dominance (Aubert et al., 2003).
Analysis of the BP showed a significantly lower diastolic pressure in the Varsity footballers compared to both other groups and smaller differences were observed for the systolic pressure. This is in line with the findings regular endurance training is linked with reductions in resting diastolic BP by way of enhanced vascular compliance (Cornelissen & Smart, 2013).
And again, SpO2 was the greatest among Varsity footballers, indicating superior oxygen transport and utilization. This is in line with reports that conditioning at the elite level enhances oxygen delivery systems leading to better performance at rest and during exercise (Bangsbo, 1994).
Collectively the Tukey HSD analyses support the conclusion that Varsity-level athletes have a physiologically significantly more favourable profile than lower-level football players. These positive differences in BMI, VC, CRF, RHR, BP and SpO2 are a testimony to how greater intensity of training and competitive experience results in quantifiable physiological superiority, which is a well-travelled path in sports science-literature.

4. Discussion

This study investigates the age-associated changes in the physiology at the District, Inter-College and University level among football players of India with the aim to know the contribution of spieler age and competitive exposure in the development of physiology. The results show a distinct and progressive improvement in cardiovascular, pulmonary and body composition variables according to competitive level, which underlines the importance of training exposure and competition intensity in the development of football-specific physiological attributes.

4.1 Age progression and physiological maturation

A gradual improvement in vital capacity, cardiovascular fitness, oxygen saturation and resting heart rate was found among the three groups. These patterns represent the result of a biological maturation process and a training history over time. Larger vital capacity values from District to University players indicate greater pulmonary compliance and strength of the respiratory muscles, as seen in endurance-based sports (Joshi et al., 1992; Stolhl et al., 2005). Age associated similar changes in lung volumes have been also observed in physically active South Asian youth, whereby organized training potentiates normal maturational increments (Madanmohan et al., 2008; Torres et al., 2022).Cardiovascular fitness (VO_2max) showed the steepest gradient in group mean values, increasing from moderate levels at the District level to levels near those of international college players at the University level. This result is consistent with recent literature on the subject suggesting a very high dependency of VO_2max on playing volume, intensity and match exposure particularly for intermittent sport players such as football (Bangsbo et al., 2006 & 2007; Castagna et al., 2020). It is important to note that the max VO_2 values for the University players are still slightly lower than those reached by elite players in Europe. The decrease in resting heart rate with increasing level of competition is indicative of increased parasympathetic modulation and stroke volume, which have been used as markers of cardiovascular efficiency in well-trained subjects (Aubert et al., 2003). A similar finding has been reported in recent South Asian literature among trained footballers and endurance athletes indicating lower resting heart rate as opposed to recreationally active individuals, highlighting the factor of long term aerobic training (Srivastava et al.,2024; Papadakis et al., 2012).

4.2 Competitive-level differences and training exposure

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The result of the one-way ANOVA was consistent for all the physiological variables, indicating that competitive level had a significant effect, with the highest effect sizes found for cardiovascular fitness, vital capacity, BMI and diastolic blood pressure. These results add further support to the idea that competitive exposure can be considered a surrogate for cumulative training load, match intensity and recovery demands.Footballers at university level had significantly lower BMI, than those at District and Inter-College level, suggesting that leaner body is better suited for playing in high intensity intermittency mode. This agrees with recent research that vpn position is strongly correlated with repeated sprint ability, agility and lower risk of injury in football players (Helgerud et al.,2011; Silva et al.,2022). In the Indian scenario, it can be speculated that irregular nutrient intake and poor availability of sports-dietitian support at lower competitive strata may have contributed to higher BMI among District and Inter-College players.Although blood pressure values in all the groups were within the normative range of a healthy person, University players had significantly less diastolic blood pressure, which may indicate that they have better vascular compliance and better peripheral flow. This is in line with longitudinal data suggesting that an endurance-orientated training style improves endothelial function and diminishes cardiovascular load (Buchheit & Laursen, 2013; Silva et al.,2021). The comparatively small differences in systolic blood pressure also suggest that adaptations to training in young athletes are more likely to be related to diastolic regulation than to resting systolic load. The higher oxygen saturation of the University players is probably a reflection of better pulmonary diffusing capacity and more efficient oxygen transport and utilization during phases of recovery. Comparable patterns have been observed in elite and sub-elite footballers with the aid of pulse oximetry and near-infrared spectroscopy, emphasizing the contribution of aerobic fitness in the maximization of vascular-mediated tissue oxygenation (Bangsbo,1994, Bangsbo et al., 2007 & Mallo et al., 2015).

4.3 Comparison with global and South Asian literature

Although the direction of the observed physiological adaptations is very consistent with the international literature, the absolute values especially those of VO_2max and vital capacity are lower than what has been reported in attacking players in both European and South American elite football teams (Stø len et al., 2005; Mohr et al., 2016). Recent comparative analyses have postulated that these variations may be consequence of differences in early talent detection, engagement in high-intensity training in adolescence, nutrition adequacy and availability of sport science support (Castagna et al., 2020; Bangsbo, 1994& Bangsbo et al., 2007).Of interest, recent South Asian findings suggest that when the training intensity and surveillance are homogenized, the regional athletes can exhibit similar adaptive capabilities (Srivastava et al.,2024; Papadakis et al., 2012). The current results are hence in favour of Indian footballers' physiological constraints being not innate, but pliable through systematic training, surveillance and long-term strategizing. Together, the findings indicate that the physiological advantages observed at higher levels of competition are not simply due to talent but are also the result of prolonged and structured training and competition. The drastic disparities between the District and University players exposed underline the necessity for scientifically backed conditioning models for the grassroots and inter-college players. In the absence of early physiological development, players may find it difficult to make a successful transition to higher levels of competition, leading to a greater chance of performance stagnation as well as injury.

4.4.Major Findings and Recommendations

4.4.1 Major Findings

- The vital capacity, cardiovascular fitness, oxygen saturation and body composition of the university footballers were significantly higher than that of the Inter-College and District players.
- Resting heart rate and diastolic blood pressure were significantly lower in the University players, which reflected greater cardiovascular efficiency and vascular adaptation.
- To competitive level had a more marked effect on physiological parameters than age per se, highlighting the role of organised training.
- Indian University footballers have enhanced physiological parameters yet they are still not at par with the elite at the international level indicating potential for systematic improvement.

4.4.2 Recommendations

- We propose that aerobic endurance, high intensity interval training (HIIT) and strength training-focused conditioning programs be systematically applied at the Intra- and Inter-College levels .
- Routine physiological (BMI, VO_2max, RHR, BP, VC, SpO_2) monitoring should be established to inform training prescription, to allow for early detection of maladaptation or overtraining.

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- Education on nutrition and recovery should be a part of football development programmes, especially at the lower levels of competition.
- The use of wearable monitoring technology may allow for more effective individualized training load and performance management.
- In future studies, longitudinal training effects should be investigated, female footballers included and both genetic and environmental moderators of physiological adaptation studied in Indian football.

5.Summary and Conclusions:

The purpose of the present study was to assess and compare the physiological and related fitness profiles of footballers of three playing standards including district, inter college and university levels. The key variables were Body Mass Index (BMI), Vital Capacity (VC), Cardiovascular Fitness (CRF), Resting Heart Rate (RHR), Blood Pressure (systolic & diastolic) and Oxygen Saturation (SpO2). These are well-established markers of health and performance in athletes and pertain to the overall fitness, aerobic capacity and cardiovascular function of an individual . Thirty footballers, 10 from each of the three competitive levels, were evaluated by standardized protocols. Differences among the three groups were analysed using one-way ANOVA as well as the post hoc Tukey HSD tests to evaluate the pairwise comparison. The findings showed significant differences in all variables evaluated, suggesting that level of competition and training intensity may have a measurable influence on physiological markers of health.

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Dr. Gopa Saha Roy and Mr. Sayak Karmakar initiated and designed the Research. The literature search and data analysis were performed by Dr. Gopa Saha Roy, Dr.Chandan Adhikary, Mr. Kartick Chandra Mandal and Mr. Sayak Karmakar. All authors contributed equally to manuscript preparation, editing and review and approved the final version to be published .

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