https://doi.org/10.47183/mes.2025-295



# INFLUENCE OF DENTAL AND ORTHODONTIC DISEASES ON PHYSICAL PERFORMANCE AND ENDURANCE OF HIGH-CLASS COMBAT SPORTS ATHLETES

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**Introduction.** Oral health issues, such as dental caries, periodontal diseases, or malocclusion, can cause pain, discomfort, and systemic health problems, which in turn may negatively affect the performance and endurance of athletes. In this context, the development of comprehensive dental programs for athletes involved in professional sports is a relevant task.

**Objective.** To determine statistically significant differences in performance parameters among combat sports athletes for the development of measures to correct the dental status of highly qualified athletes.

**Materials and methods.** A mathematical and statistical analysis of anonymized medical data on comprehensive medical examination of elite athletes was conducted. Data from 1887 combat sports athletes were processed ($n$ = 1887; males $n$ = 1190; females $n$ = 697). The sample was divided into two groups: athletes without dental pathologies — Group 0 ($n$ = 791; $M_e$ median age 21.00 [19.00; 25.00]); athletes with confirmed dental pathologies — Group 1 ($n$ = 1096; $M_e$ median age 19.00 [17.00; 24.00]). Diagnoses from endocrinologists and gastroenterologists were also taken into account. Morphometric characteristics and physiological parameters from exercise stress testing were analyzed. Statistical analysis was performed using the StatTech v. 4.6.0 software.

**Results.** A significant influence of dental diseases on physical performance and endurance was identified. Compared to the group of athletes without a dental diagnosis (Group 0), the presence of a dental diagnosis (Group 1) was associated with statistically significant differences ($p < 0.05$) across a range of physiological indicators characterizing physical endurance and performance: respiratory exchange ratio $R(0)$ = 1.05 [1.03; 1.09], $R(1)$ = 1.04 [1.03; 1.07]; heart rate at the aerobic threshold level $HR_{AerT}(0)$ = 110.00 [100.00; 122.00], $HR_{AerT}(1)$ = 114.00 [102.00; 126.00]; heart rate at the anaerobic threshold $HR_{AT}(0)$ = 143.00 [132.00; 154.00], $HR_{AT}(1)$ = 147.00 [134.00; 158.00]; peak heart rate at peak load $HR_{peak}(0)$ = 151.00 [144.00; 160.00], $HR_{peak}(1)$ = 152.00 [144.00; 163.00]; heart rate at the 3rd min of recovery $HR_{3min}(0)$ = 91.00 [82.00; 101.00], $HR_{3min}(1)$ = 93.00 [84.00; 102.00]; power output at the level of the anaerobic threshold $Pwr_{AT}(0)$ = 190.00 [165.00; 230.00], $Pwr_{AT}(1)$ = 200.00 [165.00; 240.00].

**Conclusions.** Dental diseases reduce the performance athletes, in particular at submaximal load levels. This has a negative effect on the training process and competitive results in martial arts. In this regard, a comprehensive prevention program and regular dental checkups are recommended as an essential part of preparation, in particular, in contact sports. The use of individual aligners for mitigating excessive impact on teeth under the conditions of overload and extreme situations is proposed.

**Keywords:** dentistry; sports medicine; combat sports athletes; comprehensive medical examination; aligners; retrospective study; physical performance; physical endurance

**For citation:** Rusak Zh.I., Baginsky A.L., Milashenko E.V., Petrova V.V., Artamonov A.A. Influence of dental and orthodontic diseases on physical performance and endurance of high-class combat sports athletes. *Extreme Medicine.* 2025;27(4):550–557. https://doi.org/10.47183/mes.2025-295

**Funding:** the work was carried out within the framework of the FMFR-2024-0042 project of the Fundamental Scientific Research Program of the Russian Academy of Sciences.

**Compliance with ethical principles:** the study was approved by the Local Ethical Committee of the Burnasyan Federal Medical Biophysical Center (Protocol No. 121 of 23.01.2025). All participants provided signed informed consent for the use of their anonymized medical data in scientific research.

**Potential conflict of interest:** the authors declare no conflict of interest.

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**Received:** 20 Mar. 2025 **Revised:** 17 July 2025 **Accepted:** 25 Aug. 2025 **Online first:** 7 Oct. 2025

УДК 616.314-08:76.35.41

# ВЛИЯНИЕ СТОМАТОЛОГИЧЕСКИХ И ОРТОДОНТИЧЕСКИХ ЗАБОЛЕВАНИЙ НА ФИЗИЧЕСКУЮ РАБОТОСПОСОБНОСТЬ И ВЫНОСЛИВОСТЬ СПОРТСМЕНОВ-ЕДИНОБОРЦЕВ ВЫСОКОГО КЛАССА

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**Введение.** Проблемы со здоровьем полости рта, такие как кариес зубов, заболевания пародонта и неправильный прикус, могут вызывать боль, дискомфорт и системные проблемы со здоровьем, что, в свою очередь, может негативно сказаться на работоспособности и выносливости спортсмена. Наряду с этим существует и необходимость разработки комплексных стоматологических программ для профессионального спорта.

**Цель**. Определение статистически значимых различий параметров работоспособности у спортсменов-единоборцев для разработки мероприятий по коррекции стоматологического статуса у высококвалифицированных спортсменов.

**Материалы и методы.** Проведен математико-статистический анализ деперсонализированных медицинских данных результатов углубленного медицинского обследования спортсменов высокого класса. Обработаны данные 1887 представителей спортивных единоборств ($n$ = 1887; мужчины $n$ = 1190; женщины $n$ = 697). Выборка была разделена на 2 группы: спортсмены без стоматологической патологии — группа «0» ($n$ = 791; $M_e$ среднего возраста 21,00 [19,00; 25,00]); спортсмены со стоматологическими диагнозами — группа «1» ($n$ = 1096; $M_e$ среднего возраста 19,00 [17,00; 24,00]). В работе учитывали также диагнозы эндокринолога и гастроэнтеролога. Анализировали морфометрические характеристики и физиологические показатели нагрузочного тестирования. Статистический анализ проводился с использованием программы StatTech v. 4.6.0.

**Результаты.** Выявлено значительное влияние стоматологических заболеваний на физическую работоспособность и выносливость. Наличие стоматологического диагноза (группа «1») связано со статистически значимыми различиями ($p$ < 0,05) по сравнению с группой спортсменов без стоматологического диагноза (группа «0»), по ряду физиологических показателей характеризующих физическую выносливость и работоспособность: дыхательный коэффициент $R(0)$ = 1,05 [1,03; 1,09], $R(1)$ = 1,04 [1,03; 1,07]; частота сердечных сокращений аэробного порога $ЧСС_{АП}(0)$ = 110,00 [100,00; 122,00], $ЧСС_{АП}(1)$ = 114,00 [102,00; 126,00]; частота сердечных сокращений на уровне анаэробного порога $ЧСС_{ПАНО}(0)$ = 143,00 [132,00; 154,00], $ЧСС_{ПАНО}(1)$ = 147,00 [134,00; 158,00]; частота сердечных сокращений на пике нагрузки $ЧСС_{ПИК}(0)$ =151,00 [144,00; 160,00], $ЧСС_{ПИК}(1)$ = 152,00 [144,00; 163,00]; частота сердечных сокращений на 3-й минуте восстановления $ЧСС_{3\ мин}(0)$ = 91,00 [82,00; 101,00], $ЧСС_{3\ мин}(1)$ = 93,00 [84,00; 102,00]; мощность ступени, на которой достигнут уровень порога анаэробного обмена, $Мощ_{ПАНО}(0)$ = 190,00 [165,00; 230,00], $Мощ_{ПАНО}(1)$ = 200,00 [165,00; 240,00].

**Выводы.** Стоматологические заболевания снижают работоспособность спортсменов, особенно на субмаксимальных уровнях нагрузки, что может негативно сказываться на тренировочном процессе и соревновательных результатах в боевых искусствах. В связи с этим рекомендованы комплексная программа профилактики и регулярные стоматологические осмотры как обязательная часть подготовки, особенно в контактных видах спорта. На основании анализа результатов исследования предложено использовать индивидуальные элайнеры для предотвращения избыточного воздействия на зубы в условиях перегрузок и экстремальных ситуаций.

**Ключевые слова:** стоматология; спортивная медицина; единоборцы; углубленное медицинское обследование; элайнеры; ретроспективное исследование; физическая работоспособность; физическая выносливость

**Для цитирования:** Русак Ж.И., Багинский А.Л., Милашенко Е.В., Петрова В.В., Артамонов А.А. Влияние стоматологических и ортодонтических заболеваний на физическую работоспособность и выносливость спортсменов-единоборцев высокого класса. *Медицина экстремальных ситуаций*. 2025;27(4):550–557. https://doi.org/10.47183/mes.2025-295

**Финансирование:** работа выполнена в рамках темы FMFR-2024-0042 программы фундаментальных научных исследований РАН.

**Соответствие принципам этики:** исследование одобрено ЛЭК ФГБУ ГНЦ ФМБЦ им. А.И. Бурназяна ФМБА России (протокол № 121 от 23.01.2025). Всеми участниками подписано добровольное согласие на использование своих обезличенных медицинских данных в научных исследованиях.

**Потенциальный конфликт интересов:** авторы заявляют об отсутствии конфликта интересов.

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**Статья поступила:** 12.03.2025 **После доработки:** 19.07.2025 **Принята к публикации:** 25.08.2025 **Online first:** 07.10.2025

## INTRODUCTION

Dental and orthodontic diseases represent a multifaceted problem that directly or indirectly affects the performance of athletes. Oral diseases can cause severe pain, which directly impacts the ability of athletes to train and compete [1]. This is particularly relevant in combat sports, where physical conditioning, concentration, and endurance are crucial. The presence of oral diseases can affect the ability to eat properly, leading to nutritional deficiencies that negatively impact physical performance and endurance. Pain caused by dental caries or periodontal disease can result in reduced training volumes and complicate participation in competitions. Teixeira et al. demonstrated that athletes with oral diseases may experience up to a 21% decline in performance [2]. Unsatisfactory dental conditions can lead to systemic diseases, such as cardiovascular and respiratory complications, impairing muscle recovery and overall physical performance [2]; negatively affect the confidence and quality of life of athletes [3], their appearance and social interactions, which are extremely important for maintaining a positive mental state [4]. Additionally, there is evidence suggesting that oral health problems can impact cognitive functions necessary for strategic thinking and decision making [5].

This study aims to determine statistically significant differences in performance parameters among combat sports athletes to develop measures for correcting the dental status of highly qualified athletes.

## MATERIALS AND METHODS

A mathematical and statistical analysis of anonymized medical data from the comprehensive medical examination (CME) of high-class athletes, not lower than Masters of Sport of Russia, was conducted.

Data on 1887 ($n$ = 1887; males $n$ = 1190; females $n$ = 697) representatives of combat sports, including aikido, arm wrestling, boxing, wrestling, belt wrestling, freestyle wrestling, Greco-Roman wrestling, grappling, jiu-jitsu, judo, karate, kickboxing, Kyokushin, hand-to-hand fighting sport, savate, sambo, sumo, Muay Thai, taekwondo, universal fighting, and wushu, were analyzed. The sample was divided into two groups: athletes without dental pathologies (median age 21.00 [19.00; 25.00]); athletes with dental diagnoses (median age 19.00 [17.00; 24.00]). Athletes with a dental diagnosis listed under K02–K08.9 according to ICD-10 formed Group 1 ($n$ = 1096); those without a dental diagnosis ($n$ = 791) formed Group 0.

The study also considered endocrinological (ICD-10 codes: E00–E07, E10–E16, E40–E46, E65–E68, E70–E90) and gastroenterological (ICD-10 codes: K00–K93) diagnoses.

Data for both groups were compared based on the results of the CME, including functional testing on a bicycle ergometer using the Ramp-30 protocol. This is a method of stress testing involving ergospirometry on a V-ergoPro bicycle ergometer: "to failure" under gradually increasing load starting from 5 W.

The inclusion criteria for the study were completion of the CME and the athlete's clearance for competitions.

For subsequent processing, the following quantitative indicators were identified: height (cm); weight (kg); oxygen consumption at the anaerobic threshold level ($VO_{2\ AT}$, mL/min/kg), i.e., the amount of oxygen utilized primarily by working muscles per unit time at the moment of reaching the anaerobic threshold; oxygen consumption at the maximum stage of load testing ($VO_{2\ peak}$, mL/min/kg), i.e., the amount of oxygen utilized primarily by working muscles per unit time at the maximum achieved power during testing with submaximal loads (if $VO_{2\ max}$ — maximal oxygen consumption — is not reached, then it coincides with $VO_{2\ max}$); respiratory exchange ratio ($R$, relative units), i.e., the ratio of carbon dioxide released to oxygen consumption, reflecting the ratio of oxidized substrates, ventilation-perfusion ratios in the lungs, and the activity of the blood bicarbonate buffer; heart rate before exercise ($HR_{rest}$, bpm), which depends on age, gender, stage of the training process, and skill level; heart rate at the aerobic threshold ($HR_{AerT}$, bpm), which is the upper limit of the individual aerobic zone and the lower limit for the developmental zone of exercise intensity; heart rate at the anaerobic threshold level ($HR_{AT}$, bpm), which is the upper limit of the developmental and lower limit of the anaerobic individual zones of exercise intensity; heart rate at peak load ($HR_{peak}$, bpm), i.e., the maximum recorded heart rate during exercise "to failure"; heart rate at the 3$^{rd}$ min of recovery ($HR_{3\ min}$, bpm), i.e., supporting the body's recovery processes, one of the criteria for assessing fitness; power output at the level of the anaerobic threshold ($Pwr_{AT}$, W), reflecting the absolute power that an athlete can generate at the anaerobic threshold level; power output at the maximum stage of testing ($Pwr_{peak}$, W), reflecting the absolute power that an athlete can generate; relative power at the anaerobic threshold level ($Pwr_{AT}$/weight, W/kg), i.e., a relative indicator that takes into account the athlete's body weight and allows for comparing work efficiency considering individual physical parameters (it is particularly important when assessing athletes of different weights, due to its more accurate representation of functional capabilities per unit of body weight); ($Pwr_{peak}$/weight, W/kg) is the relative power at peak load.

In modeling formulas, quantitative indicators are represented by adding the index $X$ to the studied parameters and $Y$ to the analyzed value; diagnoses from gastroenterologists, dentists, and endocrinologists (presence of diagnosis — 1, absence of diagnosis — 0); gender (0 — female (F), 1 — male (M)).

Quantitative indicators were assessed for compliance with normal distribution using the Shapiro–Wilk test (for sample sizes less than 50) or the Kolmogorov–Smirnov test (for sample sizes greater than 50). Quantitative indicators with normal distribution were described using arithmetic means (M) and standard deviations (SD), and 95% confidence interval (95% CI) limits. In the absence of normal distribution, quantitative data were described using median ($M_e$) and lower and upper quartiles [$Q_1$; $Q_3$] ([IQR]). Comparison of the study groups for a quantitative indicator with normal distribution, assuming equal variances, was performed using Student's $t$-test; for unequal variances, Welch's $t$-test was used. Comparison of the study groups for a quantitative indicator with a distribution different from normal was performed using the Mann–Whitney $U$-test.

A predictive model characterizing the dependence of the quantitative variable $HR_{AerT}$ (heart rate at aerobic threshold) on gender, diagnoses from gastroenterologists, dentists, endocrinologists, weight, and indicators $HR_{rest}$, $HR_{AT}$, $HR_{3min}$, $Pwr_{AT}$, $Pwr_{AT}$/weight, was developed using the linear regression method. Differences were considered statistically significant at $p < 0.05$. Statistical analysis was performed using the StatTech v. 4.6.0 software (StatTech, Russia).

## RESULTS AND DISCUSSION

Table 1 presents the results of descriptive statistics for groups of high-class combat athletes.

Table 1 demonstrates statistically significant differences between the groups of athletes with (Group 1) and without a dental diagnosis (Group 0) across several parameters. For instance, heart rate before exercise was higher in Group 1 ($M_e$ = 81.00 bpm) compared to Group 0 ($M_e$ = 78.00 bpm, $p < 0.001$). A similar trend was observed for heart rate at the aerobic threshold ($HR_{AerT}$) (114.00 vs. 110.00 bpm, $p < 0.001$) and heart rate at the anaerobic threshold ($HR_{AT}$) (147.00 vs. 143.00 bpm, $p < 0.001$). These differences may indicate higher baseline activation of the sympathetic nervous system in athletes with oral health issues, likely associated with chronic inflammation or pain caused by dental caries or periodontitis. Studies by other authors confirm that inflammatory processes in the oral cavity can exacerbate

**Table 1.** Descriptive statistics of quantitative variables by presence of dental diagnosis

| Parameters | Dental report | | Statistical significance level, *p* |
|---|---|---|---|
| | Group 0 ($n$ = 791) $M_e$ [IQR] | Group 1 ($n$ = 1096) $M_e$ [IQR] | |
| Age, years | 21.00 [19.00; 25.00] | 19.00 [17.00; 24.00] | 0.285 |
| Height, cm | 174.00 [167.00; 182.00] | 173.00 [166.00; 181.00] | 0.285 |
| Body weight, kg | 73.00 [63.00; 87.00] | 73.00 [63.00; 87.00] | 0.852 |
| Oxygen consumption at the anaerobic threshold level ($VO_{2\ AT}$), mL/min/kg | 31.02 [26.68; 35.45] | 31.31 [26.84; 36.11] | 0.333 |
| Oxygen consumption at the maximum stage of exercise testing ($VO_{2\ peak}$), mL/min/kg | 33.84 [29.59; 38.18] | 33.59 [29.01; 38.03] | 0.449 |
| Respiratory exchange ratio ($R$), rel. units | 1.05 [1.03; 1.09] | 1.04 [1.03; 1.07] | 0.002 |
| Heart rate before exercise ($HR_{rest}$), beats per min (bpm) | 78.00 [70.00; 87.00] | 81.00 [72.00; 89.00] | <0.001 |
| Heart rate at aerobic threshold ($HR_{AerT}$), beats per min (bpm) | 110.00 [100.00; 122.00] | 114.00 [102.00; 126.00] | <0.001 |
| Heart rate at anaerobic threshold ($HR_{AT}$), beats per min (bpm) | 143.00 [132.00; 154.00] | 147.00 [134.00; 158.00] | <0.001 |
| Heart rate at peak load ($HR_{peak}$), beats per min (bpm) | 151.00 [144.00; 160.00] | 152.00 [144.00; 163.00] | 0.025 |
| Heart rate at 3 min of recovery ($HR_{3min}$), beats per min (bpm) | 91.00 [82.00; 101.00] | 93.00 [84.00; 102.00] | 0.017 |
| Power output at the anaerobic threshold level ($Pwr_{AT}$), W | 190.00 [165.00; 230.00] | 200.00 [165.00; 240.00] | 0.028 |
| Power output at the maximum stage of testing ($Pwr_{Peak}$), W | 215.00 [180.00; 260.00] | 215.00 [175.00; 260.00] | 0.982 |
| Relative power output at anaerobic threshold per body weight ($Pwr_{AT}$/weight), W/kg | 2.63 [2.27; 3.01] | 2.72 [2.29; 3.16] | 0.006 |
| Relative maximal power output per body weight during testing ($Pwr_{Peak}$/weight), W/kg | 2.94 [2.59; 3.31] | 2.96 [2.54; 3.36] | 0.568 |

Table compiled by the authors based on their own data

**Note:** IQR — interquartile range

systemic stress, increasing cortisol levels and affecting cardiovascular regulation [12].

Furthermore, power output at the anaerobic threshold (W) and relative power at the anaerobic threshold (W/kg) were higher in Group 1 ($p$ = 0.028 and $p$ = 0.006, respectively), which may suggest compensatory mechanisms. Thus, athletes with chronic pain or discomfort might exert more effort to achieve the same performance level. However, peak power and $VO_{2\ peak}$ showed no significant differences ($p$ = 0.982 and $p$ = 0.449), indicating that dental issues have a limited impact on maximal aerobic capacity.

For each parameter reflecting the performance and endurance of athletes, regression models were developed. Our approach was strictly guided by statistical analysis, and we present robust mathematical models. The strength and closeness of the relationship between the studied parameters were assessed based on the correlation coefficient, considering the appropriate level of statistical significance and the observed variance magnitude. The corresponding data are presented in Table 2.

The observed dependence of the $HR_{AerT}$ (bpm) indicator is described by the following linear regression equation:

$$Y_{HR\ AerT} = -18.046 - 4.633 \times X_M + 5.500 \times X_{gastro} + 1.375 \times X_{dent} + 2.219 \times X_{endo} + 0.167 \times X_{weight} + 0.120 \times X_{HR\ rest} + 0.646 \times X_{HR\ AT} + 0.130 \times X_{HR\ 3min} - 0.079 \times X_{PWR\ AT} + 8.007 \times X_{PWR\ AT/weight}.$$

Based on the presented regression model equation, athletes can expect an increase in $HR_{AerT}$ with a gastroenterological diagnosis (by 5.500 bpm), a dental diagnosis (by 1.375 bpm), and an endocrinological diagnosis (by 2.219 bpm).

The $HR_{AerT}$ indicator will increase with a 1 bpm increase in $HR_{rest}$ — by 0.120 bpm; with each kilogram increase in the athlete's body weight — by 0.167 bpm; with a 1 bpm increase in $HR_{AT}$ — by 0.646 bpm; with a 1 bpm increase in $HR_{3min}$ — by 0.130 bpm; with a 1 W/kg increase in $Pwr_{AT}$/weight — by 8.007 bpm. At the same time, with an increase in $Pwr_{AT}$, a decrease in the $HR_{AerT}$ indicator by 0.079 bpm can be expected. According to the regression model results, males are expected to have a decrease in $HR_{AerT}$ by 4.633 bpm compared to females.

The obtained regression model is characterized by a multiple correlation coefficient $R_{xy}$ = 0.830; ($p$ < 0.001), which corresponds to a high strength of association according to the Chaddock scale. The obtained model allowed the change in the $HR_{AerT}$ indicator to be predicted with high accuracy, accounting for 68.9% of the observed variance. The assessment of the dependence of $HR_{AT}$ (bpm) on quantitative factors was performed using the linear regression method. The number of observations was 1887.

The linear regression results (Table 2) confirm that the presence of a dental diagnosis is independently associated with an increase in $HR_{AerT}$ by 1.375 bpm ($p$ = 0.017). Although this effect seems minor, it has cumulative significance in the context of other factors, such as gender (increase in $HR_{AerT}$ in men by 4.633 bpm, $p$ < 0.001), presence of a gastroenterological diagnosis (increase by 5.500 bpm, $p$ = 0.021), and endocrinological problems (increase by 2.219 bpm, $p$ = 0.039). The model explains 68.9% of the variance in $HR_{AerT}$ ($R_{xy}$ = 0.830, $p$ < 0.001), indicating high predictive power and confirming the systemic nature of the influence of dental diseases.

Interestingly, an increase in power at the anaerobic threshold ($Pwr_{AT}$) is associated with a decrease in $HR_{AerT}$ (-0.079 bpm per 1 W, $p$ = 0.007), which may reflect better cardiovascular adaptation to exercise in more trained

**Table 2. Statistical description of the regression model**

| Parameters | Contribution in regression equation | Standard error of the mean | *t*-test of regression model parameters | Statistical significance level, *p* |
|---|---|---|---|---|
| *Intercept* | -18.046 | 6.357 | 2.839 | 0.005 |
| Gender: M | 4.633 | 0.759 | 6.105 | <0.001 |
| Gastroenterologist | 5.500 | 2.389 | 2.302 | 0.021 |
| Dentist | 1.375 | 0.573 | 2.398 | 0.017 |
| Endocrinologist | 2.219 | 1.073 | 2.069 | 0.039 |
| Body weight, kg | 0.167 | 0.074 | 2.262 | 0.024 |
| Heart rate before exercise ($HR_{rest}$), beats per min (bpm) | 0.120 | 0.029 | 4.174 | <0.001 |
| Heart rate at anaerobic threshold ($HR_{AT}$), beats per min (bpm) | 0.646 | 0.027 | 23.870 | <0.001 |
| Heart rate at 3 min of recovery ($HR_{3min}$), beats per min (bpm) | 0.130 | 0.024 | 5.470 | <0.001 |
| Power output at the anaerobic threshold level ($Pwr_{AT}$), W | -0.079 | 0.029 | -2.706 | 0.007 |
| Relative power output at anaerobic threshold per body weight ($Pwr_{AT}$/weight), W/kg | 8.007 | 2.340 | 3.421 | < 0.001 |

Table compiled by the authors based on their own data

**Note**: *Intercept* — dimensionless indicator athletes. However, an increase in relative power at the anaerobic threshold ($Pwr_{AT}$/weight) increases $HR_{AerT}$ by 8.007 bpm ($p < 0.001$), highlighting the complex relationship between body weight, strength, and cardiac response. It should be noted that, despite the significance of the identified differences in cardiorespiratory parameters, peak power output metrics showed no statistically significant differences between the groups. This may indicate that short-term maximal performance remains unaffected, while endurance and recovery speed are impaired, which is particularly critical for combat sports athletes.

The data obtained are consistent with those reported in literature demonstrating that oral health affects athletic performance through several mechanisms. First, chronic pain from dental caries or periodontitis can reduce training volumes and concentration, which is particularly critical in martial arts where strategic thinking is required [13]. Second, systemic inflammation caused by periodontal infections may impair muscle recovery and increase the risk of cardiovascular complications [14]. Third, nutritional problems due to pain or tooth loss can lead to deficiencies in macronutrients and micronutrients, thus reducing endurance [15].

Our study used the data of comprehensive medical examinations (CME) of 1887 combat sports athletes to reveal a significant impact of dental diseases on physical performance and endurance. The analysis showed that the presence of dental problems leads to changes in a range of physiological indicators, including heart rate (HR) during various phases of exercise and recovery, as well as power output at the anaerobic threshold (AT). These results underscore the importance of oral health as a factor influencing athletic performance [5], particularly in martial arts, which demand a high level of physical conditioning [8] and concentration [1, 9].

The identified dependence of $HR_{AT}$ and $HR_{peak}$ on the presence of dental diseases confirms the hypothesis of the negative impact of dental pathologies on the adaptive capabilities of athletes. Elevated HR during various exercise phases may indicate reduced efficiency of energy metabolism and slower recovery processes, which are crucial in professional sports. The conducted regression analysis also revealed that, in addition to dental diseases, physiological parameters of athletes are influenced by conditions affecting other body systems, such as gastrointestinal and endocrine pathologies [10, 11]. This reinforces the need for comprehensive medical support for athletes, with an emphasis on an interdisciplinary approach.

The obtained data are consistent with the results of similar studies [16, 17] and indicate a high prevalence of dental diseases affecting physiological indicators and athletic performance among combat sports athletes. The presence of dental pathologies is associated with increased load on the cardiovascular system [19], which may reduce the body's adaptive capabilities to physical exertion and impair recovery processes [18, 20–22]. Many athletes lack sufficient awareness and, consequently, adherence to preventive oral hygiene practices [7], leading to the neglect and exacerbation of oral health problems [5]. Increasing awareness among athletes, coaches, and sports organizations about the importance of oral hygiene could lead to improved preventive measures and better outcomes [10]. The use of aligners or braces for bite correction, adapted for contact sports [23], may serve as an effective prevention measure of orthodontic issues. Regular dental checkups and the use of protective devices, such as custom-made mouthguards, can help prevent oral injuries and diseases [1]. Effective strategies for promoting oral health are necessary to minimize its impact on performance [4].

The similarity of psychophysiological stress during combat in martial artists to the overload states experienced by pilots, astronauts, and military personnel [10] suggests the potential applicability of individual aligners in aerospace medicine and extreme situation medicine.

The identified differences highlight the need to integrate dental care into training programs. The absence of significant differences in $VO_{2\ peak}$ and peak power may indicate that a greater level of impact of dental diseases at submaximal exertion levels, which are characteristic of prolonged training and competitions in martial arts. This aligns with data from [9], which revealed up to a 21% decrease in performance among athletes with poor oral health.

## CONCLUSION

The presence of a dental diagnosis is associated with increased heart rate at rest, at the anaerobic threshold, and during the recovery phase, as well as with changes in power output at the anaerobic threshold. These changes may be attributed to pain, systemic inflammation, and nutritional disturbances, highlighting the systemic nature of the problem. The regression model demonstrated high predictive power, identifying dental diseases as an independent factor influencing $HR_{AerT}$, alongside gender, weight, and other medical diagnoses.

In our study, a significant impact of dental diseases on physical performance and endurance was identified. The presence of a dental diagnosis (Group 1) was associated with statistically significant differences ($p < 0.05$) compared to the group of athletes without a dental diagnosis (Group 0) across a range of physiological indicators characterizing physical endurance and performance: respiratory exchange ratio $R(0) = 1.05$ [1.03; 1.09], $R(1) = 1.04$ [1.03; 1.07]; heart rate at aerobic threshold $HR_{AerT}(0) = 110.00$ [100.00; 122.00], $HR_{AerT}(1) = 114.00$ [102.00; 126.00]; heart rate at anaerobic threshold $HR_{AT}(0) = 143.00$ [132.00; 154.00], $HR_{AT}(1) = 147.00$ [134.00; 158.00]; heart rate at peak load $HR_{peak}(0) = 151.00$ [144.00; 160.00], $HR_{peak}(1) = 152.00$ [144.00; 163.00]; heart rate at 3 min of recovery $HR_{3min}(0) = 91.00$ [82.00; 101.00], $HR_{3min}(1) = 93.00$ [84.00; 102.00]; power output at the anaerobic threshold level $Pwr_{AT}(0) = 190.00$ [165.00; 230.00], $Pwr_{AT}(1) = 200.00$ [165.00; 240.00].

The identified patterns indicate the need to incorporate dental examinations and preventive measures into mandatory medical support for athletes. Regular checkups, timely treatment of oral diseases, and the use of protective devices, such as mouthguards, can mitigate the negative impact of dental pathologies on athletic performance. Based on statistically significant differences in performance parameters among combat sports athletes, measures have been proposed to develop interventions for correcting the dental status of highly qualified athletes. These include:

1) need for prevention (regular dental examinations, the use of protective mouthguards, and increased awareness among athletes and coaches about oral hygiene are key measures to minimize negative impacts);

2) comprehensive approach (integrating dental care into the athletes' medical support system should become a mandatory part of preparation, particularly in contact sports);

3) further research (additional studies are needed to assess the long-term effects of dental interventions and their impact on cognitive functions and psychological state of athletes);

4) use of individual aligners (to prevent excessive impact on teeth under conditions of overload and extreme situations.

These findings and recommendations can serve as a basis for developing prevention programs and improving athletic performance through optimizing oral health. The use of individual aligners is recommended for specialists whose activities involve overload and extreme situations (pilots, astronauts, military personnel). Individual aligners are considered as a means of prevention and adaptation to real and simulated conditions of changing gravity, relevant to the development of adequate methods for preventing the negative impact of space flight factors.

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**Authors' contributions.** All authors confirm that their authorship meets the ICMJE criteria. The main contributions were as follows: Zhaklin I. Rusak — draft manuscript writing, conducting the research, text editing and conceptualization; Aleksey L. Baginsky — research managing, conceptualization, and formal analysis; Ekaterina V. Milashenko — data administration and visualization; Victoria V. Petrova — conducting the research, verifying the data, and conceptualization; and Anton A. Artamonov — manuscript writing, manuscript editing and conceptualization.

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