

Original Research

Cardiopulmonary Reactivity in Bulgarian National Taekwon-Do Team Athletes

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Background

The specific demands of Taekwon-Do, involving dynamic kicks, hand strikes, controlled breathing, and high- intensity efforts under psychological stress, require athletes to maintain optimal cardiorespiratory fitness.

Hypothesis/Purpose

This study aimed to evaluate the reactivity of the cardiopulmonary system in athletes from the Bulgarian National Taekwon-Do (International Taekwon-Do Federation, ITF) team before and after a training camp. The authors hypothesized that intensive training would improve cardiovascular response and recovery.

Study Design

Observational cohort; pre-post study

Methods

Eleven male athletes from the Bulgarian National Taekwon-Do ITF team were evaluated using the Ruffier test and the Master two-step test before and after a three - week training camp. Heart rate and blood pressure were recorded at rest, immediately post-exercise, and during recovery. Cardiovascular reactivity was analyzed using calculated indices from the Ruffier test and workload- and recovery-based metrics from the Master test. Data were analyzed using descriptive and non-parametric statistics to discern changes.

Results

Improvements were found in resting heart rate, post-exercise recovery rate, and Ruffier indices, with significant changes in recovery parameters ($p < 0.05$). Performance metrics from the Master test-such as total workload (in kg) and two- minute recovery heart rate also improved, with a statistically significant increase in workload. ($p = 0.002$) These changes indicate enhanced functional adaptation of the cardiopulmonary system.

Conclusion

The findings demonstrate improved cardiopulmonary reactivity after intensive training. Functional tests such as Ruffier and Master are effective tools for evaluating cardiovascular performance and guiding training decisions in elite athletes.

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Level of Evidence

Level 3

INTRODUCTION

Taekwon-Do is a martial art that combines mental discipline with self-defense techniques involving kicks, punches, and blocks.¹ The International Taekwon-Do Federation (ITF) style emphasizes dynamic movements, frequent stance changes and powerful head-level kicks, requiring high level flexibility, balance, speed, and endurance.^{2,3} These technical demands engage both anaerobic and aerobic energy system: powerful strikes rely on anaerobic ATP resynthesis, while sustained movements utilize aerobic metabolism.⁴

In addition to physical demands, Taekwon-Do athletes must maintain effective breathing control, respond to short bouts of high-intensity activity, and perform under psychological stress. This places a premium on optimal cardiorespiratory regulation. Reliable assessment of this system is essential for monitoring fitness and guiding training interventions. Field tests are especially useful in this context due to their simplicity, minimal equipment needs and suitability for team testing.

Step tests, such as the Master two-step test, simulate stair climbing and are especially useful for evaluating physical work capacity in settings with limited space or equipment availability.^{5,6} Originally developed by Master and Oppenheimer in 1929 for cardiac assessment, the Master two-step test gained broad clinical use through the mid-20th century. It was applied for the detection of latent coronary disease and became a standard cardiac screening method.^{7,8} Although its application later declined due to the low exercise intensity and lack of continuous ECG monitoring, the test has maintained clinical relevance. More recently, it has been used in patients with cardiovascular and respiratory conditions, including post-COVID-19 recovery, and for early detection of pulmonary.⁹⁻¹¹ The Master two-step test was originally developed in the 1930s and gained wide application during World War II as a practical tool for screening the cardiovascular fitness of military personnel.^{12,13} Although later considered less specific for elite athletes, step-based protocols have evolved into established methods in sports medicine and remain widely used for field assessment of cardiorespiratory fitness when laboratory resources are not available.¹⁴ Step protocols more broadly have been successfully applied in pediatric and general rehabilitation contexts, as they are easy to perform, well understood even by children, and provide valuable information about endurance and cardiorespiratory status.⁶ Moreover, simplified adaptations of the Master two-step have been specifically reported in preschool populations,¹⁵ further supporting the feasibility of step-based testing in diverse age groups. Heart rate (HR) is a sensitive indicator of cardiovascular load and is commonly used to monitor training response and assess physical fitness.¹⁶

Squat-based assessments, including the Ruffier test, evaluate autonomic reactivity by measuring the cardiovascular response during transition from squatting to stand-

ing, offering insight into sympathetic -parasympathetic balance.¹⁷ These squat-based tests are often used in cardiology and sports medicine to detect early signs of autonomic dysfunction. The Ruffier test is a simple and reproducible tool requiring no specialized equipment. It has been widely used in sports medicine, rehabilitation and physical education settings.¹⁸ In contrast to the Master two-step, the Ruffier test appears better suited for athletes, as it reflects autonomic reactivity and recovery dynamics under conditions that engage large muscle groups. This provides insight into cardiovascular regulation and adaptation that is especially relevant for combat sport performance. Despite widespread use of squat-based assessments, such as Ruffier test, in clinical and sport settings, there is limited data on their application in elite combat sports. To date, no study has evaluated cardiopulmonary reactivity in Taekwon-Do athletes using the Master step test and the Ruffier index before and after an intensive training cycle.

Although originally developed in the early-to-mid 20th century, the Ruffier and Master tests remain relevant in specific sport and clinical settings. Their continued application is supported by their simplicity, cost-effectiveness, and suitability for field-based assessment.^{19,20} These protocols offer valuable insight into cardiovascular reactivity and recovery, particularly when laboratory-based tools are not feasible. The Ruffier test has been validated in contemporary studies for its reliability in evaluating autonomic reactivity and recovery, and has been applied in combat sports including karate and Taekwon-Do.^{21,22} Thus, combining the diagnostic value of the Master test with the practicality of the Ruffier test provides a feasible strategy for monitoring cardiovascular adaptation in Taekwon-Do athletes under field conditions.

The purpose of this study was to evaluate the reactivity of the cardiopulmonary system in athletes from the Bulgarian National Taekwon-Do (International Taekwon-Do Federation, ITF) team before and after a three-week training camp. The authors hypothesized that athletes would demonstrate improved cardiopulmonary reactivity following the training camp, as reflected by reduced resting heart rate, faster recovery, and improved functional indices.

METHODS

STUDY DESIGN

This was a prospective pre-post cohort study conducted over a three-week period. The aim was to evaluate changes in cardiopulmonary reactivity in national-level Taekwon-Do athletes with international competition experience following an intensive training camp.

PARTICIPANTS

Eleven male athletes from the Bulgarian National ITF Taekwon-Do were recruited for participation in the study. All athletes were actively preparing for the European Championship in Koper, Slovenia. Inclusion criteria were: (1) minimum five years of Taekwon-Do experience, (2) national team status, and (3) absence of acute injury or known cardiovascular disease. Written informed consent was obtained from all participants prior to testing. The study was approved by the institutional ethics committee (Protocol № 2403-1, March 4, 2024).

TRAINING CAMP CONTEXT

The training camp lasted three weeks. The content and progression of the three-week training camp were managed by the national coaching staff and included a combination of aerobic endurance sessions, anaerobic interval work, and sport-specific technical and tactical drills. Training intensity was progressively increased to simulate competitive conditions and promote cardiovascular adaptation. The role of the kinesi therapists (equivalent to physical therapists) was to assess the functional condition of the athletes before and after the camp, support rehabilitation in case of injury, and guide individualized recovery protocols when needed. The kinesi therapy team was not involved in designing the training load or structure.

TESTING PROCEDURES

All assessments were conducted in a controlled environment within the Taekwon-Do hall of TKD Club “Falcon”, Blagoevgrad. Testing was conducted in a thermally comfortable environment, under stable ambient conditions. All sessions took place in the morning hours (between 9:00 and 12:00), at least one hour after a light meal. A schedule was developed to ensure individual testing and avoid cumulative fatigue.

Prior to each test, athletes rested in a seated position for 5-10 minutes to allow heart rate and blood pressure to reach stable resting values following postural adjustment. The same rest protocol was applied between tests to ensure consistency and physiological recovery. Heart rate measured using a fingertip pulse oximeter (Medisana GmbH, Neuss, Germany), and blood pressure was assessed using a standard automatic upper-arm monitor. Both devices were routinely used and calibrated for clinical and field purposes.

MASTER TWO STEP TEST

For the Master two-step test, athletes performed step climbing for 90 seconds using a 23 cm platform. A 23 cm step platform, designed in accordance with the original specification of the Master two-step test, was utilized in the absence of commercially available alternatives. Heart rate and blood pressure were measured at rest and two minutes post-exercise to assess cardiovascular recovery rather than immediate exertional response. Load tolerance was calculated as the product of body mass and number of steps

performed. An efficiency coefficient was obtained by comparing the actual step test count to normative theoretical values described by Dushkov et al., who reference the original methodology of Amosov and Bendet.²³

RUFFIER TEST

Participants completed 30 bodyweight squats within 45 seconds, performing full squats with arms extended forward at 90° for balance. Verbal instructions were provided to ensure correct technique and consistent tempo throughout the test. Heart rate was measured at rest (HR_0), during the first 15 seconds of recovery after 30 squats (HR_1), and during the last 15 seconds of the first recovery minute (HR_2), according to the Ruffier protocol. Two indices were computed:

- Ruffier index: $RI = \frac{(HR_0 + HR_1 + HR_2) - 200}{10}$
- Ruffier- Dickson index: $RDI = \frac{(HR_1 - 70) + 2(HR_2 - HR_0)}{10}$

The RI provides a general measure of cardiovascular efficiency, while the RDI places greater emphasis on recovery and autonomic reactivity. Prior studies have reported that the RDI correlates more strongly with cardiorespiratory fitness when considering sex, age, and recovery dynamics.¹⁰ In the current study, both indices were reported to allow comprehensive assessment.

Interpretation of results was guided by established normative criteria. For the Ruffier Index (RI), the classification of Pérez et al.²⁴ was utilized: 0–5 = excellent, 5.1–10 = good, 10.1–14 = average, 14.1–18 = poor, >18 = very poor. For the Ruffier-Dickson Index (RDI), recently published distributions in a college youth population²⁵ were utilized, where values of 0–3 were associated with very good endurance, 3–6 with reasonably good, 6–9 with average, 9–12 with moderate, and 12–15 with poor endurance. While the latter are empirical categories rather than strict normative cut-offs, they provide useful context for interpreting cardiovascular recovery. Additional normative interpretation criteria were also referenced from Zanevsky,²⁶ who introduced seven levels of physical capacity according to the Dickson index: values < 0 indicate “excellent,” 0–2 “very good,” 2–4 “good,” 4–6 “average,” 6–8 “passable,” 8–10 “bad,” and > 10 “very bad”.

TESTING SCHEDULE

Baseline testing was conducted one day before the start of the camp; follow – up testing occurred on the final day.

STATISTICAL ANALYSIS

Data were analyzed using GraphPad Prism 3.0 (GraphPad Software Inc., USA). Descriptive statistics were calculated for all measured variables, including mean, standard deviation (SD), minimum, and maximum values. Prior to hypothesis testing, data distributions were assessed for normality using the Shapiro- Wilk test. Given the small sample size ($n=11$) and the non-normal distribution of some variables, non-parametric testing was applied. The Wilcoxon signed-

Table 1. Two- step Master Test Results. Reported as Mean $\pm$ standard deviation (SD) of cardiovascular and performance parameters before and after the training camp (n=11)

Measurements	Before	After	p- value
HR at rest (bpm)	67.18 $\pm$ 7.39	68.09 $\pm$ 6.38	0.82
HR 2 min after test (bpm)	66.55 $\pm$ 15.04	66.09 $\pm$ 5.38	0.19
SBP at rest (mmHg)	125.7 $\pm$ 10.59	123.6 $\pm$ 8.25	0.70
SBP 2 min after test (mmHg)	137.6 $\pm$ 13.99	130.4 $\pm$ 8.25	0.04*
DBP at rest (mmHg)	67.64 $\pm$ 9.79	63.82 $\pm$ 6.87	0.19
DBP 2 min after test (mmHg)	72.55 $\pm$ 7.45	67.09 $\pm$ 6.63	0.04*
Tolerance to load (kg) [†]	2585 $\pm$ 331.1	2794 $\pm$ 379.1	0.002*
% efficiency	1.506 $\pm$ 0.09	1.653 $\pm$ 0.09	0.002*

HR= heart rate; SBP= systolic blood pressure; DBP=diastolic blood pressure; bpm= beats per minute.

[†] Tolerance to load calculated as number of steps x body mass (kg). *Statistically significant difference ($p \leq 0.05$), Wilcoxon signed- rank test.

rank test was used to compare pre- and post-training values for each variable. Statistical significance was set at $p \leq 0.05$.

Effect sizes were calculated using Cohen's r to better interpret the magnitude of observed differences, where 0.10, 0.30, and 0.50 indicate small, medium, and large effects, respectively.²⁷ No correction for multiple comparisons was applied due to exploratory nature of the study. All statistical analyses were aligned with the study's hypotheses and methodological design.

RESULTS

ANTHROPOMETRIC CHARACTERISTICS

The study included 11 male athletes from the Bulgarian National ITF Taekwon-Do team. The mean age of the participants was 23.09 ± 3.91 years (range: 18-28 years). The average height was 179.7 ± 5.88 cm, with values ranging from 170 cm to 191 cm. The mean body mass was 71.24 ± 9.06 kg (range: 57-84 kg), and the mean body mass index (BMI) was 21.99 ± 1.96 kg/m² (range: 17.6-24.8 kg/m²).

CARDIOVASCULAR PARAMETERS: MASTER TWO-STEP TEST

The results of the Master two-step test are summarized in [Table 1](#). No statistically significant differences were observed in resting heart rate ($p=0.82$) or in heart rate two minutes after exercise ($p=0.19$). However, systolic blood pressure two minutes post- test showed a significant decrease after the training camp ($p=0.04$). A statistically significant reduction was also observed in diastolic blood pressure two minutes after exercise ($p=0.04$).

Furthermore, the mean tolerance to load (calculated as number of steps $\times$ body mass) significantly improved from 2585 ± 331.1 kg to 2794 ± 379.1 kg ($p=0.002$). The percentage of load efficiency also increased significantly from 1.506 ± 0.09 to 1.653 ± 0.09 ($p=0.002$).

CARDIOVASCULAR PARAMETERS: RUFFIER TEST

The results of the Ruffier test are presented in [Table 2](#). A statistically significant reduction in heart rate was observed

at HR₁ ($p=0.01$) and HR₂ ($p=0.012$). No significant differences were found in resting heart rate ($p=0.49$), Ruffier Index ($p=0.05$), or Ruffier-Dickson Index ($p=0.41$).

Effect size analysis showed small to medium magnitudes of change across the significant variables (Cohen's $r = 0.35-0.50$), indicating a modest but meaningful improvement in cardiovascular performance following the training camp.

DISCUSSION

Taekwon-Do ITF is among the fastest- growing modern sports disciplines, underscoring the need for a scientific approach to developing of athletes' physical and functional capacities.²⁸ The Bulgarian National ITF Taekwon-Do men's team, composed of predominantly young athletes (mean age = 23.09 ± 3.91 years), displays anthropometric characteristics within normative ranges for the local population. BMI classification identified, one competitor as underweight and two at the lower margin of normal range, which may reflect weight category constraints.

According to Dushkov et al.²³ in individuals with a well-functioning cardiovascular system, heart rate and blood pressure values measured two minutes after physical exertion should not exceed resting levels by more than 10 beats per minute (bpm) or 10 mmHg, respectively. Negative values after the Master two-step test are indicative of good cardiovascular adaptation and may exclude the presence of coronary heart disease.²⁹ In line with these observations, heart rate recovery (HRR) has been recognized as a sensitive marker of autonomic regulation, reflecting the balance between parasympathetic reactivation and sympathetic withdrawal. Similarly, heart rate variability (HRV) provides a complementary, more detailed assessment of autonomic function, offering insight into vagal tone and cardiac adaptability during both rest and recovery phases.³⁰ A decrease of ≥ 12 bpm within the first minute after exercise is considered normal, whereas slower recovery is associated with impaired parasympathetic reactivation and increased cardiovascular risk.³¹ More recent findings confirm that faster HRR is strongly correlated with enhanced cardiovagal modulation and more efficient autonomic balance.³² This per-

Table 2. Ruffier Test Results. Presented as Mean±standard deviation (SD) of heart rate values and calculated indices before and after the training camp (n=11).

Measurements	Before	After	p- value
HR at rest (bpm)	68.09±10.03	66.64±7.28	0.49
HR in the first 15 s (bpm)	108.5±12.36	105.2±11.61	0.01*
HR in the last 15 s (bpm)	84.18±13.64	81.82±11.92	0.02*
Ruffier index	6.73±3.27	5.36±2.72	0.05
Ruffier-Dickson index	7.06±2.9	6.55±2.71	0.41

HR= heart rate; s= second; bpm= beats per minute.

*Statistically significant difference ($p \leq 0.05$), Wilcoxon signed- rank test.

spective supports the interpretation that the lower post-exercise heart rate and blood pressure values observed in the athletes after the training camp reflect improved recovery capacity and cardiovascular adaptation.

Analyzing the results of the current study, prior to training camp one athlete demonstrated an excessive heart rate increase of 36 bpm. After the training camp, no participant exceeded the normative post-exercise heart rate threshold. The same athletes showed a negative post-exercise difference, with heart rate and blood pressure values measured two minutes after the test falling below their resting levels, indicating improved cardiovascular recovery.

Regarding systolic blood pressure, post-exercise values remaining more than 10 mmHg above resting levels were observed in five athletes before the camp and in four after, exceeding the expected 2-minute recovery threshold.²³ Negative differences were recorded in one athlete before the camp and in three afterwards. For diastolic blood pressure, elevated values were found in three athletes prior to the camp, whereas no such increases were recorded after the camp.

The mean difference in load tolerance during the Master two-step test between the pre-and post-camp measurement was 209 ±48 kg, reflecting a marked improvement. The calculated percentage of efficiency improved by 0.147 at the end of the study period. The observed effect sizes (Cohen's $r = 0.35$ – 0.50) indicated small-to-moderate magnitudes of change across the significant variables, suggesting meaningful but not large physiological adaptations resulting from the three-week training camp. Although the effect sizes were small to moderate (Cohen's $r = 0.35$ – 0.50), they indicate that the improvements in recovery heart rate, systolic and diastolic blood pressure, and overall efficiency were clinically physiologically meaningful. Similar magnitudes of change are commonly observed in short-term training interventions among combat sport athletes, reflecting early stages of cardiovascular adaptation rather than large structural changes.

According to De Mondenard,³³ a resting heart rate below 65 bpm is indicative of proper cardiovascular function. In more emotionally reactive or anxious individuals, a resting heart rate slightly above 70 bpm may still be considered within normal physiological limits.

An individual analysis of heart rate values before and after the training camp revealed that five athletes had resting HR below 65 bpm prior to the camp, and six after its

completion. According to de Mondenard, exceptions exist in highly neurotonic individuals whose resting HR rarely drops below 70 bpm, whereas a resting HR below 65 bpm is already indicative of good baseline cardiac function.³³ By the end of the study period, ten out of the eleven athletes fulfilled the criteria for appropriate cardiovascular function at rest. The remaining athlete maintained a slightly elevated resting heart rate (>70 bpm), which may be attributed to transient sympathetic activation related to pre-competition weight reduction and electrolyte imbalance, both of which can influence cardiac autonomic regulation.

The heart rate measured during the first 15 seconds following exercise (HR_1) served as a key indicator of cardiovascular adaptation in the study. According to De Mondenard,³³ this value should not exceed twice the resting heart rate. A sharp increase beyond this threshold may be indicative of overtraining. In the current sample, none of the Taekwon-Do athletes exhibited a doubled heart rate during the first 15 seconds of recovery.

Comparative analysis showed a statistically significant improvement in cardiovascular adaptation following the training camp. The mean difference between resting heart rate and the first 15-second post-exercise value decreased from 40.36±7.46 bpm before the camp to 38.55±8.92 bpm afterwards ($p = 0.01$), indicating faster heart rate recovery and enhanced autonomic regulation. The smallest increase observed was 30 bpm pre-camp and 23 bpm post camp, while the maximum increase was 53 bpm and 49 bpm, respectively. These results suggest improved cardiovascular responsiveness after the training camp.

Heart rate measured during the last 15 seconds of the first recovery minute (HR_2) reflects resistance to physical exertion and the efficiency of post-exercise recovery. Ideally, this value should approximate the resting heart rate. A lower heart rate at this time point, compared to the initial resting value, indicates excellent cardiovascular adaptation. Conversely, if recovery is incomplete after one minute, it is considered a sign of poor recovery may reflect inadequate autonomic or cardiovascular adaptation to exercise stress.³³

Before the training camp, three athletes achieved heart rate values close to their resting levels in the last 15 seconds of recovery; after the camp, this number increased to five. Although this indicates a modest improvement in recovery capacity, the overall group difference was not statistically significant. The minimal difference between end-test

and resting heart rate was 2 bpm pre-camp and 1 bpm post – camp. The maximum differences observed were 38 bpm before the camp and 29 bpm after it. The calculated average difference between resting and end-test values was 16.27 ± 11.88 bpm pre-camp, and 15.18 ± 10.04 bpm post-camp, indicates a trend toward better recovery, although not significantly different. This limited change may be explained by individual differences in training adaptation, transient fatigue accumulated during the camp, or the short duration of the intervention period.

Analysis of the Ruffier index indicated that most athletes demonstrated good to excellent cardiovascular adaptation to exercise, both before and after the training camp, with a slight overall improvement in classification scores. This finding suggests that the team entered the camp with a relatively high baseline level of cardiovascular fitness, leaving limited room for further measurable improvement. The minor post-camp enhancement likely reflects increased autonomic efficiency and better recovery control following intensive training, consistent with the expected adaptations from short-term conditioning.

The Ruffier-Dickson index showed improvement in six athletes following the training camp, while five exhibited a slight deterioration. This divergence likely reflects the limited sensitivity of the Ruffier-Dickson modification in detecting subtle physiological changes in well-trained individuals. The index incorporates resting heart rate into its calculation, which can introduce variability unrelated to true changes in cardiovascular function – for example, due to transient fatigue, hydration status, or emotional stress during testing. Consequently, the Ruffier-Dickson index may be less specific than the original Ruffier index for monitoring short-term adaptations in elite athletes. This divergence is an important methodological consideration. Cojocaru and Doina³² emphasize that only one of the two indices – either Ruffier or Ruffier-Dickson – should be used when interpreting test results, as they may yield differing assessments of load.³⁴

Guo et al.³⁵ applied the Ruffier test to a sample of 18 healthy, physically active men (mean age 32.1 years) from the general population. The reported mean heart rate values were: 68 ± 9.7 bpm at rest, 128.7 ± 17.3 bpm in the first 15 seconds, and 92.6 bpm in the last 15 seconds of the first minute. The calculated Ruffier index was 8.9 ± 4.1 , and the Ruffier – Dickson index was 10.8 ± 4.1 .³⁵ Compared to the current study, the Taekwon-Do athletes showed more favorable cardiovascular indicators, suggesting better adaptation to physical load.

Although ITF Taekwon-Do is not an Olympic sport, it continues to evolve and gain broader international recognition. Bulgarian athletes and coaches have contributed to development through consistent participation and results in international competitions.³⁶ Aerobic training is known to positively influence the development of athletes, particularly by enhancing cardiovascular function and promoting faster recovery after high-intensity exertion.³⁷ In Bulgaria, ITF Taekwon-Do is not recognized as a professional sport. National team athletes typically engage in other professional or educational pursuits outside of training. Nev-

ertheless, the current results show that they maintain good cardiovascular function and exhibit recovery patterns comparable to those of professional athletes.

One of the strengths of this study is the use of simple, accessible field tests that can be applied in real-world training environments. While the Master and Ruffier protocols were originally developed several decades ago, they have maintained relevance due to their practicality and ease of use in both sports and rehabilitation contexts.^{19,24} The Ruffier-Dickson modification in particular allows for individualization based on baseline heart rate. These tools provide a functional, if indirect, evaluation of cardiovascular response, making them suitable for field-based monitoring in high-level athletes.

STUDY LIMITATIONS

This study is subject to several limitations. The sample size was small ($n=11$), which limits the statistical power and generalizability of the findings. Participants trained under different coaches in separate clubs across various cities, leading to differences in baseline conditioning and adaptation potential. Some athletes were in the process of reducing body mass to qualify for weight categories, which may have affected electrolyte balance and, consequently, heart rate and blood pressure. Mild signs of incomplete recovery were noted in a few athletes at the end of the camp, which may suggest transient overreaching rather than full adaptation to the training load. This could also be related to dehydration and electrolyte imbalance associated with weight reduction practices, as commonly reported in combat sports. The sensitivity of the Master two-step test for elite athletes is limited due to ceiling effects, which reduce its discriminatory capacity in highly trained populations. This represents a methodological limitation; however, in the current study context the test still provided comparative value for field-based monitoring of Taekwon-Do athletes. Another limitation is that cardiopulmonary reactivity was assessed using functional field tests rather than direct physiological measures such as heart rate variability (HRV). Modern wearable technologies – including smartwatch-based sensors, chest-strap cardiac monitors, and devices like the Oura Ring – now allow continuous HRV tracking and could complement traditional field assessments in future studies.

PRACTICAL APPLICATION

The results of this study provide valuable insight for coaches and support staff regarding the athletes' initial level of fitness and functional capacity at the beginning of the training camp as well as the degree of adaptation and endurance development achieved by its conclusion. The applied functional tests allow for rapid, non-invasive assessment of cardiovascular response and recovery dynamics, supporting individualized training load adjustments and early detection of overtraining symptoms. Such data can be instrumental in optimizing preparation strategies and ensuring athletes maintain safe and effective performance progression.

CONCLUSION

The results of this study indicate that the athletes demonstrated improved cardiopulmonary reactivity following the three-week training camp, reflected by lower post-exercise blood pressure, faster heart rate recovery, and better Ruffier and efficiency indices. These findings suggest enhanced autonomic regulation and cardiovascular adaptation in response to intensive training. The applied measurements enabled the assessment of cardiorespiratory reactivity in male athletes from the Bulgarian National ITF Taekwon-Do team before and after a structured training camp. The selected tests, being simple, time-efficient, and equipment-independent, proved effective in evaluating the athletes' functional status. When implemented systematically and interpreted appropriately, these tools can guide timely interventions that improve adaptation to physical exertion and enhance overall athletic performance, particularly in resource-limited field settings. Their accessibility also re-

inforces their value in clinical and field-based settings, as they can be administered without expensive laboratory equipment, allow for repeated monitoring over training cycles, and provide immediate feedback for coaches and medical staff. This practicality makes them especially useful in sports such as Taekwon-Do, where resources are limited and there is a need to assess large groups of athletes efficiently.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this study.

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