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Original Research

Enhancing Mental Toughness and Strength and Conditioning Performance in Collegiate Athletes Through Pressure Training

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Abstract

International Journal of Exercise Science 18(4): 456-469, 2025. https://doi.org/10.70252/GBPT2217 This study is the first to investigate the role of mental toughness (MT) in predicting strength and conditioning (S&C) performance outcomes and the impact of pressure training (PT) on MT development among NCAA athletes. A women's Division I field hockey team (n = 15) participated in five 1-hour sessions focused on psychological skills training to enhance MT, followed by two S&C sessions under PT conditions. Using the Mental Toughness Index, MT was assessed after the workshops/before PT and following PT. Regression analysis revealed that pre-PT MT scores predicted S&C performance outcomes during PT sessions (F(1, 16) = 4.67, p = .0499, 95% CI [0.154, 0.803]), with a positive correlation between MT scores and performance (R2 = 0.26, β = 0.07, 95% CI [0.00, 0.15]). A paired samples t-test revealed a significant increase in MT scores post-PT (t(12) = -3.34, p = .006, d = 0.93, 95% CI [-3.31, -0.69]), suggesting PT effectively enhances MT. PT sessions incorporated relevant-to-the-team demands and consequences, incidentally leading to increased athlete engagement and performance intensity. Overall, the findings demonstrate the relevance of PT as an innovative and practical tool for S&C coaches, offering initial evidence of its capability to enhance athlete development and optimize performance under high-stake conditions with strong ecological validity due to its application in real-world training environments. Future research should explore the longitudinal application of PT across larger samples, diverse sports, and its long-term effects on performance outcomes.

Keywords: Mental performance, collegiate athletes, CSCCa, NSCA, sport psychology, NCAA athletes, mentally tough, AASP, strength and conditioning coach

Introduction

In collegiate strength and conditioning (S&C), the pursuit of professional excellence is the norm.[1] Strength and conditioning coaches (SCCs) take pride in their daily grind, their hard-earned participant matter expertise, and the impact they have on the student- athletes and teams that they serve. In short, SCCs aspire to be the most effective coaches they can be. Côté and Gilbert[2] describe coaching effectiveness as "the consistent application of integrated professional,

interpersonal, and intrapersonal knowledge to improve athletes' competence, confidence, connection, and character in specific coaching contexts". SCCs primarily focus on physical training, but in their pursuit of more effective coaching, they inevitably utilize aspects of other vocations, such as mental performance coaching.

Mental toughness (MT), a positive psychology construct, is a domain of mental performance of particular interest to SCCs. In particular, collegiate SCCs report that they consider MT an important aspect of sport performance, believe it is trainable, and engage in efforts to improve it through physical training.[3,4] However, the majority of interventional studies have employed psychological over physical training.[5] Although SCCs have some training in psychology, formal education on developing MT is not typically part of the SCC curriculum.[4,6] Consequently, many SCCs resort to methods they perceive as mentally demanding, such as military-style training, to impact psychological aspects of performance.[7] Despite the perceived importance of MT, there is little consensus among SCCs on how to measure it or its components.[3]

Although views on MT still differ, common to each of these descriptions is the ability to persist in achieving a goal in the face of adversity.[3] Therefore, individuals' MT levels are exposed in the presence of adversity (e.g., difficult task that challenges the function of the individual) and are trained through adversity.[8] One notable definition by Gucciardi et al[9] defines MT as "a personal capacity to produce consistently high levels of subjective (e.g., personal goals or strivings) or objective performance (e.g., sales, race time, GPA) despite everyday challenges and stressors as well as significant adversities". Based on a uni-dimensional conceptualization, the Mental Toughness Index (MTI) was developed, consisting of a validated 8-item scale that measures specific key dimensions of MT (i.e., buoyancy, facing adversity, emotion regulation, attention regulation, generalized self-efficacy, optimistic style, success mindset, and context knowledge). Consequently, MT is a developmental psychological resource characterized by these eight key dimensions/skills, which are rooted in purposefulness, flexibility, and efficiency, in the process of goal-directed pursuits.[10]

Weinberg et al[11] argued that aspects of MT exhibited by athletes, such as the eight described above, are both "caught" through personal experiences and their environment and "taught" through intentional exposure and the learning of coping skills. In addition, the classic psychological skills training (PST) framework consists of three phases: education, skill acquisition, and application.[12] While adversity seems to be an irreplaceable environmental component, transparent and clear reporting of MT interventions is uncommon.[13] Furthermore, even if successful interventions exist, more research is needed to determine whether higher MT scores translate into higher performance outcomes.[10] Specifically, it is crucial to explore how SCCs can both test the acquisition of MT skills and apply them in specific sport contexts to validate improvements in performance. Furthermore, it is essential to investigate whether the additional application of these skills through interventions (e.g., adversity/pressure) results in increased MT scores post-training.

A proven strategy that may offer a viable solution is called *pressure training* (PT). PT is the process of strategically applying pressure during training to improve performance under pressure during competition.[14] The aim of PT is to expose an athlete to pressure progressively

during domain-specific practice by manipulating the *demands* on the athletes and the *consequences* for performance. Baumeister[15] conceptualizes pressure in this sense: "any factor or combination of factors that increases the importance of performing well on particular occasions". Concurrently, it is important to educate participants/athletes on specific skills and strategies to cope with increased pressure/adversity and manage performance.[16–19] A meta-analysis of 14 studies on PT by Low et al[20] found that PT consistently improves performance under pressure with both closed and open skills in novice and elite performers and in multiple vocations.

Rather than introducing new exercises, PT aims to enhance current training methods by strategically applying performance pressure, aligning with the emphasis on bridging the research-practice gap through practical and context-relevant interventions.[21] Stoker et al[14] developed a comprehensive framework for PT, detailing how to manipulate the consequences and demands of training. *Consequences* are categorized into forfeits, rewards, and judgment, while *demands* include task stressors, performer stressors, and environmental stressors. These elements are adjusted to increase both the physical and cognitive demands of a task, thereby exposing athletes to the types of stressors they will encounter in competition. Stoker et al[14] found that consequences are generally more effective at creating perceived pressure than demands alone, with the combination of both proving to be the most impactful. However, the effectiveness of PT hinges on the relevance of these consequences and demands to the individual athlete. To ensure this relevance, sport psychologists recommend involving athletes in the PT design process, asking them directly about what they find meaningful and what would induce pressure.[17] Additionally, incorporating mental debriefing/recovery after PT sessions is suggested not only ensuring participants' wellness and for educational purposes but also for receiving feedback and enhancing participants' inclusion and the accuracy of subsequent sessions.[22]

Although key stakeholders recognize MT as a critical component of sport performance, there is little agreement on the best methods for its development. Additionally, evidence supporting the effectiveness of S&C activities to enhance MT is limited. PT offers a novel approach to developing and applying MT in real-sport environments. However, no research has been conducted on the application of PT within S&C settings. If PT proves to be effective, it could fill a significant gap in current MT practices in collegiate strength and conditioning, benefiting student-athletes, SCCs, and the overall organization. Therefore, this study aims to investigate whether pre-training MT scores can predict performance during S&C sessions with PT and whether PT can enhance MT scores post-training in NCAA athletes. We hypothesize that individuals who present with higher pre-training MT scores will show greater performance during S&C sessions with PT. Subsequently, we also theorize that MT post-scores will be greater following the S&C PT intervention.

The following research questions were evaluated: 1. Do pre-training mental toughness (MT) scores predict performance outcomes during strength and conditioning (S&C) sessions when pressure training (PT) is applied? 2. Does the application of pressure training (PT) result in a significant increase in post-training mental toughness (MT) scores?

Methods

Participants

A convenience sample (n = 15) of a women's Division I field hockey team from an institution, member of the Atlantic Coast Conference (ACC) participated (Mage = 20; SD = 1.25). As this study was conducted under an Omnibus IRB, predefined inclusion and exclusion criteria were not applied, as the data were collected as part of routine team activities. Participants (freshmen = 4, sophomore = 7, junior = 2, senior = 2) were current, healthy members of the same women's Division I field hockey team, cleared to practice by the team's medical staff, and had formal strength and conditioning training experience (M = 1.63, SD = 0.99 years). All participants were actively engaged in both the MT intervention and the S&C sessions, with this study representing their first exposure to MT and PT. None of the participants had sustained any major injuries prior to the study. Overall, the same underlying criteria were used for all participants and all participants who met them enrolled in this study. Data reflect the experiences of actively competing collegiate athletes during their regular training environment. This study was conducted under the approval of existing omnibus Institutional Review Board (IRB) protocol (#21.0866). The original intent for data collection was for clinical and practical purposes. One of the authors is one of team's mental performance specialists and included in that protocol and the other author is the team's SCC, ensuring that the data collected was both relevant and accurately reflective of the participants' clinical and practical experiences. Consequently, retrospective data was utilized for research purposes in compliance with our existing omnibus IRB. The ethical guidelines outlined by the IRB ensured the protection and confidentiality of all participant information. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[23]

Protocol

In terms of methodology, we conducted a comprehensive intervention program comprising five 1-hour team sessions focusing on MT and PT. Each session was designed to address specific aspects of the Psychological Skills Training (PST) framework, emphasizing Education and Skill Acquisition.

1. Session 1: Introduction to Mental Toughness and Pressure Training
2. Session 2: Recap and Education/Skill Acquisition on Overcoming Adversity and Buoyancy (2 of the 8 MT key dimensions)
3. Session 3: Recap and Education/Skill Acquisition on Emotion Regulation and Attention Regulation
4. Session 4: Recap and Education/Skill Acquisition on Optimistic Style and Generalized Self-Efficacy

5. Session 5: Recap and Education/Skill Acquisition on Success Mindset and Context Knowledge

The Mental Toughness Index (MTI) was employed to measure individual levels of MT at three different points: before the workshops, after the workshops, and after the PT. The MTI is a self-report inventory developed by Gucciardi et al. The MTI consists of eight items (e.g., "I strive for continued success," "I consistently overcome adversity") scored from 1 (False, 100% of the time) to 7 (True, 100% of the time), with the total score ranging from 8 to 56.[9] Each item measures each of the eight key MT dimensions explained above (e.g., Item #1 captures levels of Generalized Self-efficacy). Higher scores indicate higher individual MT. Reliability and validity evidence can be found here [5,24–26].

Performance was also self-assessed using a scale designed by the authors, which mimicked the MTI's range (1-7; 7 indicating the highest level of performance). The choice of a one-item 7-point scale, common in psychology for capturing variability efficiently, also facilitates statistical analysis. In more detail, the study used a single-item scale to measure performance outcomes, a decision informed by the need for efficiency and alignment with the exploratory nature of the research. Single-item measures are widely accepted for capturing specific, unidimensional constructs in applied settings, with evidence supporting their validity when the construct is narrowly defined and well understood by respondents.[27] Additionally, athlete responses were triangulated with assessments from the strength coach, who used the same scale to evaluate performance. While the coach's data could not be included in this study due to being collected outside the study's IRB protocol, their alignment with athlete responses reinforces the scale's face validity. This approach ensured minimal participant burden while providing meaningful data for the study's aims. This and all other surveys were administered via Qualtrics.

Concerning procedures, below, we present details on a) PST team sessions, b) administration of MTI, c) design and application of PT, and d) mental debriefing.

a. Team Sessions:

Before commencing the team sessions, participants were asked two questions:

1. "What 'rewards' would motivate you to perform better?"

2. "What 'punishments' would make you more anxious about your performance?"

These questions were posed before participants were aware of the intervention to ensure honest responses. The answers were utilized during PT to create specific demands and consequences. Qualitative analysis identified the most relevant and feasible rewards and punishments for designing the PT sessions.

b. Measurement of Mental Toughness

The MTI was applied at 3 stages:

1. Before the workshops (MT0)
2. After the workshops (MT1)
3. After the pressure training (MT2)

c. Pressure Training:

Following the team MT sessions, two S&C sessions were conducted under PT conditions. Each session was designed to address specific aspects of the PST framework, emphasizing Skill Acquisition and Application. Collaboration between the SCC (first author) and the mental performance specialist (second author) was critical in designing these sessions to simulate pressure by integrating predetermined workouts with specific demands and consequences (Please see Appendix for more details). The drills used for the PT sessions were pre-existing drills the strength and conditioning program that the team was undergoing at the time of the intervention. Each participant had completed the drills on multiple occasions without the pressure manipulations prior to the PT intervention as part of their physical development routine. The intent of the drills selected are the development sprinting speed and aerobic performance. Both of which are critical components to field sport performance. Furthermore, the use of pre-existing drills allows for minimal disruption to the existing training process and removes the need for familiarization with an exercise prior to the application of PT within it. Demands and consequences were selected based on participants' feedback and the practical feasibility of implementation. Participants were briefed on the nature of the training, the expected outcomes, and the rewards or forfeits associated with their performance prior to the beginning of each individual session. Participation was voluntary.

d. Mental Debriefing:

After each PT session, participants completed a mental debriefing survey. This survey included questions on their perception of their performance (range: 1-7, identical to MTI) and other related metrics (details provided in the Appendix). The Mental Performance Specialist was present.

Statistical Analysis

Initially, the dataset included all participants, but two participants (at indices 5 and 14) were identified via standardized residuals, leverage values, and Cook's distance as outliers and removed, resulting in a final participant count of 13 after cleaning. While we acknowledge that outlier removal can significantly influence results in small sample sizes, our decision was: a) informed by data and guided by established statistical diagnostics, b) aimed at minimizing undue influence to enhance the robustness of the analysis, and c) aligned with the exploratory nature of the study, which prioritizes identifying general trends over confirmatory conclusions. This is a pioneering/hypothesis-generating study based on a convenience sample. Given the hypothesis-generating nature of the research and the practical constraints of participant availability (e.g., under Omnibus IRB, convenience sample, real-world and high-performance

athletic environment), an a priori power analysis was not conducted. While this approach aligns with the goals of exploratory studies, a post hoc power analysis was performed to assess the sufficiency of the sample size for the observed effects.[28] To determine if pre-PT MT (MT1) scores predict performance in S&C sessions (the performance scores from the two S&C sessions were averaged to obtain a single performance score for each participant), we performed descriptive statistics and a regression analysis, calculating the standardized regression coefficient (effect size) to assess practical significance. Additionally, a scatter plot with a regression line was created to visualize the relationship. For the impact of PT on MT scores, we calculated descriptive statistics for MT1 (pre-PT) and MT2 (post-PT) scores and conducted a paired t-test to compare them, computing Cohen's d (effect size) to evaluate practical significance (small, $d \leq 0.2$; medium, $d = 0.5$; large, $d \geq 0.8$).[29] A plot was generated to visualize the difference between MT1 and MT2 scores. The assumptions underlying the regression analysis (e.g., linearity, homoscedasticity, independence, and normality of residuals) and those for the paired t-tests (e.g., normal distribution of differences) were assessed and satisfied, ensuring the appropriateness of the statistical tests. The alpha-level for determining statistical significance was set at 0.05. MATLAB (2024a) was used for all analyses, and sample scripts are provided in the Appendix for replication.

Results

Table 1 presents descriptive statistics for pre-PT MT scores (MT1) and performance averages during S&C activities while applying PT. A regression analysis was conducted to predict performance from pre-PT MT scores (MT1) (Table 2). The overall model was significant: $F(1, 16) = 4.67$, $p = .0499$, with an R-squared value of 0.26. A bootstrapped 95% CI for R^2 ranged from 0.154 to 0.803. The intercept was 3.03 (SE = 0.31, $t = 9.77$, $p < .001$, 95% CI [-0.37, 6.43]), and the MT1_total coefficient was 0.07 (SE = 0.31, $t = 2.26$, $p = .035$, 95% CI [0.00, 0.15]) (Figure 1). This indicates that those individuals with a higher MT1 score performed better during the S&C sessions when PT was applied.

Table 1. Descriptive statistics for pre-pressure training mental toughness scores (MT1) and performance outcomes during strength and conditioning sessions with pressure training.

Variable	Mean	Standard Deviation	Minimum	Maximum
MT1_total (Pre-PT)	46.00	4.81	37.00	56.00
Performance Average	6.42	0.64	5.50	7.00

Table 2. Results of the regression analysis predicting performance outcomes from pre-pressure training MT scores (MT1), including unstandardized coefficients, standard errors, p-values, and 95% confidence intervals.

Predictor	B	SE	95% CI LL	95% CI UL	t	p
Intercept	3.03	0.31	-0.37	6.43	9.77	0.0000
MT1_total	0.07	0.31	0.00	0.15	2.26	0.0345

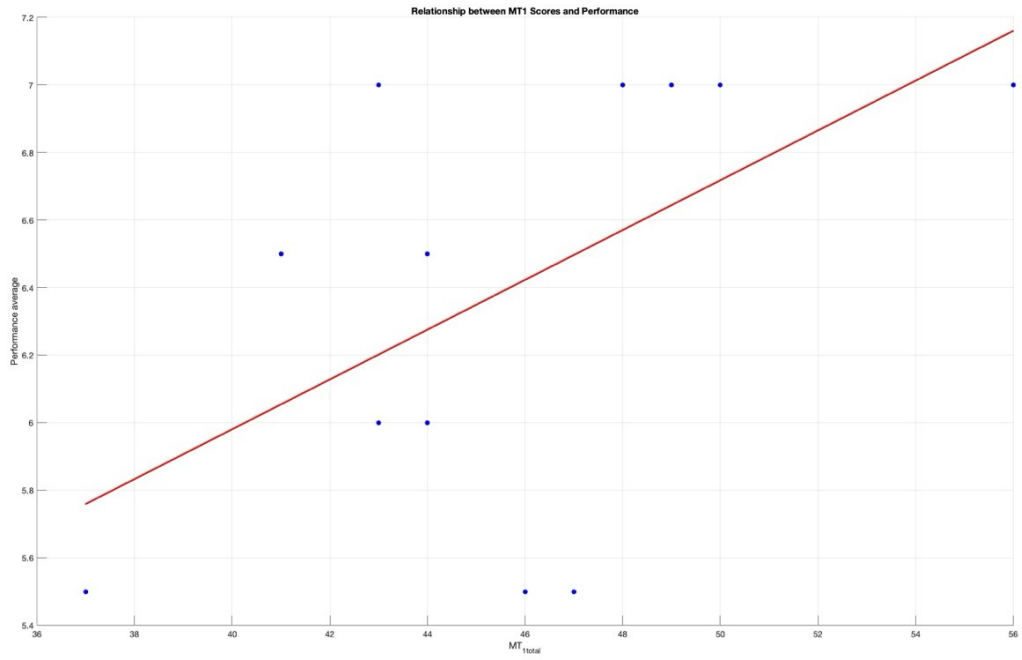

Figure 1. Scatter plot showing the relationship between pre-pressure training mental toughness scores (MT1) and performance outcomes during strength and conditioning sessions, with a fitted regression line illustrating the predictive relationship.

To determine if PT during S&C sessions resulted in significant increases in post-training MT scores, a paired samples t-test was conducted comparing MTI scores pre-PT (M = 46, SD = 4.81) to MTI scores post-PT (M = 48, SD = 3.76) (Table 3). The results indicate that the post-PT MTI scores were significantly different than pre-PT, t(*17*) = -3.34, p = .006, 95% CI [-3.31, -0.69], d = 0.93 (Figure 2). This suggests that the PT intervention may have had a positive impact on the post-intervention MT scores (MT2). Cohen's d (0.93) indicates a large effect size, suggesting practical significance.[29] A post hoc power analysis for the paired samples t-test revealed a power of 0.87 (d = 0.93, α = 0.05, n = 13), indicating sufficient power to detect the observed effect. However, the power for the regression analysis was 0.05 (R^2 = 0.26, a = 0.05, n = 13), suggesting that the sample size was insufficient for this analysis. These results highlight the variability in the ability to detect effects across different statistical tests within this study.

Table 3. Descriptive statistics for pre-pressure training (MT1) and post-pressure training (MT2) mental toughness scores, illustrating the impact of pressure training on mental toughness.

Variable	Mean	Standard Deviation	Minimum	Maximum
MT1_total (Pre-PT)	46.00	4.81	37.00	56.00
MT2_total (Post-PT)	48.00	3.76	41.00	56.00

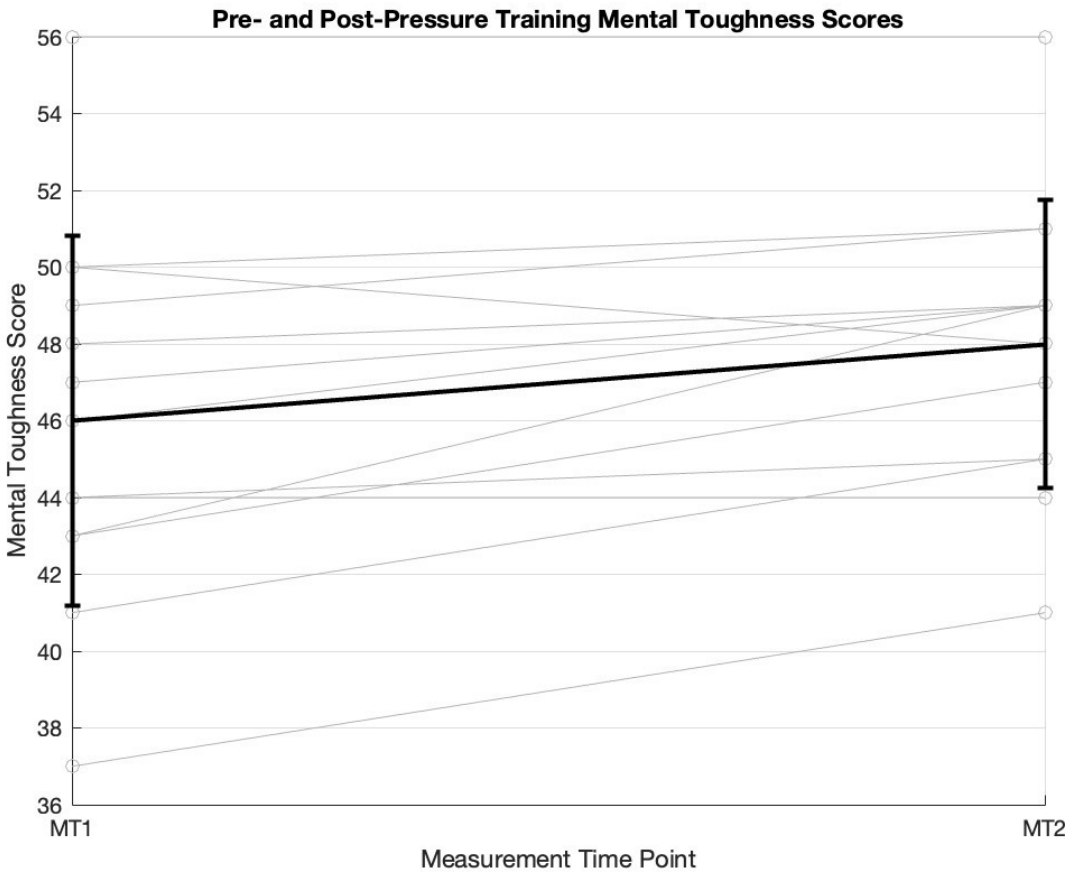

Figure 2. Pre- and Post-Pressure Training Mental Toughness Scores. Changes in mental toughness scores are shown for two measurement time points: MT1 (pre-pressure training) and MT2 (post-pressure training). The *y*-axis represents mental toughness scores, while the *x*-axis represents the measurement time points. Gray lines depict individual participant scores, and the bold black line represents the group average, which increases from MT1 to MT2. Error bars indicate a reduction in score variability post-training, suggesting greater consistency in mental toughness scores after pressure training.

Discussion

This exploratory study represents a pioneering application of PT in real-world S&C activities, specifically exploring the impact of a) MT on performance outcomes during PT and b) PT on MT scores among collegiate athletes. The regression analysis revealed a marginal but statistically significant relationship, with pre-PT MT scores positively predicting performance outcomes during S&C sessions when PT was applied. The paired t-test demonstrated a significant improvement in MT scores following PT. Collectively, these results suggest that PT may enhance MT and its association with performance outcomes, while highlighting variability inherent to the exploratory nature of the study. However, while a post hoc power analysis indicated sufficient power for the paired samples t-test ($1 - \beta = 0.87$), the regression analysis was underpowered ($1 - \beta = 0.05$). Overall, the findings underscore the importance of cautious interpretation while providing an initial foundation for the formation of hypotheses to guide future confirmatory research.

Specifically, and concerning our first research question, the findings provide statistical evidence addressing it. Besides warranting further research with larger samples to confirm and expand upon these findings, the results provide initial insights, indicating that pre-PT MT scores could predict performance outcomes during S&C sessions when PT is applied. This finding aligns with previous research demonstrating the influence of mental skills on performance under pressure.[15] Practically, this suggests that MT training should be encouraged and facilitated by SCCs, as it may be positively associated with S&C performance. This finding helps explain why SCCs value MT so highly.[3] Evidence was found to answer our second research question, as well. In more detail, the paired samples t-test scores support the notion that PT also contributes to the development of MT skills. This suggests that SCCs could leverage PT to facilitate mental skill rehearsal, providing athletes with a robust platform to consistently improve their performance levels despite adversity. This is in accordance with previous research that indicates that adversity is an essential component of MT development in S&C.[3] The observed increase in MT scores post-PT highlights the practical significance of PT interventions, emphasizing their potential to enhance MT as part of the broader role of SCCs in athlete development.

Although not our primary research interest, a notable observation from the first author and master SCC —the highest accolade in US collegiate S&C— was the heightened engagement and intensity exhibited by participants during PT sessions. This increased focus and effort align with Nieuwenhuys and Oudejans'[30] model, which suggests that pressure can prompt performers to enhance their mental effort, concentrating more on task completion rather than the pressure itself. Our observations support this model, indicating that PT may effectively channel athletes' mental effort towards their S&C performance tasks, reducing anxiety about the pressure. This insight might offer valuable implications for S&C practitioners, as strategically incorporating PT can create an environment that encourages athletes to perform at their peak, ultimately enhancing overall training efficacy. Although this study was conducted using S&C sessions with US NCAA Division I women's field hockey, the potential efficacy of PT application within S&C sessions has implications for a wide range of performance contexts that have need to perform under pressure. This provides S&C practitioners a potential tool to address what practitioners, coaches, and athletes perceive to be an important aspect of sport performance.

Despite these promising findings, the study has limitations that warrant consideration. Firstly, the small sample size limits the generalizability of the results, and the limited number of PT sessions restricts the scope of the conclusions. However, the significant changes observed with a concise intervention suggest that even a few targeted PT sessions, informed by psychological skills training and participant feedback, may produce meaningful improvements in MT. Secondly, it is pertinent to note that methodological triangulation (e.g., incorporating objectives measures, not reliance on self-assessment only) and multi-informant assessment are recommended for effective utilization of MT questionnaires.[31] However, practical constraints can limit implementation; for instance, having the SCC assess all 15 athletes would require approximately 30 minutes per assessment session (assuming 2 minutes per athlete), which was not feasible due to time constraints. Thirdly, the absence of a control group limits the ability to attribute observed changes in MT and performance outcomes solely to the PT intervention. This limitation is a characteristic of studies conducted under Omnibus IRB protocols, where data are

collected as part of routine team activities rather than through controlled experimental designs. Furthermore, conducting randomized controlled trials in high-performance athletic environments is often impractical due to logistical and ethical constraints. Lastly, another inherent limitation of Omnibus IRB studies is the dual role of practitioners serving as both researchers and intervention facilitators. While standardized protocols were followed, the lack of adequate blinding may have introduced potential bias, potentially affecting the internal validity of the study. Future confirmatory research should replicate and expand on these findings by developing relevant hypotheses. Involving larger and more diverse cohorts, as well as exploring the application of PT across various sports and performance domains is recommended. Moreover, applying a longitudinal design (more than 2 S&C sessions) and investigating the long-term effects of PT on MT and performance outcomes will further elucidate its potential as a sustainable training strategy. Furthermore, triangulation (e.g., incorporating multiple perspectives and/or data sources, such as biomechanical or physiological indicators, to cross-verify results) would reduce potential biases and increase the robustness of the conclusions. Additionally, future research efforts should methodically investigate whether the increased engagement and intensity observed during PT sessions is a replicable phenomenon and a potential mechanism explaining enhanced S&C performance. Specifically, studies should aim to establish whether PT consistently channels athletes' mental effort toward S&C task completion, as proposed by Nieuwenhuys and Oudejans'[30] model and evaluate its efficacy in reducing performance-related anxiety. Lastly, future research must critically assess the methodological trade-offs inherent in studies conducted under Omnibus IRB protocols. While these protocols facilitate the integration of research within real-world contexts, enabling the quick collection of ecologically valid data as part of routine team activities, they impose constraints on the design and execution of studies with rigorous methodological controls. Specifically, the absence of predefined experimental conditions, such as control groups and randomization, limits internal validity and the ability to draw causal inferences. Furthermore, the reliance on existing data restricts the scope for customized data collection, including the acquisition of objective performance metrics tailored to the research objectives. To address these limitations, future studies should consider utilizing standalone IRB approvals designed for controlled experimental investigations. Such designs would allow for the incorporation of randomization, a priori power analyses, and broader participant sampling, thereby enhancing methodological rigor and facilitating more robust generalizations.

In addition to conceptual and methodological recommendations, our findings offer quantitative guidance for future sample size planning. Based on the observed effect sizes from this exploratory study, we generated sample size estimates to inform future confirmatory designs: A) For the within-subjects comparison of pre- and post-PT MT scores, the paired-samples t-test yielded a large effect size (d = 0.93). A post hoc power analysis using G*Power[28] indicated that the achieved power for this analysis, with n = 13, α = .05 (two-tailed), and d = 0.93, was 0.87, exceeding the conventional 0.80 threshold. Accordingly, future studies aiming to detect a similar within-subjects effect with 80% power and α = .05 would require a minimum of 10 participants. For reference, detecting the same effect in a between-subjects design would require approximately13 participants per group (total N = 26) and B) For the regression analysis, examining the predictive value of pre-training MT scores on performance outcomes, the

observed coefficient of determination was $R^2 = 0.26$. A post hoc power analysis indicated low statistical power for this model with $n = 13$, one predictor, and $\alpha = .05$ (power = 0.05), which limits the reliability of this result. Using G*Power, the estimated sample size required to detect a comparable effect ($f^2 = 0.35$, derived from $R^2 = 0.26$) with 80% power at $\alpha = .05$ is approximately 33 participants. These estimates offer a practical reference point for future studies aiming to rigorously test the efficacy of PT interventions on mental toughness and performance."

In conclusion, this exploratory study underscores the value of PT as a "practical theory" for MT skill acquisition and application within S&C settings.[32] Given the critical importance of MT in athletic performance, PT may offer a structured and evidence-based method for addressing this essential psychological component. By integrating PT into training regimens, SCCs can potentially play a pivotal role in enhancing the MT and competitive capabilities of their athletes, contributing to a more comprehensive approach to sports performance optimization. Importantly, this study offers a foundation for future confirmatory research, which can refine and test hypotheses more rigorously. By addressing the methodological limitations and leveraging the insights of this pioneering investigation, subsequent studies can improve statistical power, incorporate control groups, and explore objective metrics to advance our understanding of PT's role in athletic development.

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