Russian Journal of Information Technology in Sports, 2026, 3 (1), e202603
Российский журнал информационных технологий в спорте. 2026. Т. 3, № 1. e202603

DIGITAL TECHNOLOGIES IN EXTREME AND SPORTS PHYSIOLOGY
Short communication
https://doi.org/10.62105/2949-6349-2026-3-1-e202603
UDC 796.01:159.9

Psychophysiological signatures of competitive anxiety in martial arts athletes outside competition: a multivariate perspective

A. V. Kovaleva [1]✉, **N. G. Toloraya** [1,2], **I. A. Belousov** [1,2], **A. M. Andreeva** [2]

[1] Federal Research Center for Innovator and Emerging Biomedical and Pharmaceutical Technologies, Moscow, Russian Federation
[2] Russian University of Sports (SCOLIPE), Moscow, Russian Federation

✉ kovaleva_av@academpharm.ru

Abstract

Relevance. The association between competitive anxiety and heart rate variability (HRV) remains inconsistent, especially when athletes are evaluated outside the immediate pre-competition period.

Objective. To examine relationships between competitive anxiety and autonomic, respiratory, and sensorimotor regulation in martial arts athletes during a non-competitive training phase.

Methods. Forty athletes (aged 16–27) who practice karate, kyokushin, wushu, or taekwondo were assessed during regular training sessions. Competitive anxiety was measured using the Competitive State Anxiety Inventory-2 (CSAI-2). Resting photoplethysmography (5-minutes, seated) was recorded to calculate linear and nonlinear heart rate variability (HRV) indices, as well as respiratory parameters. Sensorimotor performance was assessed using a battery of visual-motor tasks. All variables were standardized using z-scores. Correlation analysis, k-means clustering, and PERMANOVA were used for analysis.

Results. No significant correlations were found between anxiety subscales and autonomic or sensorimotor indicators. Cluster analysis identified two psychological profiles: a group with higher anxiety and lower confidence, and a more adaptive group with lower anxiety and higher confidence. Although univariate differences did not reach statistical significance, the group with higher anxiety showed consistent trends towards lower vagal activity (RMSSD, pNN50), reduced abdominal respiratory amplitude, reduced autonomic complexity, and increased variability in choice reaction time. Multivariate analysis suggested a trend towards differentiation of integrated psychophysiological profiles ($p=0.08$).

Conclusion. In non-competitive conditions, anxiety was not related to individual physiological markers, but rather reflected in integrated, multivariate configurations. These findings emphasize the significance of multidimensional approaches in sports psychophysiology.

Keywords: competitive anxiety, martial arts athletes, heart rate variability (HRV), sensorimotor functions, permutation-based multivariate test

Российский журнал информационных технологий в спорте. 2026. Т. 3, № 1. e202603
Russian Journal of Information Technology in Sports, 2026, 3 (1), e202603

ЦИФРОВЫЕ ТЕХНОЛОГИИ В ЭКСТРЕМАЛЬНОЙ И СПОРТИВНОЙ ФИЗИОЛОГИИ
Краткое сообщение
https://doi.org/10.62105/2949-6349-2026-3-1-e202603
УДК 796.01:159.9

Психофизиологический профиль соревновательной тревожности у спортсменов-единоборцев вне соревновательного контекста: многомерный анализ

А. В. Ковалева [1]✉, **Н. Г. Толорая** [1,2], **И. А. Белоусов** [1,2], **А. М. Андреева** [2]

[1] Федеральный исследовательский центр оригинальных и перспективных биомедицинских и фармацевтических технологий, Москва, Российская Федерация
[2] Российский университет спорта (ГЦОЛИФК), Москва, Российская Федерация

✉ kovaleva_av@academpharm.ru

Аннотация

Актуальность. Связь между соревновательной тревожностью и показателями вариабельности сердечного ритма (ВСР) неоднозначна, особенно если спортсменов оценивают за пределами непосредственно предсоревновательного периода.

Цель. Изучить взаимосвязи соревновательной тревожности с автономной, дыхательной и сенсомоторной регуляцией у спортсменов единоборств вне соревновательной ситуации.

Методы. Обследованы 40 спортсменов (16–27 лет), занимающихся каратэ, киокушинкай, ушу и тхэквондо. Тревожность оценивали по CSAI-2. В покое регистрировали фотоплетизмограмму с расчетом линейных и нелинейных показателей ВСР, а также параметры дыхания. Сенсомоторные функции оценивали по комплексу визуально-моторных тестов. Данные были z-стандартизированы, применялись корреляционный анализ, кластеризация k-means и PERMANOVA.

Результаты. Значимых корреляций между шкалами тревожности и автономными или сенсомоторными показателями не выявлено. Кластерный анализ выделил две группы: с более высокой тревожностью и сниженной уверенностью и с адаптивным психологическим профилем. При отсутствии значимых однофакторных различий отмечена тенденция к снижению вагусных индексов (RMSSD, pNN50), амплитуды абдоминального дыхания и автономной сложности, а также к большей вариабельности сложной реакции в группе с более высокой тревожностью. Многомерный анализ показал тенденцию к различию интегральных психофизиологических профилей ($p=0{,}08$).

Заключение. Вне соревновательного контекста тревожность не связана с отдельными физиологическими показателями, однако проявляется на уровне интегративных многомерных конфигураций. Результаты подчеркивают значимость системного подхода к анализу психофизиологических состояний спортсменов.

Ключевые слова: соревновательная тревожность, спортсмены-единоборцы, вариабельность ритма сердца (ВРС), сенсомоторные функции, пермутационный многомерный анализ

Background

Competitive anxiety is widely understood as a complex state that includes cognitive anxiety, physical arousal, and confidence. It is commonly measured using the Competitive State Anxiety Inventory-2 (CSAI-2). A significant portion of the sports psychology literature shows that increased cognitive and physical anxiety is associated with decreased heart rate variability, including RMSSD, SDNN, and high-frequency power [1, 2]. When significant, this relationship follows a consistent pattern: higher anxiety is linked with decreased vagal activity and increased LF/HF ratios [3]. In contrast, confidence often shows positive correlations with vagal tone [4].

However, null findings are also common, especially in studies where HRV is measured outside of the immediate pre-competition period or where athletes exhibit low variability in both psychological and autonomic markers [5, 6]. According to recent studies, methodological differences, such as timing of measurements, sample homogeneity, and recording duration, may partly explain these inconsistent results [7].

The current study examines these relationships during a non-competitive period, focusing on elite and sub-elite martial artists. Unlike pre-competition assessments, this data was collected under stable, routine training conditions, allowing us to investigate whether subjective anxiety is related to autonomic or sensorimotor function in the absence of acute stress.

Methods

Participants

The study sample included 40 active martial arts athletes who were examined during a regular training period outside any competitive context. The participants were between 16 and 27 years old (mean age = 19.63 ± 2.13), with 37.5% of them being women. Their height ranged from 174.38 ± 8.41 centimeters and their body weight ranged from 65.48 ± 9.80 kilograms. The sample consisted of four different striking-based martial arts: Karate (n=20), Kyokushin (n=7), Wushu (n=7), and Taekwondo (n=6).

Psychological assessment

Competitive anxiety was measured using the Russian adaptation of the Competitive State Anxiety Inventory-2 (CSAI-2), which consists of three subscales: cognitive anxiety, somatic anxiety, and self-confidence [8].

Physiological recordings

We assessed autonomic regulation under resting conditions (5 minutes, sitting), measuring respiratory rate and amplitude via abdominal and thoracic pneumography, and extracting beat-to-beat intervals from photoplethysmography (PPG). We used Kubios HRV Standard (version 3.5.0) to compute standard time domain, frequency domain, and nonlinear HRV indices.

Sensorimotor tasks

To evaluate sensorimotor performance, we used a battery of visual-motor and coordination tasks, including simple and choice reaction time, coincidence anticipation timing, grip force

differentiation, and stylus tracking (certified neurophysiological systems NS PsychoTest, Neurosoft LLC, Ivanovo, Russia; software version 1.6.9.3). All physiological and behavioral indicators were standardized for comparability across different measurements using z-scores.

Statistical analysis

Correlation analysis, k-means clustering (based on CSAI-2 subscales), and Mann-Whitney U tests were conducted. Multivariate profile differences were assessed using PERMANOVA with 999 and 5000 permutations. Significance was set at $p < 0.05$.

Ethical approval

The study protocol was approved by the Local Bioethics Committee of SCOLIPE under Protocol Number 15 on 9 September 2024.

Results

Initially, the CSAI-2 scores obtained from our sample were compared with published normative data and pre-competition information for combat sports athletes in similar age groups. This revealed a pattern that was broadly consistent with previous findings: male athletes generally reported higher self-confidence, while cognitive and somatic anxiety levels were within the typical range for non-competitive periods [9, 10, 11]. To futher explore the data, correlation analyses were conducted between the CSAI-2 subscales and sensorimotor and autonomic indicators. However, no significant associations were found across domains. In order to investigate potential heterogeneity within the sample, a k-means clustering analysis based on the three CSAI-2 subscales was performed. This yielded a two-cluster solution. The first cluster was characterized by increased cognitive and somatic anxiety, accompanied by decreased self-confidence. In contrast, the second cluster showed a more adaptive psychological profile, with lower anxiety levels and increased confidence.

These psychologically defined clusters were then compared in terms of their sensorimotor and physiological characteristics using the Mann-Whitney U test. Although none of the univariate comparisons reached statistical significance, several variables showed consistent trends differentiating the groups. Guided by these tendencies, six psychophysiological indicators (movement frequency, Choice RT variability, RMSSD, pNN50, abdominal respiratory amplitude, and ApEn) were selected to construct normalized profile plots representing the multivariate configuration of each cluster. Cluster-specific multivariate profiles were then visualized using profile plots summarizing the six principal psychophysiological indicators (Figure 1). A permutation-based multivariate test (PERMANOVA) was then applied to formally assess differences in the overall configuration of autonomic, respiratory, and sensorimotor functioning between the clusters.

The results showed a consistent trend towards differences in global psychophysiological patterns between high- and low-anxiety groups (Pseudo-F=2.07; p=0.081 after 999 randomizations; p=0.078 after 5,000 randomizations), suggesting that athletes' autonomic, respiratory, and sensorimotor characteristics diverged at the group level, despite the lack of significant univariate effects.

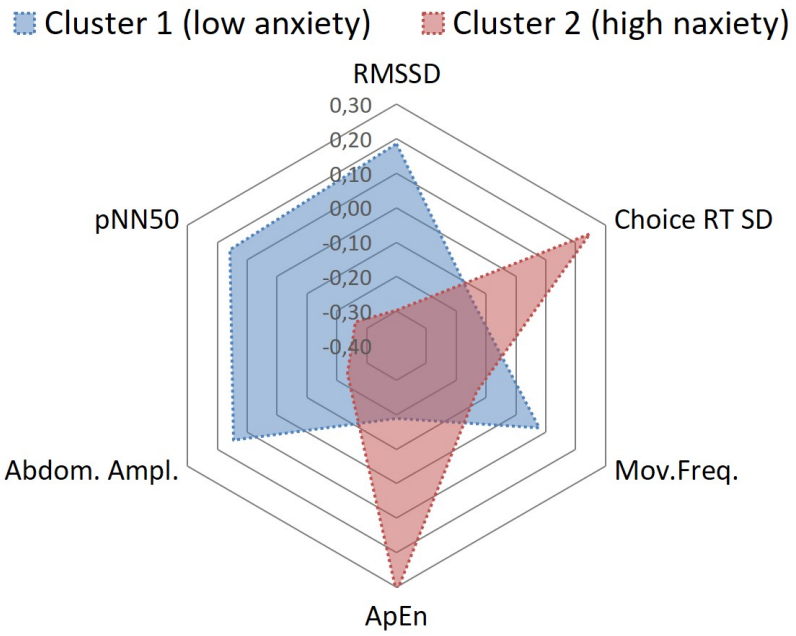

Figure 1: Radar chart illustrating the multivariate configuration of six psychophysiological indicators in two groups defined by CSAI (high vs low anxiety). The values are Z-standardized mean valuess for each group.

Discussion

The absence of direct HRV or sensorimotor correlations with anxiety is in line with previous work showing null associations under conditions of low arousal or non-competition [5, 6]. Studies that report strong negative associations between anxiety and HRV typically assess athletes immediately prior to competition or under conditions of heightened emotional stress [2, 3, 4], highlighting the importance of timing in assessment. Outside of immediate performance demands, autonomic markers tend to reflect stable, trait-like physiological states, such as recovery, fitness, and long-term adaptation, rather than transient emotional states. The homogeneity of elite and sub-elite athletes may also contribute to reduced variability, and the lack of research on respiratory amplitude may explain the current null findings in light of existing evidence.

Beyond correlations, multivariate analyses revealed additional patterns. K-means clustering of CSAI-2 scores identified two distinct psychological profiles: one with high levels of cognitive and somatic anxiety, and low self-confidence; the other with a more adaptive emotional profile. Although univariate tests showed no significant differences in physiology or sensorimotor responses between the groups, several trends emerged. The group with high anxiety had lower RMSSD, pNN50, and abdominal amplitude, as well as greater variability in choice reaction time (RT); conversely, the group with low anxiety had higher vagal activity, larger respiratory amplitudes, greater autonomic complexity, and more consistent motor responses.

While none of the individual indicators differed significantly, the combined pattern of six variables revealed a clear qualitative difference. PERMANOVA supported the trend towards multivariate differentiation ($p=0.078$), suggesting that psychological grouping is not expressed through individual physiological markers, but rather through their integrated configuration. These findings require careful interpretation due to the small sample size and non-competitive

context. However, they indicate that multidimensional physiological signatures may still reflect underlying psychological states even under neutral training conditions.

Conclusion

In summary, competitive anxiety among high-level martial artists assessed outside of competitive conditions did not directly correlate with autonomic, respiratory, or sensorimotor indicators. However, psychological clustering based on CSAI-2 revealed two distinct subgroups of athletes whose physiological and sensorimotor characteristics, although not significantly different at the univariate level, ehxibited systematically divergent patterns when viewed in multivariate terms. These profiles, characterized by various combinations of vagal activity, respiratory amplitude, autonomic complexity, and motor stability, consistently demonstrated a trend towards multivariate differentiation, as confirmed by PERMANOVA analysis. Overall, the findings suggest that subtle psychophysiological signs of anxiety may only be detectable when analyzed as integrated, multivariate patterns, rather than isolated variables. this underscores the importance of multidimensional approaches in sport psychophysiology and highlights the need for research conducted under conditions of genuine competitive stress.

References

1. Fortes L.S., da Costa B.D.V., Paes P.P., do Nascimento Júnior J.R.A., Fiorese L., Ferreira M.E.C. Influence of competitive anxiety on heart rate variability in swimmers. *Journal of Sports Science and Medicine*, 2017, 16 (4), pp. 498–504. URL: https://www.jssm.org/jssm-16-498.xml%3EFulltext

2. Cervantes Blásquez J.C., Rodas G., Capdevila Ortís L. Heart-rate variability and precompetitive anxiety in swimmers. *Psicothema*, 2009, 21 (4), pp. 531–536. URL: https://www.redalyc.org/pdf/727/72711895005.pdf

3. Zhao C., Wang K., Li D., Li Y., Wang Z., et al. Relationship between state anxiety, heart rate variability, and shooting performance in adolescent shooters. *BMC Psychology*, 2024, 12 (1), 736. https://doi.org/10.1186/s40359-024-02062-4

4. Villafaina S., Crespo M., Martínez-Gallego R., Fuentes-García J.P. Heart rate variability in elite international ITF Junior Davis Cup tennis players. *Biology (Basel)*, 2022, 12 (1), 17. https://doi.org/10.3390/biology12010017

5. Souza R.A., Beltrán O.A.B., Zapata D.M., Silva E., Freitas W.Z., et al. Heart rate variability, salivary cortisol and competitive state anxiety responses during pre-competition and pre-training moments. *Biology of Sport*, 2019, 36 (1), pp. 39–46. https://doi.org/10.5114/biolsport.2018.78905

6. Mallory J., Marshall A.H., Williams M., Heilman J., Shoemaker M.K., Walbolt J. Effects of personality and competition anxiety on heart rate variability and salivary stress markers. *International Journal of Exercise Science: Conference Proceedings*, 2023, 16 (2), 29. URL: https://digitalcommons.wku.edu/ijesab/vol16/iss2/29

7. Lapo H.M., Chacon-Mikahil M.P.T., Sardeli A.V. Psychophysiological factors are not directly associated with heart rate variability in athletes: A meta-analysis. *Journal of Mental Health & Clinical Psychology*, 2024, 8 (3), pp. 7–16. https://doi.org/https://doi.org/10.29245/2578-2959/2024/3.1323

8. Bochaver K.A., Bondarev D.V., Dovzhik L.M. Psikhologicheskaya diagnostika v sporte [Psychological assessment in sport]. Moscow: Sport, 2023, 232 p.(in Russ.)

9. Terry P.C., Slade A. Discriminant effectiveness of psychological state measures in predicting performance outcome in karate competition. *Perceptual and Motor Skills*, 1995, 81 (1), pp. 275–286. https://doi.org/10.2466/pms.1995.81.1.275

10. Ağaoğlu Y.S. Responses to the Competitive State Anxiety Inventory-2 by the athletes participated in the (IJF) Judo Grand Prix competition, Samsun 2015 in Turkey. *International Journal of Environmental & Science Education*, 2016, 11 (10), pp. 3259–3275.

11. Mojtahedi D., Dagnall N., Denovan A., Clough P., Dewhurst S., et al. Competition anxiety in combat sports and the importance of mental toughness. *Behavioral Sciences (Basel)*, 2023, 13 (9), 713. https://doi.org/10.3390/bs13090713

Information about the authors

Anastasia V. Kovaleva — Cand. Sci. (Biology), Federal Research Center for Innovator and Emerging Biomedical and Pharmaceutical Technologies, Rehabilitation and Sport Psychophysiology Lab (125315, Russian Federation, Moscow, Baltiyskaya str., 8); *kovaleva_av@academpharm.ru*; https://orcid.org/0000-0001-7377-3408

Nikola G. Toloraya — Russian University of Sport (SCOLIPE) (105122, Russian Federation, Moscow, Sirenevyy bulvar, 4); Federal Research Center for Innovator and Emerging Biomedical and Pharmaceutical Technologies, Rehabilitation and Sport Psychophysiology Lab (125315, Russian Federation, Moscow, Baltiyskaya str., 8); *toloraya_ng@academpharm.ru*

Ivan A. Belousov — Russian University of Sport (SCOLIPE) (105122, Russian Federation, Moscow, Sirenevyy bulvar, 4); *belousov_ia@academpharm.ru*

Albina M. Andreeva — Cand. Sci. (Biology), Russian University of Sport (SCOLIPE) (105122, Russian Federation, Moscow, Sirenevyy bulvar, 4); *moymio@yandex.ru*; https://orcid.org/0000-0002-8826-9586

Contribution of the authors

Kovaleva A.V. — Conceptualization, Methodology, Investigation, Formal analysis, Writing — original draft.

Toloraya N.G. — Data curation, Investigation, Visualization.

Belousov I.A. — Formal analysis, Software, Writing — review & editing.

Andreeva A.M. — Methodology, Investigation, Writing — review & editing.

Conflict of interests

The authors declare no relevant conflict of interests.

Funding

This research was supported by the Federal Research Center for Innovator and Emerging Biomedical and Pharmaceutical Technologies (research topic no. 122040500027-7 “Investigation of system physiological mechanisms of psychoemotional stress and pain reactions” (FGFW-2022-0001)).

Citation

Kovaleva A.V., Toloraya N.G., Belousov I.A., Andreeva A.M. Psychophysiological signatures of competitive anxiety in martial arts athletes outside competition: a multivariate perspective. *Russian Journal of Information Technology in Sports*, 2026, 3 (1), e202603. https://doi.org/10.62105/2949-6349-2026-3-1-e202603 EDN NUQPCZ

Received/Получено: *31.01.2026*
Accepted/Одобрено: *04.03.2026*
Published/Опубликовано: *10.03.2026*