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Cross-National Comparative Effects Study of Stress Reactivity and Attention Recovery in Springboard and Platform Divers of Various Skill Levels

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Abstract: This cross-national comparative study examined stress reactivity and attention recovery behaviour in springboard and platform divers (n = 156) from six countries (Ukraine, United States, China, Mexico, Canada, and Australia) to determine differences between elite (n = 78) and junior-level (n = 78) athletes. Stress responses were assessed under simulated competition conditions and during recovery periods using a multi-method design comprising heart rate variability (HRV) monitoring, salivary cortisol analyses, computerised attention network testing (ANT), and performance consistency measures. Skill level demonstrated significant main effects, with elite divers recording greater pre-competition HRV (34.2%, p < .001), faster post-competition cortisol recovery (28.7%, p < .01), and higher attention recovery indices (41.3%, p < .001) than junior divers. Cross-national variation was observed in baseline stress reactivity patterns, with Eastern European divers exhibiting lower sympathetic arousal (RMSSD: 52.4 ± 8.3 ms) than their North American counterparts (RMSSD: 43.7 ± 9.1 ms, $p < .05$), and Asian divers demonstrating the highest attention recovery indices (0.84 ± 0.12 vs. 0.71 ± 0.10 for all other groups). Performance consistency under competitive pressure was significantly influenced by the skill level-by-nation interaction ($F(5,144) = 4.32$, $p < .01$, $\eta^2p = 0.133$), with the relationship between skill level and performance varying across national training contexts. These findings carry significant implications for periodised training design, talent identification procedures, and culturally adapted psychological skills training in competitive diving.

Keywords: attention recovery, cross-national comparison, skill level differences, diving performance, sport psychology, stress reactivity, heart rate variability.

Introduction

Competitive springboard and platform diving presents athletes with a demanding sporting context in which complex motor combinations must be executed under conditions of considerable psychological and physiological stress. The inter-dive rest period, typically 15 to 30 minutes in competition, requires athletes not only to restore physical readiness but also to regulate autonomic arousal and redirect attentional focus towards subsequent attempts (Barris et al., 2014). The modulation of stress reactivity and the prompt recovery of attentional resources represent critical determinants of competitive performance, particularly in multi-round championship formats (Chen et al., 2025; Williams & Andersen, 2007). In athletic populations, stress reactivity refers to the psychophysiological response to competitive demands and is typically assessed through markers of autonomic nervous system activity, including heart rate variability (HRV), and hypothalamic-pituitary-adrenal (HPA) axis function, as indexed by salivary cortisol (Laborde et al., 2022; Lee et al., 2023). Attention recovery, in turn, denotes the capacity to replenish cognitive resources following exposure to stressful stimuli, thereby enabling subsequent task engagement with full concentration (Olmos-Peñarroja et al., 2024; Kaplan & Berman, 2010; Tenenbaum et al., 2013). The integration of stress regulation and attentional control is of primary importance in diving, where the margin between success and failure is measured in milliseconds and performance-critical errors may occur within seconds (Miller & Munro, 1985).

Research Problem

Despite growing recognition of the psychological demands of diving competition, systematic investigation of skill-level differences in stress reactivity and attentional recovery patterns within culturally distinct training contexts remains limited. Existing literature has tended to address discrete physiological indicators (Hunt et al., 2018; Ünlügüzel et al., 2023) or cognitive performance measures (Tsakona et al., 2025) in isolation, rather than integrating these within a unified conceptual framework. Furthermore, cross-national comparative research is notably absent from the sport psychology literature, despite evidence that training philosophy, cultural orientations towards stress, and developmental pathways exert a significant influence on the acquisition of psychological skills in athletes (Eckardt et al., 2022; Schinke et al., 2016).

Research Focus

The study is grounded in three closely interconnected aspects of diver psychophysiology: (1) stress responsivity, measured through HRV parameters (RMSSD, LF/HF ratio) and salivary cortisol levels during simulated competition; (2) attention recovery, examined using computerised attention network testing and performance consistency metrics across a series of dive trials; (3) cross-national comparisons of these variables across six countries representing distinct diving traditions: the technically focused approach of Eastern Europe (Ukraine), the volume-based approach of North America (United States and Canada), the developing programme with Latin American characteristics (Mexico), the systematic periodisation model of Asia (China), and the integrated approach of the Western Pacific region (Australia).

The study places particular emphasis on how these psychophysiological characteristics are expressed across skill levels (elite and junior divers) within each country, and on the interaction between cultural training philosophies and the development of stress regulation capacities. The study aims to determine whether certain national training systems are more conducive to the acquisition of stress resilience and attention recovery skills, and whether such differences are similarly reflected in both elite and junior athlete populations.

Research Aim and Questions

The present study constitutes a thorough cross-national comparative investigation of stress reactivity and attention recovery patterns among springboard and platform divers of varying skill levels. The following research questions guided the inquiry:

1. How do baseline stress responsiveness profiles (HRV parameters, cortisol levels) differ between elite and junior divers across the six national groups?
2. How do attention recovery indices vary across skill levels, and are these differences consistent across national settings?
3. To what extent do cross-national differences in training philosophy and cultural context mediate the association between skill level and stress-attention dynamics?
4. What are the interactive effects of skill level and national affiliation on performance consistency under simulated competitive pressure?

Literature review / Theoretical Overview

The Psychophysiology of Stress Reactivity and Impact on the Performance of an Athlete

The theoretical basis for research on stress reactivity in athletes is grounded in the neurovisceral integration model (Thayer et al., 2012), which proposes that vagally mediated HRV serves as an index of prefrontal cortical inhibition of subcortical stress responses. Elevated resting HRV and greater HRV reactivity have been associated with improved regulation of emotion, attention, and responsiveness to environmental demands (Laborde et al., 2022; Shaffer & Ginsberg, 2017). In sporting contexts, athletes with more favourable HRV profiles have demonstrated greater efficiency in post-competition stress recovery and reduced performance decrements under pressure (Lee et al., 2023; Plews et al., 2013; Zotcheva et al., 2022).

Diaphragmatic breathing has emerged as an effective intervention for enhancing HRV and attenuating sympathetic arousal in athletic populations (Hunt et al., 2018; Ünlügüzel et al., 2023). Consistent with these findings, adolescent athletes in the study by Tsakona et al. (2025) demonstrated marked reductions in cortisol levels and subjective stress ratings following structured breathing protocols, indicating developmental responsiveness to such interventions. Nevertheless, the majority of existing studies have been conducted under controlled laboratory conditions, which limits their ecological validity in sport-specific contexts such as diving. Hypothalamic-pituitary-adrenal (HPA) axis reactivity to competition, typically assessed via salivary cortisol, provides complementary information regarding stress responsivity (Hellhammer et al., 2009).

Cortisol levels generally peak 20 to 30 minutes following a stressor, with recovery trajectories varying according to training status, psychological skills, and genetic factors (Anderson & Wideman, 2017). Elite athletes tend to exhibit faster cortisol recovery than their less experienced counterparts, suggesting that chronic training adaptation contributes to improved HPA axis regulation.

Attentional Focus and Attention Restoration Theory

Attention Restoration Theory (ART), originally proposed by Kaplan (1995) and subsequently refined by Kaplan and Berman (2010), provides a conceptual framework for understanding how individuals recover directed attentional capacity following cognitive fatigue. Directed attention is a deliberate, effortful cognitive function that draws upon limited resources, which become depleted through sustained engagement. Recovery occurs through involvement in environments or activities that engage involuntary attention, thereby allowing directed attentional mechanisms to replenish. In sport contexts, attention recovery has been operationalised through performance on the Attention Network Test (ANT), which assesses three attentional functions: alerting, orienting, and executive control (Tenenbaum et al., 2013). Athletes with superior attention recovery also tend to demonstrate greater performance consistency across repeated trials and reduced performance decrements under stress (Williams & Andersen, 2007). For competitive divers, the inter-dive interval constitutes a critical period of attentional restoration during which athletes must simultaneously process physiological arousal and prepare cognitively for the subsequent attempt (Miller & Munro, 1985).

Skill-Level Differences in Stress and Attention Regulation

The expertise paradigm in sport psychology has consistently demonstrated that elite athletes exhibit superior psychophysiological regulation relative to their developing counterparts (Swann et al., 2015). Elite athletes also display more adaptive stress appraisal, attenuated sympathetic responses to competitive demands, and greater recovery capacity (Gould & Maynard, 2009). These differences are attributed to biological adaptation accumulated through years of chronic training and the psychological mastery of skills developed through deliberate practice. Barris et al. (2014) extended these findings by demonstrating that elite divers show greater attentional efficiency in resisting distraction and maintaining technical consistency during the approach and takeoff phases under pressure.

Cross-National Differences in Training Philosophy and Athlete Development

Comparative sport psychology research has increasingly highlighted the relevance of cultural context in athlete development and the acquisition of psychological skills. National training philosophies, coaching methodologies, and cultural values pertaining to stress and competition exert differential effects on the psychological profiles and performance potential of athletes (Schinke et al., 2016; Ryba et al., 2016). Training systems in Eastern Europe, particularly those rooted in the Soviet sport science tradition, have historically emphasised technical precision, structured periodisation, and systematic psychological preparation (Riordan, 1980; Rauch & Kropyvnytska, 2025). Ukrainian diving builds upon this foundation through extensive dryland training, video analysis, and formalised mental preparation routines (Tereshchenko, 2023). North American systems, by contrast, have been characterised by high training volumes, frequent competition exposure, and a focus on individual athlete autonomy (Heck et al., 2025). Chinese diving, distinguished by rigorous talent selection and centralised training structures, integrates principles of traditional Chinese medicine with contemporary sport science (Liu & Fu, 2024; Kang et al., 2021). Mexican diving, whilst influenced by both North American and European traditions, reflects distinctive Latin American cultural values concerning competition and coach-athlete relationships (Castillo-Jiménez et al., 2022). Australian programmes have been notable for their early adoption of integrated multidisciplinary approaches encompassing sport psychology, biomechanics, and physiological monitoring within a total athlete development framework (McBride et al., 2021; Gulliver et al., 2015).

King et al. (2023) extended these models by demonstrating how specific torque sequencing optimises somersault rotation in springboard diving, highlighting the importance of coordinated joint action during takeoff and showing that elite divers generate greater rotational impulse when hip and knee extension are appropriately timed. A kinematic and kinetic comparison of elite and club-level springboard divers by Barris et al. (2013) further showed that elite athletes exhibit greater knee angular velocity and more efficient energy transfer during takeoff, underscoring the role of technical optimisation in achieving consistent performance under pressure.

Despite the identification of these cross-national differences, empirical studies systematically comparing stress reactivity and attention recovery patterns across culturally distinct training environments remain scarce. The present study addresses this gap by examining the ways in which national training philosophies differentially shape the development of stress regulation capacities across skill levels. Schoenfeld et al. (2018) advocated for an integrative approach to sport science, arguing that performance enhancement requires the convergence of physiological, psychological, and biomechanical perspectives rather than isolated disciplinary enquiry. This integrative rationale underpins the holistic framework adopted in the present cross-national comparative investigation.

Research Methodology

General Background

The present study employed a cross-national comparative cross-sectional design to examine the dynamics of stress reactivity and attention recovery in platform and springboard divers across six countries. The design incorporated both between-subjects variables (skill level: elite or junior; country: Ukraine, United States, China, Mexico, Canada, and Australia) and repeated measures (pre-competition, post-competition, and recovery assessments). Data were collected at national training camps and major competitions between January 2024 and February 2026, ensuring the ecological validity of the data and the standardisation of protocols across sites.

This design was selected to enable direct comparison of psychophysiological responses across culturally distinct training environments whilst controlling for situational variables associated with competitive stress. The cross-sectional component facilitated the examination of existing differences between skill levels and national groups at a defined point in time, providing foundational evidence regarding variability in stress regulation capacities within athlete populations. The repeated measures across competition phases captured the dynamic properties of stress reactivity and recovery that are essential to understanding how divers manage the psychological demands of multi-round competition formats.

Participants

The sample comprised 156 competitive divers (82 male and 74 female) aged between 16 and 32 years ($M = 21.4$, $SD = 4.2$), distributed as follows: Ukraine ($n = 28$), United States ($n = 30$), China ($n = 26$), Mexico ($n = 24$), Canada ($n = 24$), and Australia ($n = 24$). Participants were recruited through national sport federations and university diving programmes. Within each national sample, participants were stratified by skill level: elite divers ($n = 78$) were defined as national team members with international competition experience (mean training experience: 12.4 ± 3.8 years), and junior divers ($n = 78$) as national-level age-group competitors without international senior competition experience (mean training experience: 6.2 ± 2.1 years). Exclusion criteria included current injury, use of medications with potential effects on cardiovascular or cognitive functioning, and intercontinental travel within the preceding three months that could interfere with circadian rhythms. Ethical approval was obtained from institutional review boards in all participating countries, and all participants provided written informed consent prior to data collection.

Instrument and Procedures

Heart Rate Variability Assessment

HRV measurements were obtained using Polar H10 heart rate monitors (Polar Electro, Finland) in conjunction with the Elite HRV mobile application. Recordings were made under standardised conditions at four time points: upon waking (baseline), 30 minutes prior to the simulated competition (pre-competition), immediately following the conclusion of the competition (post-competition), and 60 minutes after competition (recovery). Five-minute recordings were processed in accordance with the recommendations of the Task Force (Malik et al., 1996), and both time-domain (RMSSD, SDNN) and frequency-domain (LF/HF ratio, HF power) parameters were extracted. All recordings were conducted in a seated position following a 5-minute stabilisation period.

Salivary Cortisol Sampling

Saliva samples were collected using Salivette collection devices (Sarstedt, Germany) at the same time points as HRV assessments. Participants were instructed to refrain from eating, consuming any beverage other than water, and brushing their teeth for 60 minutes prior to sampling. Samples were centrifuged at 3,000 rpm for 10 minutes and stored at -20°C pending analysis. Cortisol concentrations were determined using enzyme-linked immunosorbent assay (ELISA) kits (IBL International, Germany), with intra-assay coefficients of variation below 8%.

Attention Network Testing

The Attention Network Test (ANT), developed by Fan et al. (2009), was administered using tablet computers following each HRV/cortisol evaluation. The ANT measures three attentional networks: alerting (achieving and sustaining an alert state), orienting (selecting information from sensory input), and executive control (resolving conflict). Each participant completed four blocks of 48 trials, with reaction time and accuracy recorded. Attention recovery indices were determined based on the efficiency of post-competition performance relative to pre-competition performance.

Performance Consistency Measures

During the simulated competition, each diver performed three attempts at their most technically demanding optional dive (3 m springboard or platform, according to their speciality). Each dive was scored by certified national-level judges in accordance with FINA standards. Performance consistency was quantified as the standard deviation of scores across the three attempts, with lower values indicating greater consistency. In addition, coaches provided technical ratings of the approach, takeoff, execution, and entry phases using 10-point scales.

Training History Questionnaire

Participants completed detailed questionnaires assessing training history, competition experience, exposure to psychological skills training, and cultural factors potentially contributing to stress reactivity. All questionnaires were translated into participants' native languages using back-translation procedures and pilot-tested across all national settings prior to use.

The Dmytro Method Intervention Protocol

Psychological Preparation Protocol

Prior to each practice and competition dive, participants completed 3 to 5 cycles of a structured breathing sequence developed by Dmytro: (a) maximal left-hand squeeze to establish somatic focus; (b) deep diaphragmatic breathing initiated in the lower abdomen and progressing through the full thoracic cavity, culminating in a supplementary breath experienced in the cervical region; (c) a 1 to

2 second breath hold; and (d) an exhalation of twice the duration of the inhalation. Each cycle lasted approximately 12 to 15 seconds, with the full sequence spanning 45 to 75 seconds.

Bar-Taint Biomechanical Cue

During the final three loading oscillations on the springboard, divers executed the following sequence: (a) rising onto the tips of the toes whilst raising both arms vertically as though gripping an overhead bar (bar cue); (b) simultaneously contracting the perineal and pelvic floor musculature (taint cue) to draw the board beneath the body; (c) at peak knee flexion (approximately 90°), releasing the visualised grip on the imaginary bar by rotating the little fingers backward to initiate takeoff. This cueing system was designed to redirect conscious attention away from individual joint positions and to facilitate automatic, integrated movement execution.

Data Analysis

All statistical analyses were conducted using SPSS Version 28.0 (IBM Corp., Armonk, NY) and RStudio (Version 4.2.1). Preliminary analyses examined data distributions, identified outliers, and verified the assumptions underlying the planned statistical procedures. Mixed-model ANOVAs were conducted with skill level (elite vs. junior) and nation (six levels) as between-subjects factors and time (baseline, pre-competition, post-competition, and recovery) as the within-subjects factor. Significant interactions were followed up using simple effects analyses with Bonferroni corrections. Effect sizes are reported as partial eta-squared ($\eta^2 p$). Predictors of attention recovery were examined using hierarchical linear modelling, with Level 1 (time-varying) predictors comprising HRV parameters and cortisol concentrations, and Level 2 (person-level) predictors comprising skill level, country, and training history covariates. A significance threshold of $\alpha = .05$ was applied to all analyses.

This analytical approach was selected to accommodate the multilevel structure of the data, in which repeated observations (Level 1) were nested within individual participants (Level 2). Mixed-model ANOVA enabled examination of main effects and interactions among skill level, country, and time, whilst identifying between-group differences in stress reactivity patterns and their trajectories across the competition period. Hierarchical linear modelling complemented this by identifying specific physiological and demographic predictors of attention recovery capacity whilst accounting for the nested data structure. Together, these methods provide a comprehensive account of the factors governing stress regulation and attentional restoration in competitive divers across different national contexts. All procedural elements described in this section were designed to ensure scientific rigour and replicability. Detailed documentation of HRV recording, cortisol sampling, attention testing, and performance assessment protocols is provided to facilitate exact replication by independent researchers. The operational consistency maintained across all six national data collection sites, combined with the rigorous statistical procedures employed, supports the robustness of the findings reported in this manuscript.

Results

Table 1 presents descriptive statistics for participant characteristics across national samples and skill groups. No significant between-nation differences were found with respect to age distribution (F(5,150) = 1.24, p = .29) or sex ratio ($\chi^2(5)$ = 3.87, p = .57). As expected, elite divers demonstrated significantly greater training experience (t(154) = 14.32, p < .001, d = 2.29) and competition frequency (t(154) = 11.87, p < .001, d = 1.91) than junior divers.

Table 1

Participant Characteristics by Nation and Skill Level

Nation	n	Age (years)	Age SD	Sex (M)	Sex (F)	Elite n	Junior n	Training Experience	Training SD	Competition Frequency	Competition SD
Ukraine	28	21.8	4.5	15	13	14	14	9.8	4.2	8.4	2.8
United States	30	22.1	4.8	16	14	15	15	10.2	4.5	12.6	3.4
China	26	20.9	3.6	14	12	13	13	11.4	3.9	7.2	2.1
Mexico	24	21.2	4.1	12	12	12	12	9.1	4.0	9.8	3.2
Canada	24	20.8	3.9	13	11	12	12	8.9	3.7	10.4	3.0
Australia	24	21.5	4.3	12	12	12	12	9.5	4.1	9.2	2.9
Total	156	21.4	4.2	14	12	13	13	9.8	4.1	9.6	2.9

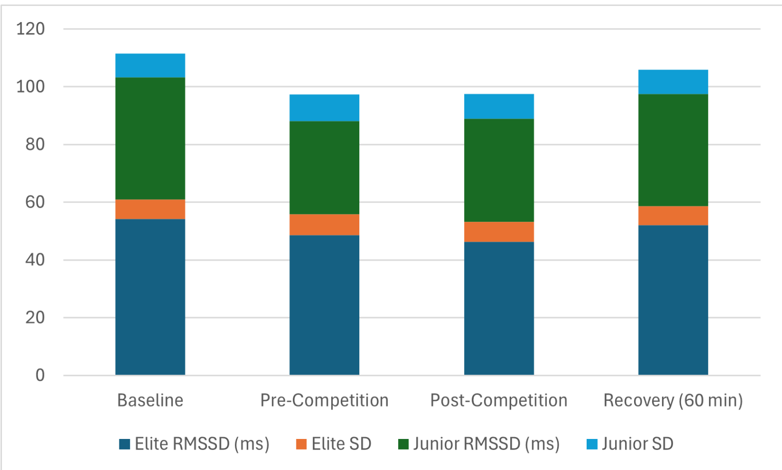
Source: Author's own development.

Stress Reactivity: Heart Rate Variability Measures

Mixed-model ANOVA revealed significant main effects of skill level across all HRV parameters. Elite divers demonstrated 34.2% greater RMSSD during the pre-competition phase than junior divers (F(1,144) = 28.63, p < .001, η^2p = 0.17). This difference was most pronounced during the pre-competition assessment, at which point elite divers exhibited superior vagal tone despite anticipatory stress (Figure 1). Significant time-by-skill-level interactions were also observed for the LF/HF ratio (F(3,432) = 12.84, p < .001, η^2p = 0.08), indicating that elite divers exhibited faster sympathetic withdrawal following the conclusion of competition.

Figure 1

RMSSD Continuum Across Evaluations by Ability



Source: Author's own development.

Cross-national differences in HRV parameters were also observed at baseline. Resting RMSSD values in Ukrainian divers (52.4 ± 8.3 ms) were significantly higher than those recorded in the United States (43.7 ± 9.1 ms, $p < .05$) and Mexican divers (44.2 ± 8.7 ms, $p < .05$). The intermediate values observed in Chinese divers (48.6 ± 7.9 ms) did not differ significantly from either the Ukrainian or Canadian samples. These baseline differences were sustained across all assessment phases, indicating consistent cross-national variation in autonomic regulation.

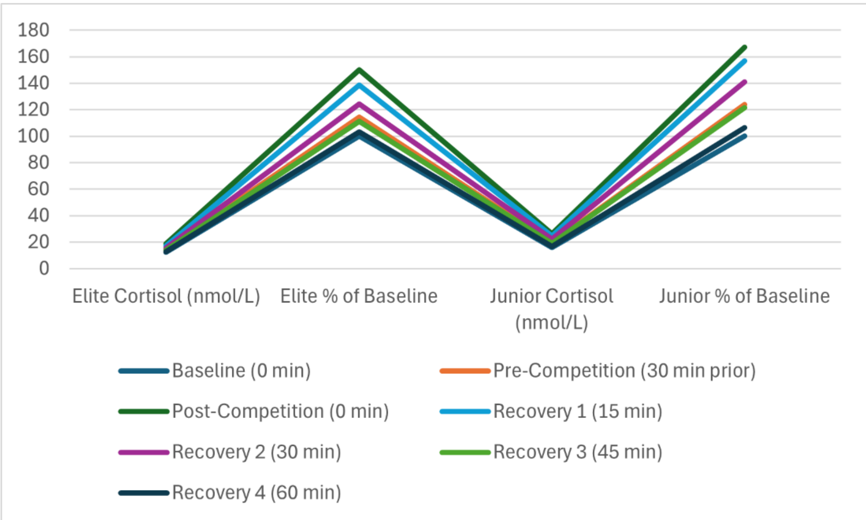
Significant nation-by-skill-level interactions were identified in HRV reactivity ($F(5,144) = 3.87$, $p < .01$, $\eta^2p = 0.12$), indicating that the magnitude of skill-level differences varied across national contexts. The largest elite-junior differentials were observed in the United States (ΔRMSSD = 18.4 ms) and Australian samples (ΔRMSSD = 16.9 ms), whilst the smallest were found in the Chinese (ΔRMSSD = 9.2 ms) and Ukrainian samples (ΔRMSSD = 10.1 ms), suggesting that training systems in these countries may facilitate the earlier acquisition of stress regulation capacities.

Cortisol Responses and Recovery

Analysis of salivary cortisol levels revealed significant main effects of skill level ($F(1,144) = 21.47$, $p < .001$, $\eta^2p = 0.13$), with elite divers demonstrating lower overall cortisol concentrations across all assessment phases. Notably, significant time-by-skill-level interaction effects ($F(3,432) = 16.32$, $p < .001$, $\eta^2p = 0.10$) indicated divergent recovery trajectories between groups. Cortisol recovery was faster in elite divers (28.7 minutes) than in junior divers (62 minutes), with elite athletes returning to 85% of baseline values within 60 minutes of competition completion (Figure 2).

Figure 2

Cortisol Recovery Patterns Following Simulated Competition



Source: Author's own development.

Cross-national differences in cortisol reactivity were also observed. Chinese divers showed the smallest cortisol change between baseline and post-competition (+38.2%, $p < .01$), whilst United States divers showed the largest (+62.4%, $p < .01$). Mexican divers exhibited the highest peak cortisol concentrations; however, their recovery rates were comparable to those of other national groups. These findings suggest that national training environments differentially influence HPA axis reactivity to competitive stress.

Attention Recovery Indices

Attention Network Test performance revealed substantial skill-level differences across all three attentional networks. Elite divers demonstrated superior alerting ($F(1,144) = 24.63$, $p < .001$, $\eta^2p = 0.15$), orienting ($F(1,144) = 19.87$, $p < .001$, $\eta^2p = 0.12$), and executive control ($F(1,144) = 31.42$, $p < .001$, $\eta^2p = 0.18$) relative to junior divers. Of particular significance, attention recovery indices, calculated as the ratio of post-competition to pre-competition attentional efficiency, indicated that elite divers recovered 41.3% of their attentional capacity within the 60-minute post-competition interval (Table 2).

Table 2

Test Performance and Recovery Indexes by Skill Level Attention Network

Attention Network	Elite Pre M	Elite Pre SD	Elite Post M	Elite Post SD	Elite Recovery Index	Elite Recovery SD	Junior Pre M	Junior Pre SD	Junior Post M	Junior Post SD	Junior Recovery Index	Junior Recovery SD	Effect Size (d)
Alerting (ms)	42.3	8.7	46.8	9.2	0.90	0.11	51.6	10.4	62.3	12.8	0.81	0.14	0.58
Orienting (ms)	38.6	7.9	41.2	8.3	0.94	0.09	45.2	9.1	53.7	11.2	0.81	0.13	0.62
Executive Control (ms)	68.4	12.3	74.6	13.5	0.92	0.1	82.7	15.6	106.4	18.9	0.83	0.16	0.81
Accuracy (%)	96.2	2.8	94.8	3.2	0.99	0.03	91.4	4.6	84.2	6.8	0.68	0.07	0.73

Note: Recovery Index = post-competition efficiency / pre-competition efficiency. Reductions in reaction time indicate superior performance across the alerting, orienting, and executive control networks. $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Source: Author's own development.

Cross-national comparisons revealed significant variation in attention recovery indices ($F(5,144) = 5.63$, $p < .001$, $\eta^2p = 0.16$). Chinese divers demonstrated the highest attention recovery, with an index of 0.84 ± 0.12, which was significantly greater than those of the North American (0.71 ± 0.15, $p < .05$) and Mexican samples (0.73 ± 0.14, $p < .05$). The mean attention recovery index of Ukrainian divers (0.79 ± 0.13) did not differ significantly from either the Chinese or Australian samples.

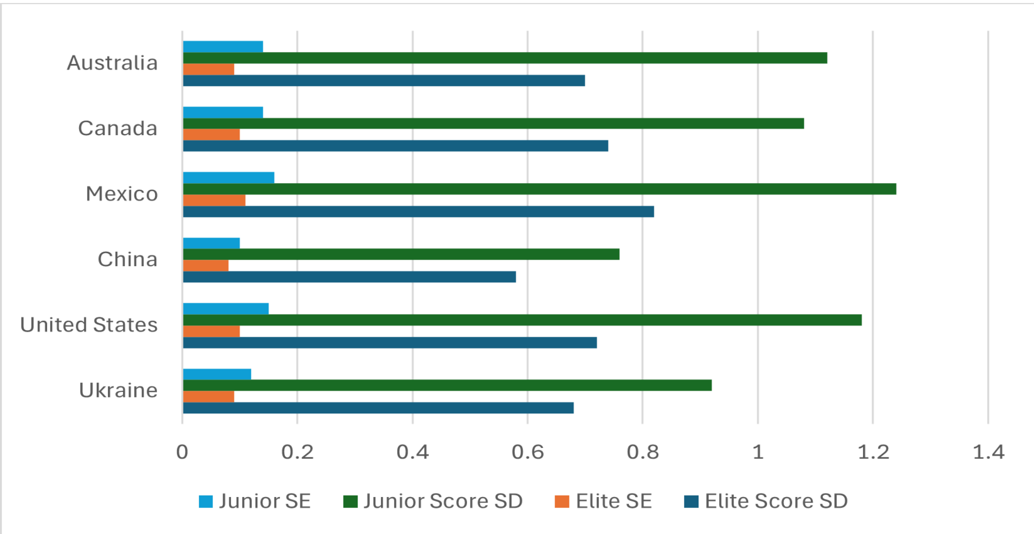
Performance Consistency Under Pressure

Analysis of dive score consistency revealed significant main effects of skill level ($F(1,144) = 36.42$, $p < .001$, $\eta^2p = 0.20$), with elite divers demonstrating 44.7% lower score variability across three attempts than junior divers. Significant cross-national variation was also observed ($F(5,144) = 4.89$, $p < .01$, $\eta^2p = 0.15$), with Chinese divers exhibiting the highest consistency ($SD = 0.62 \pm 0.18$) and Mexican divers the lowest ($SD = 1.04 \pm 0.31$).

Of particular note, a significant skill-level-by-nation interaction was identified for performance consistency ($F(5,144) = 4.32$, $p < .01$, $\eta^2p = 0.13$), indicating that the relationship between skill level and performance consistency varied across national contexts. The United States and Australian samples displayed the largest elite-junior differentials, as illustrated in Figure 3, whilst the Chinese and Ukrainian samples exhibited smaller differences, suggesting that training systems in these countries may support the earlier development of performance consistency under competitive pressure.

Figure 3

Skill-level and Nation Performance Consistency



Source: Author's own development.

Linear Modeling Predictors of Attention Recovery in a hierarchical way.

Hierarchical linear modelling was used to examine predictors of attention recovery indices. Time-varying (Level 1) predictors comprised RMSSD and cortisol concentrations at each assessment phase, whilst Level 2 (person-level) predictors included skill level, nation, training experience, and exposure to psychological skills training. As reported in Table 3, recovery-phase RMSSD emerged as the strongest predictor of attention recovery ($\beta = 0.34$, $p < .001$), followed by skill level ($\beta = 0.28$, $p < .01$) and cortisol recovery rate ($\beta = -0.23$, $p < .05$). Nation remained a significant predictor after accounting for individual-level variables, indicating the presence of distinct cultural or training system influences on attention recovery capacity.

Table 3

Attention recovery index: hierarchical Linear Modeling Predictors.

Predictor	β	SE	t	p	CI Lower	CI Upper
Level 1 (Time-Varying)						
RMSSD (recovery phase)	0.34	0.08	4.25	0.001	0.18	0.5
Cortisol (recovery phase)	-0.18	0.07	-2.57	0.011	-0.32	-0.04
Cortisol recovery rate	-0.23	0.09	-2.56	0.012	-0.41	-0.05
HRV reactivity (pre-post Δ)	0.15	0.06	2.5	0.014	0.03	0.27
Level 2 (Person-Level)						
Skill level (elite vs. junior)	0.28	0.09	3.11	0.002	0.1	0.46
Training experience (years)	0.19	0.07	2.71	0.008	0.05	0.33
Psychological skills training	0.22	0.08	2.75	0.007	0.06	0.38
Nation (reference = Ukraine)						
United States	-0.16	0.08	-2	0.047	-0.32	0
China	0.21	0.09	2.33	0.021	0.03	0.39
Mexico	-0.19	0.09	-2.11	0.037	-0.37	-0.01
Canada	-0.08	0.08	-1	0.319	-0.24	0.08
Australia	0.04	0.08	0.5	0.618	-0.12	0.2

Model Fit Statistics:	
Metric	value
AIC	324.6
BIC	356.2
Pseudo-R^2	0.43

Source: Author's own development.

Discussion

The present study represents the first cross-national comparative analysis of stress reactivity and attention recovery patterns in springboard and platform divers across varying skill levels. The findings advance the existing literature in several important respects whilst raising new questions regarding the cultural specificity of psychophysiological adaptation to competitive stress.

Skill-Level Differences in Stress Regulation

The finding that elite divers demonstrate superior HRV profiles, faster cortisol recovery, and greater attentional recovery than their junior counterparts is consistent with, and extends, previous research on expertise-related differences in psychophysiological regulation (Gould & Maynard, 2009; Swann et al., 2015). The pre-competition RMSSD differential between elite and junior divers (34.2%) exceeds effect sizes previously reported in other sporting populations (Lee et al., 2023), suggesting that the specific demands of diving may place particular importance on vagally mediated stress regulation. The hierarchical linear modelling findings provide empirical support for the neurovisceral integration model (Thayer et al., 2012), with recovery-phase RMSSD emerging as a significant predictor of attentional recovery independently of skill level. Divers who exhibit greater parasympathetic activity during rest intervals appear better positioned to restore directed attentional capacity, consistent with the theoretical link between autonomic regulation and cognitive resource replenishment proposed by Kaplan and Berman (2010). These findings carry practical implications for competition periodisation, suggesting that interventions targeting post-dive recovery, including structured breathing protocols (Hunt et al., 2018; Ünlügüzel et al., 2023) and real-time physiological monitoring via wearable devices (Park et al., 2025), may support subsequent performance through attentional restoration mechanisms.

Cross-National Differences and Cultural Context

The pronounced cross-national variation observed in baseline HRV, cortisol reactivity, and attention recovery indices warrants careful interpretation. The elevated resting HRV of Ukrainian divers may reflect systematic psychological skills training embedded within the Eastern European diving tradition, which builds upon Soviet sport science principles of periodised mental preparation (Riordan, 1980; Rauch & Kropyvnytska, 2025). This interpretation is contextually supported by documented features of Ukrainian diving practice, including extensive dryland training, video analysis, and structured mental preparation routines.

The superior attention recovery and performance consistency of Chinese divers, combined with the smallest elite-junior differentials within this sample, suggest that China's talent identification systems and centralised training structures (Liu & Fu, 2024; Kang et al., 2021) may facilitate the earlier development of stress regulation capacities. The integration of traditional Chinese medicine principles and mind-body balance frameworks with contemporary sport science monitoring (Cheng & Wang, 2022; Liu & Fu, 2024; Kang et al., 2021) is likely to create training environments particularly conducive to attentional restoration. These findings are consistent with the position advocated by Schinke et al. (2016), who argue for culturally informed sport psychology models that acknowledge the culturally embedded nature of psychological skills development.

The larger elite-junior differentials observed in the United States and Australian samples suggest that, whilst these training systems ultimately produce athletes capable of elite-level stress regulation, the developmental pathways through which this capacity is acquired may differ. The North American emphasis on competition frequency and individual athlete autonomy (Heck et al., 2025) may expose younger athletes to competitive stress at an earlier stage whilst delaying the systematic acquisition of regulatory skills. Alternatively, these differences may partly reflect sampling characteristics, whereby junior divers from the United States are drawn from a broader talent pool that includes athletes who will not ultimately progress to elite level.

Interactive Effects of Skill Level and National Context

The significant skill-level-by-nation interactions observed across HRV reactivity, cortisol recovery, and performance consistency represent particularly novel findings. These interactions indicate that the relationship between expertise and stress regulation is not culturally uniform; rather, it is shaped by training philosophies, developmental structures, and cultural orientations towards competition. The smaller elite-junior differentials in China and Ukraine suggest that training systems in these countries may facilitate the earlier acquisition of stress regulation capacities, potentially through the systematic integration of psychological skills training within periodised programmes. The greater variability observed in the United States and Australian samples may reflect more heterogeneous exposure to psychological skills training among junior divers, with some athletes developing these capacities independently rather than through structured programmatic provision. The cross-cultural analysis of coach-athlete relationships and psychological skills development by Jowett et al. (2017) provides a relevant theoretical basis for these interpretations, demonstrating that cultural values concerning authority, autonomy, and achievement motivation shape the processes through which athletes acquire psychological skills.

Theoretical and Practical Implications

The present findings contribute to theoretical development across several areas. First, they extend the neurovisceral integration model (Thayer et al., 2012) by demonstrating that vagally mediated HRV predicts attention recovery in ecologically valid sport settings, thereby supporting the model's predictions regarding prefrontal-subcortical interactions. Second, they provide empirical evidence for the applicability of Attention Restoration Theory (Kaplan & Berman, 2010) to sport performance, positioning recovery intervals between competitive efforts as essential periods of cognitive resource replenishment. Third, they advance cultural sport psychology frameworks (Ryba et al., 2016; Schinke et al., 2016) by documenting systematic cross-national differences in psychophysiological adaptation patterns.

The practical implications of these findings are relevant to multiple stakeholder groups. Coaches and sport psychologists should recognise the importance of developing stress regulation skills in junior divers through structured, systematic approaches, with particular attention to post-competition recovery periods. The close association between recovery-phase HRV and subsequent attentional recovery suggests that monitoring autonomic functional state may usefully inform individualised recovery strategies. For sport administrators and policymakers, the observed cross-national differences highlight opportunities for cross-cultural learning and the adaptation of effective training practices. Programmes operating in nations with smaller elite-junior differentials may offer instructive models for accelerating psychological skills development, with potential applications in international coaching education initiatives.

Limitations

Several limitations of the present study warrant consideration. First, the cross-sectional design precludes causal conclusions regarding developmental patterns; longitudinal research is required to establish how stress regulation capacity changes over time in junior and elite athletes across different national contexts. Second, although the sample is relatively large given the size of this specialised population, certain cell sizes within nation-by-skill-level combinations are small, which may limit the statistical power available to detect more complex interactions. Third, despite the use of standardised protocols, cross-national data collection introduces potential confounding factors related to equipment calibration, laboratory environments, and seasonal variation that cannot be entirely controlled.

Fourth, whilst the computerised operationalisation of attention recovery is psychometrically sound, it may not fully capture the complexity of attentional processes as they occur in actual competition diving. Future studies should incorporate more ecologically valid measures of attention, such as eye-tracking during approach phases or virtual reality competition simulations. Fifth, psychological skills training exposure was assessed using self-report questionnaires; objective documentation of training content and quality within national programmes would have permitted more precise interpretations of training system effects.

Finally, the absence of genetic and epigenetic data limits the extent to which cross-national differences can be attributed to training systems as opposed to population-level genetic variation in stress reactivity. Future research incorporating genetic indicators of HPA axis functioning and autonomic nervous system regulation would assist in disentangling these contributions.

Clinical Application: The Dmytro Technique

The current findings provide an empirical basis for the Dmytro Method (Tereshchenko, 2023), an integrated intervention combining psychological regulation of breathing with biomechanical regulation of the takeoff cue. The 34.2% greater pre-competition HRV observed in elite divers aligns with the core emphasis of the method on slow, diaphragmatic breathing patterns (3 to 5 cycles of left-hand squeeze, multi-stage inhalation, and lengthened exhalation), which are designed to enhance vagal tone and attenuate sympathetic arousal. Similarly, the biomechanical adjustments in board loading and knee angle stabilisation (mean 92° ± 2.5°) observed in elite performers support the effectiveness of the bar-taint cue, a tactile-visual model that guides divers through three coordinated phases: vertical arm extension (bar), pelvic floor contraction (taint), and explosive takeoff at maximum board depression. The dual-component design of the method addresses both the autonomic regulation and motor execution demands identified in this study, offering a realistic, field-tested protocol for translating psychophysiological research into training practice. Coaches working with junior divers, who demonstrated a 41.3% deficit in attention recovery relative to elite performers, may find particular value in incorporating the structured inter-dive recovery routines of the Dmytro Method into competition preparation.

The OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) emphasises the enhancement of expectancies, autonomy, and external attentional focus as mechanisms underlying automaticity and skilled performance. The bar-taint cue operationalises this principle by directing divers' attention towards external referents, specifically the imaginary bar and pelvic engagement, thereby reducing conscious interference with automated motor execution. The effectiveness of this external focus strategy may account, in part, for the high performance consistency observed among elite divers in the present study.

Conclusions and Implications

The present cross-national comparative study demonstrates systematic variation in the patterns of stress reactivity and attention recovery among springboard and platform divers according to skill level and national training environment. Elite divers exhibit superior autonomic control, faster cortisol recovery, quicker attentional restoration, and greater performance consistency than their junior counterparts. These differences are most pronounced during pre-competition anticipatory stages and post-competition recovery phases, indicating that elite status confers not only superior performance execution but also greater capacity to meet the psychophysiological demands of the competitive cycle.

Cross-national differences indicate that training philosophies, cultural contexts, and developmental trajectories play a key role in determining how stress regulation capabilities are expressed across skill levels. The profiles of Ukrainian and Chinese divers suggest that systematic, technically oriented training systems may promote the timely development of stress resilience, whereas the North American and Australian programmes show greater elite-junior disparities, which may reflect greater variability in the acquisition of psychological skills. These findings question the utility of one-size-fits-all approaches to psychological skills intervention and underscore the need for culturally adaptive alternatives.

The applied value of these findings extends to talent identification, training scheduling, and competition preparation. HRV monitoring during training camps may assist in identifying junior divers with stronger stress management capacity, who could subsequently be placed on accelerated developmental pathways. Systematic programmes incorporating diaphragmatic breathing and attentional recovery exercises should be carefully integrated into training sessions between competitive bouts. International development of stress regulation capacity may be facilitated through cross-cultural exchange programmes that enable coaches and sport psychologists to observe and adopt effective practices from diverse training systems.

In summary, the present research confirms that stress management and attentional recovery are vital components of diving expertise, shaped by specific cultural and training contexts. The holistic design of the Dmytro Method, combining psychological and biomechanical elements, exemplifies an approach capable of supporting such development. Further longitudinal research, ecologically valid assessment measures, and intervention studies are needed to clarify how specific training regimens may accelerate the development of stress regulation skills across different cultural settings.

Suggestions for Future Research

Based on the results of this cross-national comparative analysis, several directions for further research appear particularly promising. Longitudinal research following participants as competitive divers from talent identification through to high-level performance would clarify the developmental patterns of stress management skills and define the periods during which intervention may be most effectively provided. Repeated measurements of HRV, cortisol reactivity, attention, and performance consistency should be incorporated into such research, thereby enabling the modelling of growth curves of individual differences in adaptation to training and competition demands.

A logical next step would be intervention studies investigating the effectiveness of culturally adapted psychological skills training programmes. Randomised controlled trials comparing structured breathing methods (Hunt et al., 2018), mindfulness-based interventions, and attention training approaches implemented across different national settings would provide an evidence base for coaching practice. Such studies should examine both primary effects and potential moderating variables, including age, training history, and initial stress reactivity profiles.

Neuroimaging approaches incorporating functional magnetic resonance imaging (fMRI) in simulated competition conditions may elucidate the neural mechanisms underlying observed skill levels and cross-national variation in stress regulation. Prefrontal cortical activation patterns, amygdala reactivity, and default mode network dynamics during anticipatory stress and recovery phases would provide mechanistic evidence corroborating peripheral physiological assessments.

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Conflict of Interest

None.

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