

Psychological Characteristics and Pacing Strategies in Middle- and Long-Distance Running

Abstract of PhD Thesis

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Introduction

Achieving peak performance in sport is a complex, multifactorial process that requires the integration of various scientific disciplines and perspectives. Optimizing human performance necessitates thorough and systematic evaluation aimed at identifying both facilitating and potentially limiting factors (French et al., 2022). The three primary domains of athletic preparation include physical and technical training, tactical development, and mental or sport psychological preparation (Sinclair & Sinclair, 1994). Each of these components plays a critical role in overall performance, thus a holistic approach is essential for attaining athletic excellence (Short, 2023). The scientific emphasis on physical preparation has often overshadowed equally important aspects of tactical and mental preparation, despite their considerable influence on performance, particularly in endurance sports (Sandbakk et al., 2023). The aim of this dissertation is to address this gap by focusing specifically on the mental preparation of distance runners.

Over the past decades, numerous studies have been published in the international literature regarding the physiological, anthropometric, and morphological factors that are essential for successful performance in middle- and long-distance running. In terms of physiological variables, the most critical include maximal oxygen uptake ($\text{VO}_{2\text{max}}$), running economy (RE), and the velocity associated with maximal oxygen uptake (Conley & Krahenbuhl, 1980; Noakes, 2001; Noakes et al., 1990). In addition to these, the anaerobic threshold and its corresponding running speed (v_{LT2}) have been shown to be strong predictors of distance running performance (Tjelta & Tjelta, 2012). Established protocols exist for the testing and monitoring of these physiological variables (Barnes & Kilding, 2015; Goodwin et al., 2007; McConnell, 1988). Training programs aimed at improving these factors are increasingly based on scientific principles and continue to evolve through coaches' empirical observations. There is broad consensus among coaches and researchers that the development of these parameters is driven by the interaction of three main variables: training volume (e.g., weekly mileage), training density, and training intensity (Brandon, 1995; Midgley et al., 2007). However, the optimal combination of these variables may differ depending on the athlete and the specific event (Seiler & Kjerland, 2006). Variation also exists in the training methods used to elicit the desired physiological adaptations.

Whereas the physiological and physical aspects of preparation and talent identification in distance running are well-established and rooted in scientific tradition, the mental and

psychological dimensions of the sport have only begun to receive systematic attention in recent decades. The role of mental preparation raises legitimate questions from multiple perspectives. There are many examples in the sport's history where athletes with excellent season-best times have failed to perform successfully in major competitions (Kelemen et al., 2022), or have been unable to replicate their training performance in competition due to what the literature refers to as "choking" (Hill et al., 2019). Recent studies and practical observations also suggest that psychological factors may contribute to fatigue (Central Governor Model), and that optimizing these factors could further enhance performance (Noakes, 2007). In distance running events, different tactical situations require athletes to adapt their behavior in order to succeed. Due to high stakes, the unpredictability of opponents, and the intense pain associated with effort, these events demand complex mental capabilities from competitors (Renfree & Casado, 2018).

Objectives

Based on the insights presented in the introduction, the aim of this research was to review the factors that characterize the tactical preparation and competition behavior of distance runners, as well as to identify the psychological factors essential for successful performance in middle- and long-distance running. A further objective was to gain knowledge about the various intervention methods that can be used to develop these mental factors. To this end, four areas of investigation were defined.

I classified the research on race tactics into four main categories, focusing on middle-distance running. The first study analyzed the tactical behavior of the world's top-performing male middle-distance runners, with particular attention to pacing strategies and positioning within the field in major competitions (Olympic Games, World Championships) and Grand Prix events. The goal of this analysis was to cover a longer time span and thereby allow for the identification of general tactical characteristics in the two events (800 m and 1500 m). In my next study, I examined and compared the tactical profiles of more and less successful competitors. A novel aspect of this research was the inclusion of "micro-level" pacing changes and 100-meter split data, which differs from previous analyses. The third study aimed to explore tactical behaviors observed across different rounds of competition and the effects of cumulative load, with particular focus on the occurrence of slower, tactical races. Additionally, I was interested in how successful athletes manage their effort across

consecutive races. Finally, I analyzed how the individual strengths and characteristics of elite 800-meter runners influence their tactical behavior in terms of pacing and positioning. The first sport psychology study aimed to provide a comprehensive and representative picture of the psychological profiles of elite adult Hungarian distance runners, with special emphasis on personality traits, motivational structures, and competitive anxiety. This investigation sought to address gaps in the literature regarding the mental characteristics of international-level middle- and long-distance runners. Another objective was to examine whether sport psychological preparation has a measurable effect on the level of competitive anxiety. The findings of the study contribute to a deeper understanding of the mental characteristics of top-level distance runners and offer practical insights applicable to talent identification, athlete management, and race preparation.

The main objective of the second study was to assess whether the 20-item English-language Sports Mental Training Questionnaire (SMTQ) is suitable for the rapid, reliable, and valid measurement of mental preparedness in distance runners. The study analyzed whether there were statistically significant differences based on gender, competition level, and types of races. Additionally, the research aimed to explore the extent to which mental preparedness influences athletic performance and the use of athlete-specific skills in competitive situations. The purpose of this study was to contribute to the scientific understanding of the mental, psychological, and tactical preparation of distance runners while evaluating the effectiveness of practically applicable measurement tools in coaching practice.

The third and final study aimed to investigate the effects of a group-based mindfulness-based sport psychological intervention among a sample of national and international-level elite long-distance runners. The intervention analyzed psychological factors such as the experience of flow, competitive anxiety, mindfulness level, and emotion regulation. It also assessed changes in subjective satisfaction related to athletic performance and mental well-being. A control group of athletes at a similar competitive level was used to examine the effectiveness of the intervention. Given that research on the mental preparation of elite long-distance runners remains limited, the present study provides an important scientific and practical contribution to the field of sport psychology.

Methods

1. Competitive Tactics Analyses

In the first study, I analyzed 26 races over the 1500-meter distance run by 13 of the sport's most successful athletes, all of whom were world-ranking leaders and medalists at major international championships ($n = 26$; $R = 13$; $W = 13$). I compared their Grand Prix record performances with their medal-winning performances in major championship finals using video analysis, focusing on pacing and positioning at 400-meter intervals. For the 800-meter distance, I analyzed the top three finishers of 23 Grand Prix races and 25 Olympic and World Championship finals between 1983 and 2018, totaling 144 individual races ($n = 144$; $R = 69$; $W = 75$). During video analysis, I recorded athletes' positions and split times at 200-meter intervals and conducted basic statistical analyses using independent-samples t-tests and repeated measures ANOVA, complemented by Bonferroni post hoc tests. I used SPSS version 25, and the significance level was set at $p < 0.05$.

In the second study, I analyzed the final results, season bests, 100-meter split times, and positioning data from the heats, semifinals, and finals of the men's and women's 800-meter events at the 2021 Tokyo Olympics, covering 157 individual performances. Athletes were grouped by performance (successful vs. less successful), and segmental speeds were expressed as a percentage of each athlete's average speed. Changes in pacing were expressed using the coefficient of variation (CV%). I conducted basic statistical analyses, independent-samples t-tests, one-way ANOVA, and Bonferroni post hoc tests. Analyses were performed using SPSS version 27.0 and Microsoft Excel 2016, with the significance level set at $p < 0.05$.

In the third study, I processed male and female results from outdoor World Championships and Olympic Games in the 800 meters between 1999 and 2021, analyzing a total of 1000 individual performances ($N = 1000$). I retrieved time results and season bests (SB) of athletes who advanced or medaled from the World Athletics database and calculated percentage differences relative to SB (SB%) to assess tactical effort. In addition to basic statistical procedures, I applied independent-samples t-tests for comparisons across rounds and sexes. Performance trends were visualized using fourth-order polynomial regression in Microsoft Excel. The significance level was set at $p < 0.05$.

In the fourth study, I analyzed the all-time top 80 male 800-meter runners, categorizing them into three subgroups based on their 400 and/or 1500-meter performances: speed-oriented type (WA score ≥ 1150 in 400 m, $n = 11$), 800-meter specialists (WA score ≤ 1150 in both

400 m and 1500 m, $n = 40$), and endurance-oriented type (WA score ≥ 1150 in 1500 m, $n = 23$). Athletes without a documented 400 or 1500-meter result ($n = 6$) were also assigned to the endurance group. Ethical approval was granted by the Hungarian University of Sports Science. Personal best performances were collected from the World Athletics database and converted into WA scores. Race splits and positions were recorded via video analysis using Kinovea software at every 200-meter interval. Positions were determined relative to other competitors. Some races were excluded due to missing video footage. The normality of data distribution was tested using the Shapiro–Wilk test. Differences between groups were analyzed using one-way ANOVA and Bonferroni post hoc tests, and for positioning data, the Kruskal–Wallis test with Dunn’s post hoc correction. Correlations were examined using Pearson and Spearman coefficients, with strength categorized based on Hopkins’ guidelines. Analyses were performed using GraphPad Prism 9, with an alpha level of $\alpha = 0.05$.

2. Psychological Characteristics of Hungarian National Team Distance Runners

The study involved 16 middle- and long-distance runners ($n = 16$) from the 2023 Hungarian senior national athletics team, competing in events from 800 meters to the marathon. Data collection was conducted online and voluntarily in August 2023. Among the participants, there were 7 men and 9 women, with a mean age of $M = 26.75$ years ($SD = 4.26$) and an average running history of 10.75 ± 4.2 years. 56% competed at the 2023 World Championships in Budapest, several were national record holders, and 68% had undergone individual mental preparation during their training process. The control group consisted of 27 university students ($n = 27$; 16 men, 11 women) studying at the Hungarian University of Sports Science, all of whom were competitive athletes ($M = 22.74$ years; $SD = 3.68$). The sample included both professional ($n = 12$) and semi-professional ($n = 15$) athletes participating in individual ($n = 10$) and team sports ($n = 17$), such as handball and ice hockey. Their average sports history was 14.88 ± 4.52 years, and 66.6% had experience with sport psychological preparation. All participants were informed and signed written consent forms. The study was approved by the university’s ethics committee.

The aim of the assessment was to examine competitive anxiety, motivation, and personality traits, complemented by demographic and mental preparation questions. Competitive anxiety was measured using the CSAI-2 inventory (Martens et al., 1990; Hungarian adaptation: Sipos et al., 1999), which includes three subscales: cognitive anxiety, somatic

anxiety, and self-confidence. Internal consistency of the scales was adequate ($\alpha = 0.75\text{--}0.85$). Motivation was assessed using the Hungarian version of the Sport Motivation Scale II (Pelletier et al., 1995; Paic et al., 2018), which evaluates six types of motivation based on self-determination theory, with reliability values ranging from $\alpha = 0.62$ to 0.80 . Personality traits were measured using the 44-item Big Five Inventory (John et al., 2012), which assesses five major dimensions; internal consistency of the scales ranged between $\alpha = 0.62$ and 0.83 . The data met normal distribution criteria. Analyses were conducted using IBM SPSS Statistics 27, including descriptive statistics, intercorrelations, scale reliability assessments, and independent-samples t-tests for group comparisons. After verifying the assumptions of discriminant analysis, I applied multiple linear regression (enter method) to explore the explanatory power of psychological variables.

3. Analysis of Mental Preparation among International Distance Runners

The study involved 201 runners ($n = 201$; 110 men, 54.7%; 91 women, 45.3%) who completed the English-language online questionnaire between February and April 2024. The average age was $M = 35.05$ years ($SD = 11.57$) for men and $M = 35.98$ years ($SD = 10.87$) for women. Participants represented recreational ($n = 112$), national ($n = 56$), and international-level athletes ($n = 33$), competing in middle distance ($n = 44$), long distance ($n = 36$), half-marathon/marathon ($n = 79$), and ultradistance events ($n = 42$). Respondents were from multiple countries, most notably Hungary ($n = 71$), the United States ($n = 33$), and the United Kingdom ($n = 29$). The study was approved by the university ethics board (TE-KEB/08/2024), and all participants provided written informed consent.

The questionnaire included demographic items and questions regarding mental and tactical preparation. Mental preparation was assessed with a binary yes/no item, based on which participants were grouped as either mentally prepared (M.P.) or not mentally prepared (N.M.P.). Those answering “yes” could select from multiple mental techniques. Tactical preparation was assessed with a semi-open question allowing multiple selections.

To measure athletes’ mental skills, I used the validated 20-item Sport Mental Training Questionnaire (SMTQ; Behnke et al., 2019), which covers five subdimensions: Foundation Skills (F.S.), Performance Skills (P.S.), Interpersonal Skills (I.S.), Self-talk (S.T.), and Imagery (I.M.). Responses were recorded on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Prior to statistical analysis, I confirmed the normal distribution and variance of all variables. In addition to descriptive statistics, I conducted Pearson correlations. Point-biserial

correlations were used to explore relationships between gender and psychological variables. The impact of mental preparation (M.P. vs. N.M.P.) was examined using independent-samples t-tests, while the effects of competition level and event type were analyzed with one-way ANOVA.

The construct validity of the questionnaire was assessed using confirmatory factor analysis (CFA), considering multiple fit indices: χ^2/df , RMSEA, SRMR, and CFI. Based on the literature, acceptable model fit was defined as follows: $\chi^2/df < 3$ (Kline, 2023), RMSEA and SRMR < 0.08 , CFI > 0.95 (Hu & Bentler, 1999; van Laar & Braeken, 2021). Scale reliability was evaluated using Cronbach's alpha (≥ 0.60) and McDonald's omega (McDonald, 2013). Analyses were conducted using IBM SPSS 27 and JAMOVI 2.4.11, with FIML estimation used to address missing data.

4. Group Mindfulness Intervention Among Elite Distance Runners

The participants were Hungarian national and international level long-distance runners (800 m–marathon). Due to ethical reasons, the use of a randomized control group was not possible; therefore, a quasi-experimental design with a non-randomized control group was employed. Members of the control group did not participate in any organized sport psychology program. Both groups completed online questionnaires before and after the intervention (pre–post), which included demographic data, subjective performance satisfaction, and validated psychological instruments (flow, anxiety, mindfulness, emotion regulation – FAME framework; Kaufman et al., 2018). The intervention was a six-week online MSPE program (Mindful Sport Performance Enhancement), adapted for long-distance runners. Recruitment took place between August 1 and September 20, 2024, and the program was conducted from September 29 to November 3, 2024. All participants provided written informed consent, and the research was approved by the Ethics Committee of the Hungarian University of Sports Science.

A total of $N = 20$ athletes participated in the sample. The required sample size was calculated using GPower software ($f = 0.40$; $\alpha = 0.05$; $1 - \beta = 0.80$; $p = 0.5$) based on effect sizes reported in the literature (Myall et al., 2023), which indicated a minimum of $n = 16$. The mindfulness group consisted of $n = 10$ athletes (6 men, 4 women; 5 national and 5 international level competitors), with a mean age of $M = 25.00$ years ($SD = 2.00$) and running experience of $M = 12.3$ years ($SD = 5.21$). Three individuals had previously participated in some form of mental training, but none had practiced mindfulness. The control group included $n = 10$ participants (7 men, 3 women; 5 national and 5 international level athletes), with a mean age

of $M = 25.4$ years ($SD = 6.10$) and running experience of $M = 11.15$ years ($SD = 6.20$). Two participants reported prior mental training, but none had mindfulness experience.

The measurement instruments included the Flow State Questionnaire (Magyaródi et al., 2013) to assess flow experience, the CSAI-2HR scale Somatic and Cognitive Anxiety subscales (Sipos et al., 1999; Tóth et al., 2025) to measure competitive anxiety, the MAAS-H questionnaire (Simor et al., 2013) for dispositional mindfulness, and the Hungarian adaptation of the S-DERS scale to assess difficulties in emotion regulation. The applied questionnaires demonstrated adequate internal consistency ($\alpha = 0.75\text{--}0.92$).

Normality of data was checked for all measurements, and all variables followed a normal distribution (skewness between -2 and 2 ; kurtosis between -7 and 7). Subsequently, descriptive statistical analyses were conducted. Internal consistency was assessed using Cronbach's alpha, with values above 0.60 considered acceptable (Cronbach, 1951). Main analyses were performed using repeated measures ANOVA, with group as the between-subject factor (experimental and control) and time as the within-subject factor, represented by pre- and post-test scores of the five variables. This analysis was suitable for examining main effects such as group differences over time, interaction effects (time $\times$ group), and between-group differences. All statistical analyses were conducted using SPSS version 27.0.

Results

Results of Race Tactics Analyses

In the first investigation, based on the analysis of two race distances (1500 m and 800 m), performance and average race speed were significantly better in the record tactical (R) runs compared to the winning (Gy) tactics applied in world championship finals ($p < 0.05$). In the 1500 m, the times and speeds of R runners ($3:28.28 \pm 1.3$ s; 7.20 ± 0.04 m/s) significantly exceeded those of the Gy tactics runners ($3:37.22 \pm 4.9$ s; 6.90 ± 0.15 m/s). The characteristic pacing profile of R runs showed a fast first lap, followed by an even middle section, and a faster closing segment, with no significant difference between the middle two 400 m splits ($p > 0.05$). In contrast, the Gy runs exhibited a gradual increase in pace, with the last lap speed (7.58 ± 0.19 m/s) significantly faster than the third lap (7.22 ± 0.14 m/s; $p < 0.05$). In both tactics, the second half split speed was significantly greater than the first half (R: 7.24 ± 0.06 m/s vs 7.16 ± 0.06 m/s; Gy: 7.39 ± 0.11 m/s vs 6.52 ± 0.29 m/s; $p < 0.05$), though the increase was larger in the Gy tactic. Differences also appeared in position changes: Gy runners showed significant positional shifts between 800 and 1200 m (4.79 ± 2.68 vs $2.61 \pm$

2.63; $p < 0.05$), while R runners had overtakes over multiple segments. Position at the first 400 m was also significantly more favorable for R runners (3.15 ± 2.99 vs 5.46 ± 3.15 ; $p < 0.05$). The number of overtakes was higher in the Gy group in every segment, especially between 800 and 1200 m (0.69 ± 0.94 vs 2.15 ± 2.64 ; $p < 0.05$).

In the 800 m, R runs were characterized by steady deceleration (positive pacing), with significant differences between every adjacent 200 m segment ($p < 0.05$). Conversely, Gy runners had the second 200 m as the slowest segment, followed by a significant pace increase until the end ($p < 0.05$), with no difference between the last two segments ($p > 0.05$). Comparison of the first and second 400 m laps showed significant speed decreases in the second lap for both tactics (R: 7.96 ± 0.11 m/s vs 7.57 ± 0.09 m/s; Gy: 7.73 ± 0.23 m/s vs 7.59 ± 0.11 m/s; $p < 0.05$), and the first lap speed was significantly faster in the R group ($p < 0.05$). Positional dynamics showed gradual overtaking in both tactics, but no significant difference in positions between 200 and 600 m ($p > 0.05$). R runners exhibited a significant difference in overtakes between the second and third 200 m segments (0.44 ± 1.23 vs 1.62 ± 1.23 ; $p < 0.05$), highlighting the importance of the middle race section on final outcomes. The second investigation analyzed 100, 200, and 400 m split times, revealing significant differences among both female and male 800 m runners. The temporal variability of 100 m splits differed significantly ($p < 0.001$), with female final medalists showing the lowest speed variance (coefficient of variation, $CV = 4.37 \pm 0.08\%$), while qualifiers from heats exhibited significantly higher speed fluctuations ($CV = 5.57 \pm 1.49\%$). In males, medalists showed the most inconsistent pacing ($CV = 6.45 \pm 0.40\%$), whereas semifinal qualifiers had the most balanced pace ($CV = 3.41 \pm 0.72\%$). Significant differences between successful and less successful athletes were observed in the last two 100 m splits ($p < 0.05$), where successful athletes maintained or increased speed, while less successful showed marked slowing (e.g., 700–800 m segment for women: successful heat qualifiers 14.25 ± 0.50 s vs less successful 15.60 ± 1.27 s; men in finals: successful 12.62 ± 0.21 s vs less successful 13.26 ± 0.28 s). Analysis of 200 m splits showed that in 85–88% of cases, athletes ran the first 200 m fastest ($p < 0.001$), with the second 200 m interval being the slowest segment statistically ($p < 0.001$). Successful groups recorded significantly faster splits in the last 200 m compared to less successful peers (women, final: 28.30 ± 0.24 s vs 29.78 ± 0.71 s; men, final: 25.22 ± 0.14 s vs 25.94 ± 0.30 s; $p < 0.05$).

400 m split analysis also indicated significant pacing differences. Successful female athletes used negative pacing, running the second half faster than the first ($p < 0.05$), while less

successful did not increase pace. In males, negative pacing was significant only in finals; in earlier rounds both groups showed positive pacing, although successful athletes paced more evenly ($p = 0.045$). In every round, successful athletes recorded significantly faster splits in the second half than less successful ones (e.g., female final: 57.57 ± 0.25 s vs 59.26 ± 0.58 s; male final: 51.09 ± 0.06 s vs 51.92 ± 0.29 s; $p < 0.05$).

The third investigation analyzed the past two decades of men's 800 m heats. The average qualifying time was $1:46.47 \pm 0.5$ s, showing no developmental trend except for the last three world championships (Tokyo 2021: $1:45.39 \pm 0.62$ s; Beijing 2015: $1:47.01 \pm 0.84$ s). Polynomial regression showed heats had the strongest improvement trend ($R^2 = 0.41$), while semifinals and finals had negligible trends ($R^2 = 0.12$; 0.17). Final qualifying times were the most consistent (Rio 2016: $1:44.25 \pm 0.32$ s; Tokyo 2021: $1:44.35 \pm 0.23$ s). Two main race types emerged: slower tactical races with low %SB ($>99\%$) and record-breaking finals (%SB > 100). There was a significant difference in times between the first two rounds (heat: $1:46.46 \pm 0.5$ s vs semifinal: $1:45.06 \pm 0.56$ s; $p < 0.05$), but no difference between medalists and finalists in the final ($p > 0.05$). Seasonal best progression was moderate, with regression R^2 values of 0.50, 0.48, and 0.31 for heats, semifinals, and finals, respectively. Required effort (%SB) increased significantly between the first two rounds ($98.4 \pm 0.41\%$ vs $99.13 \pm 0.58\%$; $p < 0.05$), though temporal change was small (low R^2 values: heat 0.28; semifinal 0.19; final 0.08). Finals had the greatest variability ($99.4 \pm 1.06\%$), related to alternating tactical and record-type races.

No significant temporal progression was found in women's first three rounds (R^2 : heat 0.1; semifinal 0.32; final 0.38). Significant differences in mean times appeared between the first two rounds (heat: $2:01.48 \pm 0.95$ s vs semifinal: $1:58.96 \pm 0.67$ s; $p < 0.05$), and also between medalists and finalists in the final ($p < 0.05$). Seasonal best results showed no increase (R^2 between 0.18 and 0.6), averaging $1:59.4 \pm 0.27$ s for heat qualifiers, $1:58.9 \pm 0.66$ s for finalists, and $1:57.36 \pm 0.77$ s for medalists. Effort (%SB) remained stable between the first two rounds (low R^2), but was higher in finals ($R^2 = 0.42$), with average %SB reaching $100.11 \pm 1.02\%$ in finals. Female medalists achieved seasonal bests in 69% of finals, while the rate was 25% in males. The greatest sex difference in tactical behavior was that males alternated between slower and faster races, whereas in females, nearly all finals after 2005 were seasonal bests.

When examining individual characteristics, the SP group had a significantly better 400 m time in their personal best performances compared to the ET group ($p = 0.0013$), while no

significant differences were found between groups in individual bests for 1500 m and 800 m. ANOVA analysis revealed a significant group effect in the 200 m split times ($F = 5.213$; $p = 0.008$), indicating that the ST group was faster than the ET group ($p = 0.0056$); however, no significant differences were found in 400 m, 600 m, or total 800 m times. Within subgroups, ST runners' first 200 m segment was significantly faster than the subsequent three segments ($p < 0.0001$), whereas in the SP group, all 200 m splits differed significantly from each other except between the second and third segments ($p = 0.252$). In the ET group, the first 200 m was also faster, but no significant difference was observed between the next two segments. The decrease in speed between 200 m and 800 m was significantly smaller in the ET group compared to the ST group ($p = 0.032$), while the SP group showed no difference. ST runners occupied significantly higher positions at 200 m, 400 m, and 600 m than the SP and ET group members ($p < 0.05$), although there was no difference in final positions among the three groups. Correlational analysis showed that the first three 200 m split times positively correlated with 800 m performance across all runners ($r = 0.33$ – 0.41 ; $p < 0.01$), while no association was found between the last 200 m split and final result. In the ST group, the first and third 200 m splits, and in the SP group, the second and third splits showed significant correlations with performance. No significant relationships were found between split times and final results in the ET group. In the ET group, instantaneous positions at 200 m, 400 m, and 600 m positively correlated with final performance ($r = 0.54$ – 0.66 ; $p < 0.05$), but position changes and performance showed no significant association in any group.

2. Results of the Psychological Characteristics Examination of Hungarian National Long-Distance Runners

Neuroticism showed a positive correlation with cognitive and somatic anxiety and a negative relationship with self-confidence. Self-confidence was strongly negatively correlated with both forms of anxiety. The personality trait openness was positively associated with identified and integrated motivational regulation. External regulation and amotivation positively correlated with anxiety and negatively with self-confidence. The reliability of the questionnaires was adequate (Cronbach $\alpha = 0.6$ – 0.9).

Hungarian national long-distance runners scored significantly higher than the control group in conscientiousness ($t = 3.72$; $p = 0.0006$; $d = 1.17$) and openness ($t = 2.19$; $p = 0.034$; $d = 0.69$). They exhibited lower anxiety, higher self-confidence, and significantly lower

amotivation scores ($t = -2.05$; $p = 0.046$; $d = -0.65$). Although after FDR correction (Benjamini & Hochberg, 1995), conscientiousness ($FDR = 0.008$) remained significant, while openness ($FDR = 0.240$) and amotivation ($FDR = 0.217$) did not. Differences in introjected and external regulation were lower but not significant.

Multiple linear regression showed that neuroticism was significantly predicted by cognitive anxiety ($t = 4.82$; $p = 0.001$), while self-confidence had a negative relationship with it ($t = -4.12$; $p = 0.001$). Openness showed strong associations with identified ($t = 2.48$; $p = 0.02$) and integrated regulation ($t = 2.95$; $p = 0.01$). 68% of the runners participated in sport psychological preparation, averaging 2.31 hours per week ($SD = 1.84$), primarily using relaxation, cognitive, and concentration techniques. The control group's participation rate was 66.6%, with an average of 1.88 hours per week ($SD = 1.55$). The duration of mental preparation showed no correlation with anxiety levels, and participation in sport psychological training did not result in significant differences in anxiety.

3. Results of the Investigation of Mental Preparation in International Long-Distance Runners

Examining the normal distribution of the sample, skewness values ranged between -2 and +2, and kurtosis values between -7 and +7, without extreme outliers, confirming the assumption of normality and negating the need for robustness tests (Byrne, 2013; Hair et al., 2014). The subscales and total scale scores demonstrated adequate and acceptable internal consistency (Cronbach- $\alpha > 0.70$; McDonald's Omega between 0.69 and 0.95), indicating reliable measurement instruments (Cortina, 1993; Edwards et al., 2021). Significant positive correlations were found between subscales ($p < 0.001$), and point-biserial correlation indicated a significant positive association between gender and Self-Talk ($r = 0.179$, $p = 0.011$), suggesting women tend to score higher on Self-Talk, while no significant associations were found between gender and other variables.

Confirmatory factor analysis results indicated a statistically significant model ($p < 0.001$) with excellent fit indices ($\chi^2(246) = 160$, CFI = 0.95, TLI = 0.94, SRMR = 0.06, RMSEA = 0.05), confirming the construct validity of the English version of the Sport Mental Training Questionnaire (SMTQ) 20-item factor structure. All item factor loadings were significant ($p < 0.001$), and correlations between scales were also significant ($p < 0.001$), thus SMTQ's factor structure and reliability conformed to expectations.

Group comparisons via one-way ANOVA showed no statistically significant differences among runners specializing in different distances across all examined mental skill categories (e.g., Foundation Skills: $F(3, 197) = 0.268, p = 0.848$; Performance Skills: $F(3, 197) = 0.510, p = 0.676$; Self-Talk: $F(3, 197) = 0.610, p = 0.609$). Similarly, comparison by competition level (Recreational, National, International) revealed no significant differences in any skill category, although Interpersonal Skills approached significance ($F(2, 198) = 2.743, p = 0.067$) without reaching the threshold.

Independent samples *t*-tests comparing lower (recreational) and higher competition levels also found no significant differences in most skill categories (e.g., Foundation Skills: $t(199) = 0.383, p = 0.702$; Performance Skills: $t(199) = -0.443, p = 0.658$). Interpersonal Skills showed a borderline difference ($t(199) = 1.972, p = 0.050$), while Self-Talk, Imagery, and the Total Score showed no significant differences.

Importantly, comparisons between groups engaged in mental preparation (M.P.) and those not (N.M.P.) via independent samples *t*-tests revealed statistically significant differences in several mental skills. Interpersonal Skills differences were moderate ($t(199) = -2.610, p = 0.010$, Cohen's $d = 0.39$), with the non-prepared group ($M = 14.23, SD = 3.18$) scoring lower than the prepared group ($M = 15.40, SD = 2.88$). Self-Talk also showed significant differences ($t(199) = -3.303, p = 0.001$, Cohen's $d = 0.49$), with mentally prepared athletes scoring higher ($M = 12.45, SD = 2.18$) than non-prepared ($M = 11.18, SD = 3.15$). Imagery showed a significant difference ($t(199) = -3.180, p = 0.002$, Cohen's $d = 0.47$), as did the Total Score ($t(199) = -2.331, p = 0.021$), where mentally prepared athletes performed better. The most frequently used mental preparation technique was mental training (36%), followed by relaxation (27%) and mindfulness-based methods (23%). A significant proportion of athletes performed mental preparation independently or informally, with only a few under professional supervision. The most common strategies in tactical preparation were practicing pace changes (51%), simulating competition situations (25%), and video analysis (36%). No respondents reported group mental training.

4. Results of Group Mindfulness Intervention

Descriptive statistical analyses revealed no significant differences between the experimental and control groups regarding age, running experience, performance level, race distance, or gender, nor in the psychological variables at pretest ($p > 0.05$). The internal consistency of the questionnaires was acceptable for both pre- and post-tests (Cronbach's $\alpha = 0.67$ – 0.94).

Regarding the effects of the MSPE intervention, the time $\times$ group interaction was significant for flow state ($F(1,18) = 12.45$, $p = 0.002$, $\eta^2 = 0.41$), indicating intervention efficacy, although the main effect of time did not reach significance ($p = 0.072$). For cognitive anxiety, both the main effect of time ($F(1,18) = 11.51$, $p = 0.003$, $\eta^2 = 0.39$) and the interaction effect ($F(1,18) = 10.53$, $p = 0.004$, $\eta^2 = 0.37$) were significant, reflecting a strong decrease in the experimental group. Somatic anxiety decreased over time ($F(1,18) = 6.97$, $p = 0.017$, $\eta^2 = 0.28$), but the interaction effect was not significant ($p = 0.07$). For mindfulness, the interaction effect was significant ($F(1,18) = 6.21$, $p = 0.02$, $\eta^2 = 0.26$), while the main effect of time was not ($p = 0.24$). Emotion regulation showed significant improvement over time ($F(1,18) = 6.78$, $p = 0.02$, $\eta^2 = 0.27$), but the interaction was not significant ($p = 0.23$). Participants subjectively rated the intervention positively: usefulness was rated $M = 4.3$ ($SD = 0.45$) and satisfaction with practice $M = 3.9$ ($SD = 0.7$). Qualitative feedback highlighted the beneficial effects of the 3R technique and breathing exercises in training and competition settings.

Conclusions

Analyses of race tactics in male middle-distance runners revealed that the type of competition significantly influences tactical decisions. The "record tactic" used in Grand Prix races aided by pacemakers differs substantially from the more uncertain "victory tactic" characteristic of world championship finals, particularly in pacing and positioning during the first half of the race. In 800 m races, optimal times are achieved with positive pacing, where the first lap is on average two seconds faster than the second, with speed progressively decreasing by approximately 0.5 seconds per segment. For 1500 m, even or slightly negative pacing yields the best results, with the first segment slightly slower than the second, and lap times exhibiting an inverted U-shaped pattern. In world championship finals, the first segment is significantly slower than in record attempts, position changes are more frequent, and time deficits accrued in the first half cannot be compensated in the second, resulting in generally lower performance. Olympic and World Championship 800 m races show an inverted U-shaped pacing in all rounds, with a fast initial 200 m followed by deceleration and acceleration starting at 500 m. Successful athletes' physiological and psychological adaptability enables reaction to pace changes and maintenance or increase of speed at the race's end, crucial under the load of multiple rounds. Minimal form differences among finalists make appropriate tactical application critical. Strategies must leverage individual

strengths: faster runners benefit from a quick start and front positioning early, while endurance-strong runners may optimize by slower starts, even pacing, and overtaking in the second lap. The 400–600 m segment is particularly important, showing the strongest positive correlation with 800 m performance. Multi-round world competitions pose specific tactical and mental challenges requiring targeted seasonal preparation by athletes and coaches in both tactics and mental training.

Sport psychological studies indicate that personality traits, motivational patterns, and competitive spirit of international-level distance runners generally do not differ significantly from athletes in other sports at similar levels. Higher openness and conscientiousness, dominance of intrinsic motivation, and absence of amotivation are fundamental for successful long-term systematic training. Conversely, high neuroticism markedly increases the risk of competitive anxiety and amotivation, while higher self-confidence protects against cognitive and somatic anxiety.

Research on long-distance runners' mental preparedness is scarce. Results from the Sport Mental Training Questionnaire (SMTQ) confirm it as a reliable and effective tool for measuring mental skills and evaluating associations between mental preparedness and performance in long-distance runners. Mental preparedness showed no significant differences by gender, competition level, or event type; however, the positive effect of sport psychological training was evident. Women showed greater propensity for self-talk techniques. Limitations include biases of self-report methods and the cross-sectional design precluding causal inferences. Nevertheless, the SMTQ is suitable for assessing and developing mental skills in long-distance runners.

This study is the first to investigate effects of a mindfulness-based group sport psychological intervention among highly experienced national and international long-distance runners. The intervention significantly improved key psychological states, notably flow experience, mindfulness, and anxiety management compared to controls. Emotion regulation improved but was not group-specific. Although sample size was limited and the control group was non-randomized, results support the efficacy of targeted mental interventions for enhancing sport performance and mental well-being. Further research with larger samples, randomized control groups, and longer follow-up is warranted. The MSPE intervention tailored for long-distance runners is a promising approach for performance enhancement, anxiety regulation, and mental well-being improvement, with its group format, structured design, and present-focused approach offering accessibility to broader athlete populations.

Table 1: Overview of the Dissertation Hypotheses.

Hypothesis	Note
Hypotheses related to race tactical analyses.	
(H1.a): It was hypothesized that athletes show different tactical behaviors in world championship finals and Grand Prix races.	Supported
(H1.b): It was hypothesized that more pace changes can be observed analyzing 100 m split times than at 200–400 m splits.	Supported
(H1.c): It was hypothesized that pacing profiles differ between successful and less successful athletes.	Supported
(H1.d): It was hypothesized that successful athletes expend different efforts during each round.	Supported
(H1.e): It was hypothesized that at world championships, alongside tactical races, personal best performances are also typical.	Supported
(H1.f): It was hypothesized that tactics of elite 800 m runners in pacing and positioning align with their individual strengths.	Supported
Hypotheses related to psychological characteristics of Hungarian national team distance runners.	
(H2.a): It was hypothesized that there are no significant differences in personality traits between national team distance runners and the control group.	Not supported
(H2.b): It was hypothesized that national team distance runners primarily possess intrinsic motivation.	Supported
(H2.c): It was hypothesized that sport psychological preparation reduces cognitive anxiety levels.	Not supported
(H2.d): It was hypothesized that self-confidence has a protective effect against competitive anxiety.	Supported
Hypotheses regarding SMTQ reliability and mental preparedness of international distance runners.	

(H3.a): It was hypothesized that the SMTQ questionnaire reliably measures mental preparedness of distance runners.	Supported
(H3.b): It was hypothesized that sport level affects athletes' mental preparedness.	Not supported
(H3.c): It was hypothesized that gender and race distance influence the application of mental skills.	Partially supported
(H3.d): It was hypothesized that sport psychological preparation improves the level of mental preparedness.	Supported
Hypotheses regarding the effects of group MSPE intervention.	
(H4.a): It was hypothesized that the experimental group will show significant improvement in flow experience ability following group MSPE intervention, while no such changes are expected in the control group.	Supported
(H4.b): It was hypothesized that the experimental group will significantly reduce competitive anxiety following group MSPE intervention, while no changes are expected in the control group.	Supported
(H4.c): It was hypothesized that the experimental group will significantly increase mindfulness ability following group MSPE intervention, while no such changes are expected in the control group.	Supported
(H4.d): It was hypothesized that the experimental group will significantly reduce difficulties in emotion regulation following group MSPE intervention, facilitating better emotion regulation, while no such improvement is expected in the control group.	Not supported

Practical Recommendations

Based on the results, distance running training requires a complex, multidimensional approach that integrates physical, tactical, and mental preparation. Precise physiological monitoring and the development of race tactical skills are crucial for optimizing performance. Mental preparation—particularly the management of competitive anxiety, attention focus, and emotion regulation—plays a significant role in maintaining competitiveness, for which regular monitoring of mental skills is recommended. Furthermore, consideration of athletes' personality traits and motivational mechanisms is essential for personalized and sustainable long-term development.

List of Own Publications

Related to the dissertation

1. **Kelemen B**, Benczenleitner O, Tóth L. (2022) Are 800-m runners getting faster? Global competition performance trends between 1999 and 2021. *J Phys Educ Sport*, 22(9):2231–2237.
2. **Kelemen B**, Csányi T, Révész L, Benczenleitner O, Tóth L. (2023) Comparison of winning and record tactics in elite-level male middle-distance running. *J Phys Educ Sport*, 23(2):469–475.
3. **Kelemen B**, Benczenleitner O, Tóth L. (2021) A 2021-es tokiói olimpiai játékok 800 méteres síkfutásának elemzése irambeosztás szempontjából. *Testnevelés Sport Tudomány*, 6(3–4):23–28.
4. **Kelemen B**, Tóth R, Benczenleitner O, Tóth L. (2024) Psychological Profile of Hungarian International-Level Distance Runners. *J Clin Sport Psychol*, published online ahead of print. Retrieved from: <https://doi.org/10.1123/jcsp.2024-0024>
5. **Kelemen B**, Tóth R, Benczenleitner O, Tóth L. (2024) Mental preparation in runners: gender differences, competition levels, and psychological training effects on performance. *Front Sports Act Living*, 6:1456504.
6. Gyimes Z, **Kelemen B**, Kovács B. (2025) Classification and race characteristics of all-time best male 800m runners. *Sci J Sport Perform*, 4(1):000–000.
7. **Kelemen B**, Tóth R, Benczenleitner O, Tóth L. (2025) Effects of group mindfulness intervention on high-level distance runners: a quasi-experimental study. *Front Sports Act Living*, 7:1556404.

Publications Not Related to the Dissertation

1. **Kelemen B**, Benczenleitner O, Gyimes Z, Tóth L. (2023) Polarized training intensity distribution in distance running: A case study of the 2021 Olympic long-distance runner. *Sustain Sports Sci J*, 2(1):58–66.
2. **Kelemen B**, Benczenleitner O, Tóth L. (2024) Easy interval method, an alternative approach to improve anaerobic threshold speed. *Sci J Sport Perform*, 3(2):220–227.
3. **Kelemen B**, Benczenleitner O, Tóth L. (2021) Magyarországi utcai hosszútávfutó versenyek tendenciájának elemzése részvételi szám és teljesítmény szempontjából (1984 és 2020 között). *Magy Sporttud Szle*, 22(94):17–23.

4. **Kelemen B**, Benczenleitner O, Tóth L. (2023) Norwegian double-threshold method in distance running. *Sci J Sport Perform*, 3(1):38–46.
5. **Kelemen B**, Benczenleitner O, Tóth L. (2022) Polarized and pyramidal training intensity distributions in distance running: An integrative literature review. *Testnevelés Sport Tudomány*, 7(3–4):40–49.
6. **Kelemen B**, Benczenleitner O, Tóth L. (2022) A norvég állóképességi modell közép- és hosszútávfutásban: Szisztematikus irodalmi áttekintés = The Norwegian Endurance Model in Middle and Long-Distance Running: A Systematic Review of the Literature. *Magy Sporttud Szle*, 23(4):19–25.
7. **Kelemen B**, Benczenleitner O, Tóth L. (2024) The role of Northern European countries in the emergence of new training methods in distance running: A historical overview. *SPRINT Sports Res Int*, 2024.
8. **Kelemen B**, Benczenleitner O, Tóth L. (2025) Emerging trends in distance running training: Bridging science and empirical insights — A narrative review. *Int J Sports Sci Coach*, published online ahead of print. Retrieved from: <https://doi.org/10.1177/17479541251356570>