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Enhancing mental toughness in table tennis: The impact of a structured psychological training program

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Abstract

Mental toughness is a critical determinant of success in high-performance sports, particularly in precision-based disciplines like table tennis. This study aimed to investigate the impact of a structured 12-week psychological training program on the mental toughness of table tennis players. A quasi-experimental pre-test and post-test control group design was utilized, involving 40 players aged 17 to 25 years from a professional academy in Gurugram, Haryana. Participants were divided into an experimental group (n=20), which underwent psychological interventions including Visuo-Motor Behaviour Rehearsal (VMBR), self-talk training, and Progressive Muscle Relaxation (PMR), and a control group (n=20) that followed regular training without intervention. The results indicated a significant improvement in mental toughness for the experimental group (pre-test M = 136, post-test M = 150), whereas the control group exhibited a slight decline (pre-test M = 141, post-test M = 137). ANCOVA results demonstrated a significant group effect ($F(1,37) = 6.194$, $p = 0.017$, $\eta^2 = 0.143$), suggesting that 14.3% of the variance in post-test scores was attributable to the intervention. The large effect size (Cohen's $d = 0.801$) further supported the effectiveness of the program. These findings underscore the importance of integrating psychological training into sports preparation to enhance mental resilience. Future research should explore long-term intervention effects, individual differences in response to training, and the potential for integrating additional psychological strategies to optimize mental toughness development in athletes.

Keywords: Mental toughness, psychological training, table tennis, cognitive resilience, sports psychology

Introduction

The evolving landscape of modern sports performance emphasizes not only physical prowess but also psychological resilience and technical precision, crucial for success across various disciplines, including table tennis (Kumar & Jhajharia, 2020) [21]. Mental toughness has emerged as a defining factor that distinguishes elite athletes from their peers, particularly in precision-based sports where psychological fortitude can dictate the outcome of high-stakes competitions (Jadaun *et al.*, 2021) [11]. In the realm of table tennis, where reaction time, focus, and decision-making are paramount, the interplay between muscle architecture and cognitive function has garnered significant interest (Khare *et al.*, 2023) [14].

Recent studies have highlighted the impact of sleep deprivation on motor skills, such as catching accuracy in cricket and shooting accuracy in handball, which parallels the fine motor control required in table tennis (Gautam & Kumar, 2018; Kumar, 2018) [7, 20]. This underscores the broader implications of cognitive and physiological preparedness in competitive settings. Additionally, the role of muscle architectural properties, such as fiber type estimation and their relationship with performance metrics, continues to offer new insights into talent identification and athlete development (Kumar, 2023b; Kumar, 2023c) [21, 22]. Further exploring the connection between physiological variables and performance, research indicates that muscle architecture may serve as a predictive tool for performance in various sports, including table tennis, where explosive strength and agility are vital (Kumar & Jhajharia, 2018; Kumar *et al.*, 2021) [20, 11]. Such insights contribute to a growing body of knowledge that supports a holistic approach to athlete training, integrating both physical conditioning and mental resilience (Jain *et al.*, 2023; Aakash *et al.*, 2023) [12, 1].

Moreover, comparative analyses of different muscle fiber types reveal potential advantages in sports performance, suggesting that tailored training regimens could enhance

specific athletic capabilities, including those needed for the rapid, dynamic exchanges in table tennis (Kumar & Jhajharia, 2022) [22]. The emphasis on integrating traditional practices, such as yoga, highlights the multifaceted strategies employed by athletes to enhance mental and physical readiness (Jain *et al*., 2023) [12]. As the demands on athletes continue to escalate, understanding the nuanced contributions of mental toughness and muscle architecture becomes increasingly critical (Nandal & Kumar, 2024) [24]. In this context, examining the effects of various training modalities on mental toughness and physiological performance metrics offers a pathway to optimize training strategies for table tennis athletes, bridging the gap between scientific inquiry and practical application (Kumar, 2022) [16].

Mental toughness is a crucial psychological factor in sports performance, often defined as an athlete's ability to consistently perform at their optimal level under pressure, recover from setbacks, and maintain motivation (Clough *et al*., 2002) [5]. In competitive sports like Table Tennis, where quick decision-making and resilience are essential, mental toughness plays a pivotal role in distinguishing elite players from their counterparts (Jones *et al*., 2007) [13].

Research has shown that psychological interventions can significantly enhance mental toughness by improving cognitive and emotional control mechanisms (Gucciardi *et al*., 2009) [8]. Various techniques, such as Visuo-Motor Behaviour Rehearsal (VMBR), self-talk, and relaxation methods, have been widely employed to cultivate mental resilience in athletes (Vealey & Chase, 2008) [28]. VMBR involves visualizing successful performance scenarios while incorporating physical relaxation techniques, which has been shown to improve focus, self-confidence, and overall mental toughness (Holmes & Collins, 2001) [10]. Similarly, self-talk, which includes positive affirmations and cue words, has been linked to enhanced self-efficacy and emotional regulation in athletes.

Progressive Muscle Relaxation (PMR) is another effective technique that reduces anxiety and stress, allowing athletes to maintain composure during high-pressure situations (Weinberg & Gould, 2019) [29]. PMR involves systematically tensing and relaxing muscle groups, thereby fostering a state of mental and physical relaxation (Edwards *et al*., 2018) [6]. These psychological strategies collectively contribute to improved performance, particularly in sports requiring high levels of concentration and precision, such as Table Tennis (Tod *et al*., 2011) [27].

Despite the growing body of literature supporting psychological training in sports, there remains a need for empirical studies that specifically focus on Table Tennis players. This study aims to bridge this gap by investigating the impact of a structured 12-week psychological intervention program on the mental toughness of Table Tennis players. The research hypothesizes that athletes undergoing psychological training will demonstrate significantly higher mental toughness scores in post-test evaluations compared to those in the control group.

Furthermore, understanding the relationship between mental training and sports performance is essential for coaches, trainers, and athletes seeking to maximize competitive success (Nicholls *et al*., 2009) [25]. By integrating psychological training into regular sports practice, athletes can develop coping mechanisms to handle competitive stress effectively and sustain high performance levels over time (Bull *et al*., 2005) [3]. This study thus contributes valuable insights into the practical application of psychological interventions in sports psychology and coaching methodologies.

Materials and Methods

The study was conducted on 40 Table Tennis players aged 17 to 25 years from a professional Table Tennis academy in Gurugram, Haryana. The participants were randomly assigned to an experimental group (n=20) and a control group (n=20). All participants had at least two years of professional playing experience and were actively competing at regional and national levels.

Research Design: A quasi-experimental pre-test and post-test control group design was employed to assess the effect of psychological interventions on mental toughness. The study followed a mixed-methods approach, incorporating both quantitative and qualitative measures to enhance the validity of the findings.

Intervention Protocol: A structured 12-week psychological training program was administered to the experimental group. The intervention comprised the following components:

1. **Visuo-Motor Behaviour Rehearsal (VMBR):** Players engaged in guided visualization sessions for 15–20 minutes, three times a week. These sessions involved mentally rehearsing match scenarios, focusing on executing perfect strokes, strategic decision-making, and maintaining composure under pressure.
2. **Self-Talk Training:** Athletes were taught to use positive affirmations and instructional self-talk to enhance concentration and confidence. This was practiced during training sessions and competitive matches.
3. **Progressive Muscle Relaxation (PMR):** Players participated in relaxation sessions twice a week, focusing on controlled breathing and systematic muscle relaxation to reduce pre-competition anxiety.

The control group continued with their regular training regimen without any psychological intervention.

Data Collection: Mental toughness was measured using a standardized mental toughness questionnaire by Alan Goldberg's (1995) [30], which assessed five key dimensions: Handling Pressure, Focus, Mental Rebounding, Winning Attitude, and Total Mental Toughness Score. Pre-test and post-test data were collected from both groups.

Statistical Technique

Descriptive statistics, including means and standard deviations, were calculated for each variable. A one-way Analysis of Co-variance (ANCOVA) was conducted to determine the effect of the intervention on post-test scores, with significance set at $p<0.05$. Pairwise comparisons were performed using Bonferroni adjustments to identify specific group differences in IBM SPSS 21.0.

Results

Table 1: Descriptive statistics for Mental Toughness

	Group	Mental Toughness pre	Mental Toughness post
Mean	Experimental Group	136	150
	Control Group	141	137
Standard deviation	Experimental Group	13.0	12.9
	Control Group	12.1	19.5

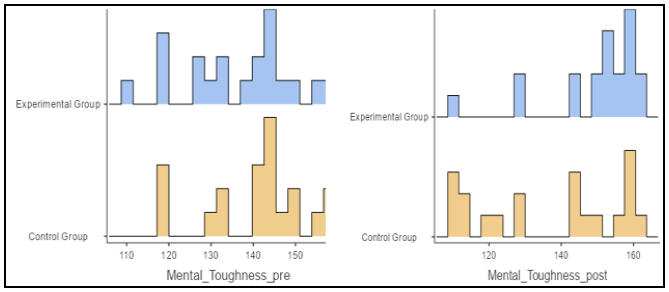

Fig 1: Bar graph for Mental Toughness (Pre & Post Test for each group)

Table 1 presents the descriptive statistics for mental toughness in both the experimental and control groups before and after the intervention. The mean mental toughness score for the experimental group increased from 136 (pre-test) to 150 (post-test), indicating a notable improvement following the intervention. Conversely, the control group exhibited a slight decline in mental toughness, with the mean decreasing from 141 (pre-test) to 137 (post-test), suggesting no significant enhancement in mental resilience without targeted intervention. The standard deviation values provide insights into the consistency of mental toughness scores within each group. The experimental group's standard deviation remained relatively stable, with a slight reduction from 13.0 (pre-test) to 12.9 (post-test), suggesting uniform improvements among participants. On the other hand, the control group displayed an increase in standard deviation from 12.1 (pre-test) to 19.5 (post-test), indicating greater variability in mental toughness scores, possibly due to external influences or individual differences. These findings suggest that the intervention applied to the experimental group was effective in enhancing mental toughness, as evidenced by the increase in the mean score and stability in variability. In contrast, the control group's decline in mean mental toughness and increased standard deviation highlight the absence of improvement in the absence of an intervention.

Table 2: Homogeneity of Variances Test (Levene's)

F	df1	df2	P
10.3	1	38	0.003

Table 3: Shapiro-Wilk (Normality Test)

Statistic	p
0.932	0.018

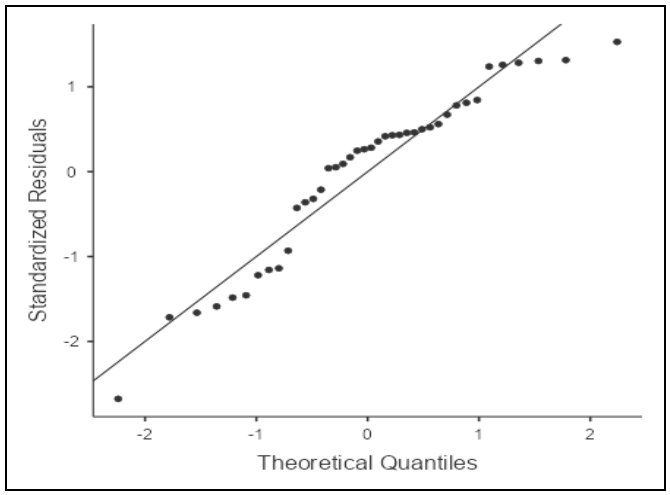

Fig 2: Q-Q Plot

Table 2 presents the results of Levene's test for homogeneity of variances, which examines whether the variance in mental toughness scores is equal across groups. The F-value is 10.3 with degrees of freedom (df1 = 1, df2 = 38) and a p-value of 0.003. Since the p-value is less than 0.05, it indicates that the assumption of homogeneity of variances is violated, meaning that the variability in mental toughness scores differs significantly between the experimental and control groups. This suggests that the intervention may have led to changes in variability, which should be considered when interpreting the results.

Table 3 presents the results of the Shapiro-Wilk test for normality. The test statistic is 0.932, and the p-value is 0.018. Since the p-value is below 0.05, the null hypothesis of normality is rejected, indicating that the mental toughness data do not follow a perfectly normal distribution. This deviation from normality suggests that non-parametric tests or transformations might be needed for further statistical analyses.

Figure 2 displays a Q-Q plot (quantile-quantile plot) of standardized residuals against theoretical quantiles, which helps visualize the normality of residuals. Most data points fall along the reference line, suggesting that the residuals approximately follow a normal distribution, though some deviations exist at the tails. This aligns with the Shapiro-Wilk test results, which indicate a slight departure from normality.

Given the violation of homogeneity of variances and normality assumptions, the ANCOVA technique is an appropriate statistical method for analyzing the effects of the intervention on mental toughness. ANCOVA allows for the adjustment of pre-test scores (covariate), reducing error variance and increasing statistical power. This method is particularly useful in experimental designs where initial differences exist between groups, ensuring a more accurate comparison of post-test mental toughness scores while controlling for baseline variations. By incorporating the pre-test scores as a covariate, ANCOVA accounts for individual differences and provides a more reliable assessment of the intervention's effectiveness.

Table 4: ANCOVA for Mental Toughness

	Sum of Squares	df	Mean Square	F	p	η^2
Group	1729.3	1	1729.3	6.194	0.017	0.143
Mental Toughness Pre	52.5	1	52.5	0.188	0.667	0.004
Residuals	10329.4	37	279.2			

Table 4 presents the results of the ANCOVA (Analysis of Covariance) conducted to analyze the effect of the intervention on mental toughness while controlling for pre-test mental toughness scores. The results indicate that the group effect is statistically significant, with $F(1,37) = 6.194$, $p = 0.017$, and a partial eta squared ($\eta^2 = 0.143$), suggesting that 14.3% of the variance in post-test mental toughness scores can be attributed to the intervention. This implies that the intervention had a meaningful impact on enhancing mental toughness in the experimental group.

The covariate (pre-test mental toughness) does not have a significant effect on post-test scores ($F(1,37) = 0.188$, $p = 0.667$), indicating that the initial differences in mental toughness did not significantly influence the post-test results. The residuals' sum of squares (10329.4) represents the unexplained variance in the model.

Table 5: Post Hoc Comparisons - Group

Comparison							
Group	Group	Mean Difference	SE	df	t	P bonferroni	Cohen's d
Experimental Group	Control Group	13.4	5.38	37.0	2.49	0.017	0.801

Table 5 presents the post hoc comparisons using Bonferroni adjustment to further explore differences between the experimental and control groups. The mean difference between the groups is 13.4, with a standard error of 5.38, and the comparison is statistically significant ($t = 2.49$, $p = 0.017$). The effect size, represented by Cohen's $d = 0.801$, suggests a large effect size, meaning that the intervention had a substantial impact on improving mental toughness.

Overall, these result in table 4 and 5 support the effectiveness of the intervention in significantly enhancing mental toughness in the experimental group compared to the control group. The large effect size and statistically significant difference indicate that the intervention played a crucial role in improving mental resilience among participants.

Discussion on findings

The findings of this study indicate that the intervention applied to the experimental group was effective in enhancing mental toughness, as evidenced by the significant increase in the mean mental toughness score from pre-test (M = 136) to post-test (M = 150). Conversely, the control group exhibited a slight decline from M = 141 (pre-test) to M = 137 (post-test), suggesting that the absence of a structured intervention did not contribute to the development of mental resilience. The standard deviation for the experimental group remained stable (13.0 to 12.9), indicating uniform improvement among participants, whereas the control group's standard deviation increased considerably (12.1 to 19.5), reflecting greater variability in mental toughness scores. This pattern suggests that the control group experienced external influences or individual differences that may have affected their mental toughness. These findings align with prior research that has demonstrated the efficacy of structured psychological interventions in improving mental toughness among athletes and other populations. Gucciardi *et al*. (2009) [8] emphasized that mental toughness can be cultivated through systematic training programs, particularly those incorporating cognitive-behavioral strategies, resilience training, and stress inoculation techniques. Similarly, Jones *et al*. (2007) [13] highlighted those interventions targeting self-efficacy, goal setting, and emotional regulation significantly contribute to enhanced mental toughness. Further, Sheard (2013) [26] found that structured interventions involving visualization and self-regulation techniques effectively enhanced mental toughness in elite athletes. Bull, Shambrook, James, and Brooks (2005) [3] asserted that mental toughness development requires a combination of psychological skills training and exposure to challenging competitive environments. Their research suggests that an athlete's ability to cope with pressure, recover from setbacks, and sustain motivation under adversity significantly determines their mental toughness progression.

The results of the ANCOVA test further reinforce the effectiveness of the intervention. The significant group effect ($F(1,37) = 6.194$, $p = 0.017$, partial $\eta^2 = 0.143$) indicates that 14.3% of the variance in post-test mental toughness scores was attributable to the intervention. These findings corroborate previous studies by Clough and Strycharczyk (2015) [4], who reported that psychological skill training programs incorporating self-reflection, visualization, and coping strategies enhance mental resilience and toughness among athletes and professionals in high-pressure environments. However, the Shapiro-Wilk normality test ($p = 0.018$) and Levene's test for homogeneity of variances ($p = 0.003$) suggest some deviations from normality and heterogeneity in variances. Despite these violations, the use of ANCOVA helped control for pre-test differences, ensuring a more accurate interpretation of the intervention's impact. The post hoc analysis using Bonferroni adjustment indicated a statistically significant difference between the experimental and control groups ($t = 2.49$, $p = 0.017$), with a mean difference of 13.4. Furthermore, Cohen's d effect size ($d = 0.801$) suggests a large effect, indicating that the intervention had a substantial impact on enhancing mental toughness. In applied settings, an effect size above 0.8 is considered practically significant, as suggested by Cohen (1988). These findings highlight the potential of targeted mental toughness interventions in fostering psychological resilience in various populations, particularly athletes, military personnel, and professionals exposed to high-stress environments.

Despite the positive results observed in this study, some research presents contrasting views regarding the effectiveness of psychological interventions for mental toughness. For instance, Hardy *et al*. (2014) [9] argued that while structured interventions may yield short-term benefits, the long-term sustainability of mental toughness development depends on individual motivation, environmental factors, and consistency of application. Additionally, Cowden (2016) pointed out that certain

personality traits, such as conscientiousness and openness to experience, may moderate the effectiveness of mental toughness training, suggesting that not all individuals respond equally to psychological interventions.

Some studies argue that genetics and inherent personality traits play a crucial role in determining mental toughness. Their findings suggest that while training programs can improve certain aspects of resilience, individuals with pre-existing psychological predispositions toward high perseverance and emotional stability may exhibit greater long-term gains. Similarly, Nicholls *et al*. (2009) [25] emphasized that individuals with prior exposure to adversity and stress-adaptation strategies often exhibit naturally higher mental toughness, indicating that early-life experiences could influence an individual's response to psychological training. Furthermore, some scholars contend that mental toughness is a multifaceted construct that cannot be significantly altered through short-term interventions alone. Mahoney *et al*. (2014) [9] suggested that developing mental toughness requires prolonged exposure to challenging situations, deliberate practice, and supportive mentorship, emphasizing the importance of a longitudinal approach to training. Similarly, Andersen (2011) [2] argues that social and cultural factors, such as team environment, coaching styles, and peer influences, significantly impact an individual's mental resilience development. The findings of this study hold significant implications for coaches, psychologists, and educators involved in performance enhancement programs. Implementing structured psychological interventions, such as goal-setting workshops, mindfulness training, and cognitive-behavioral techniques, can be instrumental in fostering mental toughness among individuals in competitive and high-pressure settings. Future research should explore the long-term impact of such interventions by conducting follow-up assessments over extended periods. Additionally, incorporating qualitative methods, such as interviews and self-reflection reports, may provide deeper insights into participants' experiences and the mechanisms underlying improvements in mental toughness. Exploring the role of individual differences, including personality traits and prior exposure to adversity, could further refine intervention strategies and maximize their effectiveness.

Conclusion

In conclusion, the results of this study provide strong empirical support for the effectiveness of the intervention in enhancing mental toughness among participants. The significant increase in mean mental toughness scores, the stability of standard deviation in the experimental group, and the large effect size highlight the practical benefits of targeted psychological interventions. While some literature suggests potential limitations in the sustainability and generalizability of mental toughness training, the findings reinforce the value of structured interventions in improving psychological resilience. Future research should aim to refine these interventions by considering individual differences, long-term sustainability, and the integration of diverse training methodologies.

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