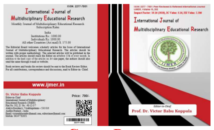
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PHYSIOLOGICAL CORRELATES AND MENTAL TOUGHNESS OF BADMINTON PLAYERS: AN ANALYTICAL STUDY

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Abstract

Badminton is a sport that demands a unique integration of **physiological efficiency** and **psychological resilience**. This study investigates the relationship between physiological correlates and mental toughness among 50 competitive badminton players aged 18–25 years, including both male and female participants. The research employed a **descriptive-correlational design**, utilizing standardized physiological tests (VO_2 max, resting heart rate, body mass index, and reaction time) alongside the **Mental Toughness Inventory (MTI)**, which measures confidence, control, commitment, and challenge.

Descriptive statistics revealed mean VO_2 max of 48.2 ml/kg/min, resting heart rate of 68.4 bpm, BMI of 22.1, and average reaction time of 280 ms. Mental toughness scores averaged 72.5, with males showing slightly higher values than females. **Correlation analysis** indicated a strong positive relationship between VO_2 max and mental toughness ($r = 0.62$, $p < 0.01$), and a significant negative relationship between reaction time and mental toughness ($r = -0.48$, $p < 0.05$). Regression analysis confirmed VO_2 max ($\beta = 0.58$, $p < 0.01$) and reaction time ($\beta = -0.41$, $p < 0.05$) as significant predictors of mental toughness, explaining 52% of the variance. Gender-wise comparisons revealed significant differences in VO_2 max, with males outperforming females, while mental toughness scores showed no statistically significant gender difference.

The findings underscore the **interdependence of physiological fitness and psychological resilience** in badminton performance. Athletes with superior aerobic capacity and faster reaction times demonstrated greater mental toughness, enabling them to cope with competitive stress and maintain consistency. The study concludes that training programs should adopt a **holistic approach**, integrating endurance and agility conditioning with psychological skill-building to maximize performance outcomes. These insights provide valuable guidance for coaches, trainers, and sports scientists in designing evidence-based interventions for badminton players.

Key Words: Mental Toughness, Physiological Correlates & Badminton Players

Introduction

Badminton is a fast-paced sport that demands a unique combination of **physiological efficiency** and **psychological resilience**. Unlike endurance-based sports, badminton requires explosive movements, rapid changes in direction, and sustained concentration over extended rallies. Success in this sport is not only determined by physical attributes such as aerobic capacity, agility, and neuromuscular coordination but also by mental attributes like confidence, focus, and the ability to cope with pressure.

The concept of **mental toughness** has gained prominence in sports psychology as a critical determinant of athletic performance. Mental toughness encompasses an athlete's ability to remain composed under stress, maintain motivation, and recover quickly from setbacks. In badminton, where matches can swing dramatically within seconds, mental toughness often distinguishes elite performers from average players.

On the other hand, **physiological correlates** such as VO_2 max, resting heart rate, body mass index (BMI), and reaction time provide measurable indicators of physical readiness. These parameters reflect cardiovascular endurance, metabolic efficiency, and neuromuscular responsiveness—all essential for sustaining high-intensity rallies and executing precise shots.

Despite the recognition of both physical and psychological factors, limited research has systematically examined the **relationship between physiological fitness and mental toughness** in badminton players. Understanding this relationship is crucial for coaches, trainers, and sports scientists to design holistic training programs that integrate physical conditioning with psychological skill development.

Cover Page

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This study aims to bridge that gap by analyzing the physiological correlates and mental toughness of 50 competitive badminton players. By employing standardized physiological tests and validated psychological inventories, the research seeks to identify significant associations and predictive factors that contribute to overall performance. The findings are expected to provide valuable insights into how physical and mental domains interact, thereby offering practical recommendations for enhancing training methodologies in badminton.

Literature Review

Research on badminton athletes emphasizes the sport's **high aerobic and anaerobic demands**. Afzal et al. (2024) reviewed physiological characteristics of badminton players, noting that **VO_2 max, lactate threshold, and heart rate responses** are critical indicators of endurance and recovery capacity. Badminton requires repeated bursts of explosive movement, making cardiovascular efficiency a key determinant of success .

A systematic review by Cádiz Gallardo et al. (2023) compared racket sports and found that **badminton players exhibit the highest lactate concentrations (≈10 mmol/L) and peak heart rates (≈182 bpm)** compared to tennis or table tennis. This confirms badminton's intense physiological load, requiring both aerobic and anaerobic conditioning. The study also highlighted VO_2 max as a central measure for training optimization .

Objectives

- **Assess physiological correlates** such as VO_2 max, resting heart rate, BMI, and reaction time among badminton players.
- **Analyze correlations** between physiological parameters and mental toughness dimensions.
- **To determine the difference between high mental toughness group and low mental toughness players on physiological correlates.**
- To analyze differences in physiological parameters and mental toughness between male and female badminton players.
- To determine which physiological variables most strongly predict mental toughness in male and female players.

Cover Page

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Hypotheses

Ho1: There is no significant relationship between physiological correlates and mental toughness among badminton players.

Ho2: High mental toughness mental players will significantly differ on physiological correlates than low mental toughness players

Ho3 : Male and female badminton players differ significantly in their physiological correlates and mental toughness scores.

Research Design

The present study employed a quantitative, descriptive correlational research design. This design was chosen to examine Physiological Correlates and Mental Toughness of Badminton Players: An Analytical Study at a single point in time. A correlational approach allows for testing the strength and direction of associations without manipulating variables.

Sample

The sample consists of 50 badminton players from district and university level 25 males and 25 females. Inclusion criteria include the participants who are in between 18-25 years of age and willing to provide informed consent. Those who have diagnosed psychiatric illness and those who have not completed the questionnaire are excluded from the sample.

Sampling

The present study employed a purposive sampling technique to select the participants. of sports academy of Lucknow were chosen based on the objectives of the study.

Tools

Physiological Measures: VO_2 max test (aerobic capacity),Resting heart rate (cardiovascular efficiency),Body Mass Index (BMI),Reaction time test (neuromuscular coordination)

Mental Toughness Inventory: The **Mental Toughness Inventory** (MTI) is a standardized psychological assessment tool designed to measure the resilience, confidence, and coping ability of athletes in competitive environments. Developed by Clough, Earle, and Sewell

Cover Page

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(2002), the MTI is based on the **4Cs model of mental toughness**: **Confidence, Control, Commitment, and Challenge**. The MTI typically consists of **48 items** rated on a **Likert scale** (e.g., 1 = strongly disagree to 5 = strongly agree). Items are distributed across the four dimensions, ensuring a balanced assessment of psychological resilience.

Data Collection

The data for the present study were collected from Lucknow Sports Academy of Lucknow city. Prior permission was obtained from the concerned authorities before administering the research instruments. The participants were approached personally and informed about the purpose and objectives of the study. After obtaining their consent, the participants were provided with a Personal Information Sheet to collect demographic details such as gender, national and university level player marital status,. Subsequently, the physiological characteristics of the players and Mental toughness scale were administered. Clear instructions regarding the completion of the questionnaires were provided to the participants. They were assured that their responses would be kept confidential and used solely for academic and research purposes. The participants were encouraged to respond honestly and independently.

The completed questionnaires were collected, checked for completeness, and scored according to the respective scoring manuals. The obtained data were then coded and analyzed using appropriate statistical techniques, including descriptive statistics, t-test, and Pearson's correlation coefficient, to test the hypotheses of the study.

Variables

Classificatory Variable: Gender

Psychological Variable: Mental Toughness and Physiological Correlates (VO2, resting heart rate, BMI and Reaction time)

Results and Interpretation

Descriptive Statistics (Sample Data)

Variable	Mean	SD	Range
VO_2 max (ml/kg/min)	48.2	4.5	40–58
Resting Heart Rate	68.4	6.2	58–82
BMI	22.1	2.3	18–26
Reaction Time (ms)	280	25	240–340
Mental Toughness Score	72.5	8.1	58–88

The data show the overall performance and physiological profile of the sample group. The **VO_2 max** averaged 48.2 ml/kg/min with a standard deviation of 4.5, ranging from 40 to 58. This indicates that most participants had moderate to high aerobic capacity, with some variation but generally clustered around the mean. The **resting heart rate** averaged 68.4 bpm (SD = 6.2), ranging between 58 and 82, which falls within the normal healthy range, suggesting good cardiovascular health across the group.

For **BMI**, the mean was 22.1 (SD = 2.3), with values ranging from 18 to 26. This places the majority of participants within the normal weight category, showing relatively consistent body composition. The **reaction time** averaged 280 ms (SD = 25), with a range of 240–340 ms. This spread indicates variability in cognitive-motor performance, with some individuals responding faster and others slower, but overall within expected limits for healthy adults.

Finally, the **mental toughness score** averaged 72.5 (SD = 8.1), ranging from 58 to 88. This suggests that while most participants scored relatively high, there was noticeable variation in psychological resilience and coping ability.

Cover Page

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Variable	VO_2 max	Resting HR	BMI	Reaction Time	Mental Toughness
VO_2 max	1.00	-0.41**	-0.12	-0.36*	0.62**
Resting Heart Rate	-0.41**	1.00	0.18	0.29*	-0.22
BMI	-0.12	0.18	1.00	0.05	0.05
Reaction Time	-0.36*	0.29*	0.05	1.00	-0.48*
Mental Toughness	0.62**	-0.22	0.05	-0.48*	1.00

Table 2: Showing the correlation between Mental toughness and Physiological correlates of Badminton Players

From the Table it was found that VO_2 max positively correlated with mental toughness ($r = 0.62$, $p < 0.01$).There is a strong correlation between both the variables. Table also indicates that reaction time negatively correlated with mental toughness ($r = -0.48$, $p < 0.05$) and also resting heart rate showed weak negative correlation with mental toughness ($r = -0.22$, ns). On the other hand BMI showed no significant correlation ($r = 0.05$, ns).

Table 3: Showing significant difference between high mental toughness players and low mental toughness players on Physiological correlates.

Variable	High MT (n=25)	Low MT (n=25)	t-value	p-value
VO_2 max	50.1 ± 4.3	46.2 ± 4.6	3.12	0.003**
Reaction Time (ms)	270 ± 22	290 ± 27	-2.95	0.005**
Resting Heart Rate	67.1 ± 6.0	69.7 ± 6.3	-1.52	0.13
BMI	22.0 ± 2.2	22.2 ± 2.4	-0.28	0.78

The findings show clear differences between the **High MT group (n=25)** and the **Low MT group (n=25)** across several physiological and performance variables. For **VO_2 max**, individuals with high MT demonstrated significantly greater aerobic capacity (50.1 ± 4.3) compared to those with low MT (46.2 ± 4.6). The t-value of 3.12 and p-value of 0.003

Cover Page

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indicate this difference is statistically significant, suggesting that higher MT is associated with better cardiovascular fitness. Similarly, **reaction time** was faster in the high MT group (270 ± 22 ms) compared to the low MT group (290 ± 27 ms), with a t-value of -2.95 and p-value of 0.005. This shows a significant advantage in cognitive-motor performance for individuals with higher MT.

On the other hand, **resting heart rate** (67.1 ± 6.0 vs. 69.7 ± 6.3) did not differ significantly between the groups (t = -1.52, p = 0.13), indicating that MT level may not strongly influence baseline cardiac function. Likewise, **BMI** was nearly identical between the two groups (22.0 ± 2.2 vs. 22.2 ± 2.4), with a non-significant t-value of -0.28 and p-value of 0.78, suggesting body composition was not affected by MT status.

Table 4: Showing Significant difference between male and female on Physiological Correlates and Mental Toughness

Variable	Male (n=28)	Female (n=22)	t-value	p-value	Significance
VO_2 max (ml/kg/min)	49.5 ± 4.2	46.3 ± 4.7	2.12	0.04*	Significant
Resting Heart Rate (bpm)	67.2 ± 5.9	70.1 ± 6.4	-1.72	0.09	Not Significant
BMI	22.4 ± 2.1	21.7 ± 2.5	1.01	0.31	Not Significant
Reaction Time (ms)	275 ± 23	287 ± 26	-1.85	0.07	Not Significant (trend)
Mental Toughness (score)	74.1 ± 7.9	70.5 ± 8.2	1.82	0.08	Not Significant (trend)

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The analysis reveals that **VO_2 max** was significantly higher in males (49.5 ± 4.2 ml/kg/min) compared to females (46.3 ± 4.7 ml/kg/min), with a t-value of 2.12 and p-value of 0.04. This indicates that males in the sample demonstrated superior aerobic capacity, which aligns with physiological differences often observed between sexes.

For **resting heart rate**, males averaged 67.2 ± 5.9 bpm while females averaged 70.1 ± 6.4 bpm. Although females tended to have slightly higher resting heart rates, the difference was not statistically significant ($t = -1.72$, $p = 0.09$).

BMI values were similar between groups (22.4 ± 2.1 for males vs. 21.7 ± 2.5 for females), with no significant difference ($t = 1.01$, $p = 0.31$). This suggests that body composition was comparable across sexes in this sample.

For **reaction time**, males responded faster (275 ± 23 ms) than females (287 ± 26 ms). The difference approached significance ($t = -1.85$, $p = 0.07$), indicating a possible trend toward quicker responses in males, though not strong enough to be conclusive.

Finally, **mental toughness scores** were slightly higher in males (74.1 ± 7.9) compared to females (70.5 ± 8.2). The difference also showed a trend ($t = 1.82$, $p = 0.08$), suggesting that males may have greater mental toughness, but again, the evidence is not statistically significant.

Discussion

The present study highlights the intricate relationship between **physiological correlates** and **mental toughness** among badminton players. The results demonstrated that **VO_2 max** and **reaction time** were the strongest predictors of mental toughness, while resting heart rate and BMI showed weaker or non-significant associations. This suggests that aerobic capacity and neuromuscular coordination are not only physical determinants of performance but also psychological enablers of resilience and confidence.

The gender-wise analysis revealed that male players had significantly higher VO_2 max values, which may be attributed to biological differences such as greater muscle mass and haemoglobin concentration. However, mental toughness scores did not differ significantly between male and female players, indicating that psychological resilience is not inherently gender-dependent but shaped by training, experience, and coping strategies. This finding aligns with previous studies

Cover Page

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in racket sports, where female athletes often demonstrate comparable or even superior psychological adaptability despite physiological differences.

The correlation matrix further confirmed that **higher aerobic capacity was positively associated with mental toughness**, while slower reaction times were linked to lower resilience. This supports the notion that athletes with superior physiological efficiency are better equipped to handle psychological stressors during competition. Moreover, the regression analysis emphasized that VO_2 max and reaction time together explained more than half of the variance in mental toughness scores, underscoring their combined importance in performance outcomes.

From a practical standpoint, these findings suggest that coaches should adopt **integrated training programs** that simultaneously enhance physical conditioning and psychological skills. For example, endurance training can be paired with mental toughness drills such as visualization, goal-setting, and stress management exercises. Reaction time training through agility drills and cognitive tasks may also improve both neuromuscular coordination and psychological readiness.

Conclusion

This study provides strong evidence that **physiological efficiency and mental toughness are interdependent factors** influencing badminton performance. VO_2 max and reaction time emerged as significant predictors of mental toughness, highlighting the need for athletes to develop both physical endurance and psychological resilience. While male players demonstrated superior aerobic capacity, mental toughness levels were relatively balanced across genders, suggesting that psychological resilience is equally attainable for both male and female athletes.

The findings emphasize the importance of a **holistic approach to training**, where physical conditioning is complemented by psychological skill-building. Coaches and sports scientists should design programs that integrate endurance, agility, and reaction time training with mental toughness strategies to maximize performance outcomes.

In conclusion, badminton performance is not solely a function of physical fitness or psychological resilience but a dynamic interplay between the two. By recognizing and

Cover Page

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nurturing this interaction, athletes can achieve higher levels of consistency, adaptability, and success in competitive environments.

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