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A comparative analysis of repetition speed development in Gyaku-Tsuki and Mae-Geri techniques in junior Kempo athletes

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Abstract

Background and Study Aim Repetition speed of specific techniques represents a component of technical and tactical performance in striking-based combat sports. It is closely related to neuromuscular control, intersegmental coordination, and execution efficiency. The development of rapid, repeated, and precise motor actions is commonly addressed within training programs using various methodological approaches. Despite the application of different training methods, their relative effectiveness in enhancing repeated execution speed remains a matter of practical interest. The aim of this study was to comparatively analyze the development of repetition speed in Gyaku-Tsuki and Mae-Geri techniques in 10–12-year-old junior Kempo athletes following an athletics-based training intervention.

Material and Methods The study included 24 male junior Kempo athletes aged 10–12 years. Participants were divided into an experimental group (n = 12) and a control group (n = 12). Assessments were conducted at two time points (T1 and T2). Repetition speed was evaluated using 10-second maximal execution tests for Gyaku-Tsuki and Mae-Geri. The Wittygate electronic timing system was employed. Statistical analysis included descriptive indicators, the Shapiro–Wilk test, the Mann–Whitney U test, and Levene's test. The significance level was set at $p < 0.05$.

Results The experimental group showed greater improvements than the control group in both tests. For VRGT, the differences were favorable to the experimental group but did not reach statistical significance. In contrast, VRMG showed statistically significant improvements in the experimental group compared with the control group.

Conclusions The results demonstrate that the introduction of athletics-based exercises into the training structure had a positive effect on VRGT and a significant effect on VRMG in junior athletes. These findings support the need for an integrative approach in combat sports training. In this approach, the development of repeated execution speed through athletic means is harmonized with the refinement of Kempo-specific techniques. This contributes to improved training efficiency and sports performance.

Keywords: neuromuscular adaptation, combat sports training, youth athletes, motor control, repeated actions, performance analysis

Introduction

Performance in combat sports is strongly influenced by the athlete's ability to execute specific motor actions rapidly and repetitively. At the same time, athletes must maintain a high level of neuromuscular control and technical precision. In combat disciplines such as Kempo, repetition speed of striking techniques represents a factor of technical and tactical efficiency. It influences both offensive capacity and the ability to adapt to the dynamic demands of competition. This component is particularly relevant in junior athletes. The early developmental period is characterized by increased neuromuscular plasticity, which is favorable for optimizing the frequency and continuity of technical executions.

Repetition speed reflects the capacity of the nervous system to coordinate successive neuromuscular activations within a limited time interval. This coordination allows the maintenance of a high execution rate without degradation of technical quality [1]. The specialized literature indicates that performance in rapid repetition tasks is influenced by training level, degree of movement automation, and the efficiency of recruitment and synchronization of motor units. These factors are particularly relevant under conditions of explosive and repetitive effort [1, 2]. In contact sports, actions follow one another rapidly and require continuous execution of specific techniques. Therefore, the development of repetition speed becomes a central objective of the neuromotor training process [1, 2]. This capacity enables athletes to maintain a high execution rhythm under repeated loading conditions without compromising technical control and neuromuscular efficiency.

Gyaku-Tsuki (VRGT) represents a relevant

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indicator of the athlete's ability to rapidly and repeatedly execute an upper-limb striking technique. This technique is characterized by linear, coordinated, and controlled movements [3]. The assessment of this test provided information regarding the efficiency of intersegmental coordination. It also reflected neuromuscular control of the upper kinetic chain and the capacity to maintain a high execution rhythm within a predetermined time interval [4]. Performance in the VRGT test reflects the level of movement automation and the efficiency of motor unit activation involved in explosive and repetitive actions.

As a complementary element, Mae-Geri (VRMG) provides information on the capacity for rapid repetitive execution of a lower-limb striking technique. This technique involves larger body segments and requires a higher level of coordination, postural stability, and neuromuscular control [5]. Successive executions in the VRMG test reflect the efficiency of integrating strength, speed, and coordination in repetitive actions. They are closely related to center-of-mass control and synchronized activation of the involved muscle chains [6].

Recent studies indicate that interventions oriented toward the development of execution speed and repetition capacity can lead to significant improvements in neuromotor performance in young athletes [7, 8]. However, data regarding technique-specific repetition speed adaptations for distinct techniques such as Gyaku-Tsuki and Mae-Geri remain limited, particularly among junior martial arts practitioners [9]. Previous research in martial arts has primarily addressed execution speed assessment or the development and validation of speed tests for techniques such as Gyaku-Tsuki and Mawashi or Mae-Geri. These studies were mainly conducted in karate-based contexts. They did not focus on repetition speed adaptations or comparative analyses in junior athletes [10, 11, 12]. In this context, the comparative analysis of repetition speed dynamics in the VRGT and VRMG tests allows a deeper understanding of how general neuromuscular adaptations transfer to the repetitive execution of Kempo-specific techniques. It also provides objective benchmarks for optimizing the training process and for the scientific substantiation of training programs oriented toward the development of neuromotor speed [13].

Analysis of research findings has shown that repetition speed is closely associated with neuromuscular coordination, movement automation, and the ability to sustain high technical performance under repeated execution conditions. Researchers emphasize that the development of this capacity plays a meaningful role in optimizing technical and tactical efficiency, particularly in striking-based combat sports during the early stages of athletic development. At the same time, unresolved aspects remain regarding how repetition speed evolves across different techniques and how training-induced neuromuscular adaptations are reflected in technique-specific performance outcomes. These observations indicate the need for a focused examination of repetition speed dynamics within applied training contexts and serve as a conceptual basis for further investigation.

In this context, greater attention has been directed toward technique-specific manifestations of repetition speed in junior athletes. Fundamental techniques such as Gyaku-Tsuki and Mae-Geri require repeated high-speed execution and place distinct demands on neuromuscular coordination and control. The 10–12-year age range represents a formative developmental stage in which motor patterns and technical habits are actively established. This makes it particularly relevant for targeted interventions aimed at repetition speed development. Within this framework, the systematic use of athletics-based training approaches may represent a relevant means of influencing repetition speed development in junior athletes. Such an approach allows the examination of how general neuromuscular adaptations induced by athletics-based exercises are transferred to the repetitive execution of fundamental striking techniques. The aim of this study was to comparatively analyze the development of repetition speed in Gyaku-Tsuki and Mae-Geri techniques in junior Kempo athletes aged 10–12 years following an athletics-based training intervention.

Materials and Methods

Participants

The study included a total of 24 male junior Kempo athletes aged between 10 and 12 years. Participants were allocated into two groups: an experimental group (n = 12) and a control group (n = 12). All athletes had a minimum of one year of training experience and regularly participated in sport-specific training activities related to Kempo. The selection of this age range was justified by the high level of neuromuscular plasticity characteristic of early developmental stages. This characteristic is favorable for functional adaptations induced by specific training [14, 15].

Inclusion and Exclusion Criteria

The inclusion criteria targeted male junior athletes aged 10–12 years who were registered with the Romanian Kempo Federation and had at least one year of practice experience. Participants demonstrated consistent attendance at training sessions within their respective clubs and had taken part in at least one official competition included in the federation's calendar. Participation in the study was based on voluntary involvement.

The exclusion criteria included athletes presenting medical conditions or musculoskeletal injuries that could affect performance or safety during exertion. Athletes whose condition could limit the capacity for repetitive execution of striking techniques were also excluded. In addition, athletes involved concurrently in other studies were excluded. Those who failed to comply with the training protocol or researchers' instructions were excluded as well. The same applied to athletes using substances or treatments incompatible with sustained physical effort or repetitive execution capacity [16].

Informed consent was obtained from the parents or legal guardians of all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki regarding research involving human subjects [17].

Study Design

The research was designed as a comparative study with repeated measurements conducted at two distinct time points: initial testing (T1) and final testing (T2). The interval between the two assessments corresponded to the duration of the intervention program applied to the experimental group, while the control group followed their regular training program. This design allowed for the analysis of changes in repetition speed of striking techniques and for the comparison of modifications between the two groups [18]. The structure and main characteristics of the athletics-based training intervention are presented in Table 1.

Testing Procedure

Testing was performed under standardized conditions in a controlled indoor environment with a constant temperature of 20–22 °C. All assessments were conducted at the same time of day to reduce the influence of circadian variations on neuromotor performance [19]. Athletes were instructed to avoid intense physical exertion for at least 24 hours prior to evaluation. Each participant underwent a familiarization period with the testing equipment and procedures. This was done to minimize learning effects and to ensure result stability [20].

Valid Execution Criteria

For both tests, a repetition was considered valid when the technique was executed correctly and the Wittygate sensor detected the presence of the striking limb. Detection occurred through interruption of the infrared signal at the predefined target point on the boxing bag. In the Gyaku-Tsuki test, a valid repetition required contact with the designated target area on the bag. Proper fist alignment and full extension of the striking arm were required, resulting in sensor activation. In the Mae-Geri test, validity was confirmed when the kicking foot contacted the predefined target zone on the bag. Sensor detection had to occur while maintaining the correct execution trajectory.

Executions that failed to activate the sensor, missed the target area, or were performed with evident technical errors were not counted. These errors included loss of balance, incomplete extension, or incorrect trajectory. This procedure ensured objective and standardized validation of repetitions across all participants. All testing procedures and execution validity were supervised and verified by an independent specialist affiliated with the Research Center for Human Performance, Faculty of Sciences, Physical Education and Informatics, Politehnica University of Bucharest.

Instruments and Measurements

Gyaku-Tsuki Repetition Speed (VRGT)

VRGT was assessed using the Wittygate electronic timing system (Microgate Srl, Bolzano, Italy) [21] through a 10-second maximal execution test. For both tests, the infrared sensors of the Wittygate system were positioned at approximately 50 cm

Table 1. Structure of the athletics-based training intervention

Training component	Experimental group	Control group
Study duration	6 months	6 months
Sessions per week	3	3
Session duration	30 min	30 min
Training integration	Integrated within regular Kempo training	Regular Kempo training only
Main training content	Hurdle jumps; multiple jumps; high-knee jumps; Mae-Geri executions over obstacles; medicine ball throws; elastic resistance exercises	Technical drills; combinations; kata practice; sparring
Targeted motor qualities	Repetition speed; coordination; explosive strength; neuromuscular control	Technical execution and general conditioning
Intensity	Moderate to high	Moderate
Work–rest structure	Short, repeated bouts with brief recovery intervals	According to regular practice
Progression	Gradual increase in execution speed, coordination demands, and task complexity	No structured progression

from the target surface of the boxing bag. Sensors were placed on either side of the expected impact trajectory of the striking limb to ensure consistent and accurate detection of valid executions across all participants. The test targeted the athletes' ability to rapidly and repetitively perform the specific technique while respecting established technical criteria within a limited time interval. The result was expressed as the total number of valid executions completed within 10 seconds. This value reflects movement frequency, the level of intersegmental coordination, and neuromuscular activation efficiency of the upper kinetic chain [22, 23]. The use of the Wittygate system enabled objective and precise recording of repetitions, ensuring good measurement reproducibility [24].

Mae-Geri Repetition Speed (VRMG)

VRMG was assessed using the same Wittygate electronic timing system, which allows precise recording of execution frequency within a predetermined time interval. The test consisted of repeated execution of the Mae-Geri technique for 10 seconds. Athletes were instructed to perform the maximum number of technically correct strikes. The analyzed parameter was the total number of executions completed during the testing interval. This parameter served as an indicator of rapid repetition capacity of a lower-limb technique [25].

This test evaluates execution speed, intersegmental coordination, postural stability, and neuromuscular activation efficiency specific to frontal kicking techniques. It represents a relevant indicator of technical and functional performance in Kempo [26, 27].

Statistical Analysis

Data were processed using the JASP software [28]. Preliminary calculations of differences between testing moments were performed using Microsoft Excel. Differences were calculated as absolute variation ($\Delta = T2 - T1$). This method is frequently employed in studies with repeated measurements to assess intervention-induced adaptations [29]. Results are presented as arithmetic means and standard error of the mean (SE). These indicators are recommended for describing central tendency and estimation precision in small sample sizes [30].

Data distribution was assessed using the Shapiro–Wilk test, which is considered one of the most sensitive tests for verifying normality in small samples [31]. When the normality assumption was not met, comparisons between the experimental and control groups were performed using the non-parametric Mann–Whitney U test. This test is recommended in sports science studies when distributions are asymmetric or variability is high [32]. Homogeneity of variances was verified using Levene's test. This test is employed to evaluate dispersion comparability between groups [33].

Statistical analysis was applied separately for the VRGT and VRMG repetition speed tests. Correlation relationships between variables were not investigated, as the main objective of the study focused on comparing the effects of the intervention on repetitive performance [29]. The level of statistical significance was set at $p < 0.05$, in accordance with conventions used in biomedical and sports research [30].

Results

The analysis of the results obtained in the repetition speed tests highlighted clear differences between the experimental group and the control group regarding performance changes between T1 and T2. In the case of VRGT, mean values indicate an increase in the number of executions in both groups. However, the improvement was more pronounced in the experimental group. The descriptive dynamics of Gyaku-Tsuki repetition speed between the two testing moments are presented in Table 2.

Table 2. Dynamics of Gyaku-Tsuki Repetition Speed (VRGT) between T1 and T2

Group	N	Mean T1	Mean T2	Δ (T2–T1)
Experimental	12	23.50	27.42	3.92
Control	12	20.58	23.00	2.42

N – number of participants; Mean T1 – mean number of valid executions at initial testing; Mean T2 – mean number of valid executions at final testing; Δ (T2–T1) – absolute change between final and initial testing.

According to the data presented in Table 2, the experimental group recorded a mean improvement of $\Delta = +3.92$ repetitions, compared with $\Delta = +2.42$ repetitions in the control group. Although the descriptive difference suggests a favorable effect of the intervention, statistical analysis did not reveal a significant difference between the distributions of the two groups ($p > 0.05$). Such results are frequently observed in studies with small sample sizes and high individual variability [32, 34]. The results of the inferential statistical analysis for VRGT are summarized in Table 3.

Table 3. Inferential statistical analysis of VRGT

U	(p)	Mean rank - EG	Mean rank - CG	Sum of ranks - EG	Sum of ranks - CG	Levene's test (p)
90.0	0.31	14.0	11.0	168.0	132.00	0.25

U – Mann–Whitney U statistic; p – significance level; Mean rank – average rank for each group; Sum of ranks – total rank sum for each group; EG – experimental group; CG – control group; Levene's test (p) – probability value for the homogeneity of variances.

The statistical variability indicators indicate greater dispersion of values in the control group, whereas the experimental group exhibits more homogeneous results. This pattern suggests superior stability of repeated executions in the experimental group and is consistent with findings reported in the specialized literature [35].

The evolution of mean VRGT values across testing moments for both groups is illustrated in Figure 1. The graphical representation confirms a more consistent progression of performance within the experimental group.

With regard to VRMG, the differences between groups were considerably more pronounced. The descriptive dynamics of Mae-Geri repetition speed between T1 and T2 are presented in Table 4.

Table 4. Dynamics of Mae-Geri Repetition Speed (VRMG) between T1 and T2

Group	N	Mean T1	Mean T2	Δ (T2–T1)
Experimental	12	14.58	17.58	3.00
Control	12	19.25	13.58	-5.67

The experimental group recorded a clear increase in repetition speed between T1 and T2 (Δ = +3.00), indicating an improvement in the capacity for repeated execution of the technique. In contrast, the control group exhibited a marked decrease in performance (Δ = −5.67). This decline reflects a reduced ability to maintain execution rhythm, possibly associated with neuromuscular fatigue and the absence of specific training stimuli [36]. The results of the inferential statistical analysis for VRMG are presented in Table 5.

Table 5. Inferential statistical analysis of VRMG

U	(p)	Mean rank - EG	Mean rank - CG	Sum of ranks - EG	Sum of ranks - CG	Levene's test (p)
144.0	< .001	18.5	6.5	222.0	78.0	0.12

The Mann–Whitney U test confirmed the presence of a statistically significant difference between the two groups in the case of VRMG ($p < 0.001$). The rank distribution indicates a clear superiority of the experimental group. The reduced variability of values within this group suggests a more stable execution pattern and more efficient neuromuscular control, which is in line with previous findings in combat sports research [37].

Overall, the results indicate that the applied intervention had a moderate impact on VRGT and a significant effect on VRMG. This suggests that neuromotor adaptations induced by the training program are more strongly reflected in techniques involving larger body segments and higher demands for intersegmental coordination and postural stability [35, 36]. The graphical representation of mean values illustrates the distinct evolution of Mae-Geri repetition speed between T1 and T2 for the two groups (Figure 2).

Discussion

The aim of this study was to analyze the evolution of repetition speed in the VRGT and VRMG tests in junior Kempo athletes and to highlight the effects of an intervention based on athletics-specific exercises oriented toward the development of repeated execution speed, in comparison with a control group. The obtained results indicate visible improvements in neuromotor performance within the experimental group. These findings confirm the effectiveness of the applied training program and support the importance of speed- and coordination-specific exercises in the preparation of young athletes [29, 30]. To the authors' knowledge, this study represents the first comparative investigation of repetition speed adaptations in Gyaku-Tsuki and Mae-Geri techniques in junior Kempo athletes following a structured athletics-based training intervention. The novelty of the

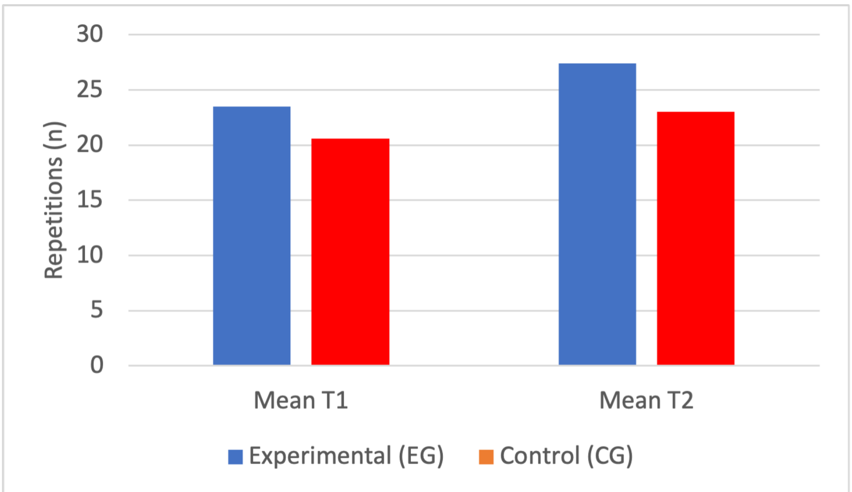

Figure 1. Mean values of Gyaku-Tsuki repetition speed (VRGT) for the experimental and control groups at T1 and T2

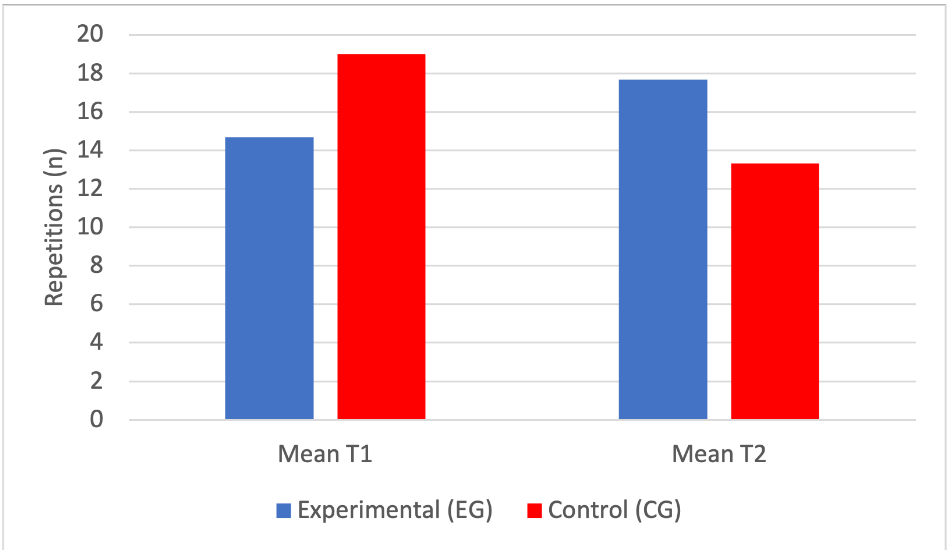

Figure 2. Mean values of Mae-Geri repetition speed (VRMG) for the experimental and control groups at T1 and T2

present research lies in the systematic integration of athletics-derived drills specifically designed to enhance repeated execution speed of fundamental Kempo techniques, rather than general physical conditioning. Furthermore, focusing on the 10–12-year age category addresses a critical developmental period in which neuromotor patterns and technical habits are established. This provides valuable insights for long-term athlete development. From a practical perspective, the findings offer coaches evidence-based guidance for optimizing repetition speed training in youth Kempo athletes through transferable athletic exercises.

In the case of VRGT, the analysis of results revealed an increase in the number of executions performed within the 10-second interval in both the experimental and control groups. However, the improvement was more pronounced among athletes who benefited from the intervention. This evolution suggests an enhanced capacity to maintain execution rhythm and movement frequency specific to the Gyaku-Tsuki technique. Although the differences between groups did not reach the threshold of statistical significance, the observed descriptive trend is consistent with research. Previous studies indicate that adaptations in upper-limb repetition speed may require longer intervention periods or higher volumes of specific stimulation in order to become statistically evident [31, 32].

An important role in these adaptations is played by the systematic inclusion of athletics-specific exercises in the training structure of the experimental group. Accelerated running drills, short-distance sprints, and coordination exercises contribute to the development of movement frequency and to the optimization of neuromuscular control. These exercises facilitate rapid and coordinated activation of motor units involved in the repetitive execution of upper-limb striking techniques [31]. Such mechanisms are essential for maintaining a consistent execution rhythm in repetition speed tests.

With regard to VRMG, the results revealed more pronounced differences between the two groups. The experimental group recorded a significant increase in the number of repetitions between T1 and T2. In contrast, the control group exhibited a clear decline in performance. This evolution indicates that the applied intervention had a major impact on the athletes' capacity to repeatedly and rapidly execute the Mae-Geri technique. This technique requires complex coordination between body segments, postural stability, and efficient control of the lower-limb neuromuscular chain [33, 34].

The athletics-based elements introduced into training contributed substantially to the optimization of VRMG. Jumping exercises, running drills with rhythm variations, and basic plyometric exercises promote the development of explosive strength and muscle contraction speed. These qualities are critical factors for the repeated execution of kicking techniques. Such adaptations allow the maintenance of a high performance level throughout the test duration. They also reduce rhythm decrements associated with neuromuscular fatigue, as reported in other research on combat sports [36].

Another relevant aspect highlighted by the obtained data is the variability of Δ values. This variability was more pronounced in the experimental group, particularly for VRMG. It reflects individual differences in response to the intervention and is characteristic of training programs oriented toward speed and repetitive executions. In such programs, adaptations are influenced by initial training level, coordination, and biological maturation [30, 37].

From a practical perspective, the study results emphasize the importance of integrating athletics-based exercises into the preparation of junior Kempo athletes. The use of running drills, sprints, coordination exercises, and jumps contributes to the development of fundamental neuromotor capacities. It also facilitates their transfer to the repeated execution of combat-specific techniques. Performance monitoring through standardized repetition speed tests conducted using the Wittygate system provides coaches with objective information for adjusting and individualizing training programs [29, 33].

In conclusion, the obtained results demonstrate that the introduction of athletics-specific elements into the training structure had a positive impact on VRGT and a significant effect on VRMG in junior athletes. These findings support the necessity of an integrative approach in combat sports preparation. In this approach, the development of repeated execution speed through athletic means is harmonized with the refinement of Kempo-specific techniques. This contributes to increased training efficiency and sports performance [34, 38].

Recommendations

Based on the results obtained in the present study, the following practical recommendations can be formulated for coaches and instructors involved in the preparation of junior Kempo athletes.

1. Clear structuring of the training process. Training sessions should be organized in a logical and progressive manner, with well-defined objectives aimed at developing repeated execution speed. Clear explanations and visual demonstrations of the Gyaku-Tsuki and Mae-Geri techniques contribute to a correct understanding of motor demands. They also support the optimization of execution rhythm during exercises.
2. Individualized approach to training loads. An initial assessment of repetition speed level is recommended for each athlete, both in the VRGT and VRMG tests. This allows exercise volume, intensity, and density to be adapted to individual capacities. The interindividual differences observed in Δ values justify the need for personalized adjustment of training tasks.
3. Integration of athletics-based elements into training. The systematic inclusion of athletics-specific exercises, such as short-distance speed runs, acceleration drills, bilateral and unilateral jumps, and speed–strength exercises for the lower limbs, contributes to improving repeated execution speed. These training means support the development of movement frequency, rapid motor unit activation, and maintenance of execution rhythm in the VRGT and VRMG tests.
4. Development of coordination and execution stability. Training sessions should include exercises that require rapid and repeated executions under conditions of technical control. Emphasis should be placed on segmental synchronization and maintenance of movement quality. These exercises contribute to increased performance stability and to the reduction of uncontrolled variations in execution rhythm.
5. Systematic monitoring of progress. Periodic use of standardized repetition speed tests for Gyaku-Tsuki and Mae-Geri is recommended. Assessments should be conducted at different time points (T1 and T2), with calculation of Δ differences (T2–T1). Recording results in individual performance sheets allows monitoring of each athlete's progression and continuous adjustment of the training program.
6. Interdisciplinary approach to training. Collaboration between coaches, instructors, and physical training specialists is recommended for the development of coherent training programs. Such programs should integrate repeated execution speed development, coordination, and explosive strength in accordance with the technical demands specific to Kempo.
7. Use of modern assessment technologies. The integration of electronic measurement systems such as Wittygate increases the objectivity of repetition speed evaluation and provides precise feedback on performance. These technologies can contribute to increased athlete motivation and to improved control of the training process.

A limitation of the present study is the relatively small sample size (n = 12 per group), which may have reduced statistical power, particularly for VRGT outcomes. Therefore, the findings should be interpreted as exploratory.

Conclusions

The comparative analysis of the results obtained in the VRGT and VRMG repetition speed tests highlights neuromuscular adaptations among the junior athletes included in the experimental group. The increase in Δ values for both indicators confirms an improvement in the capacity for rapid and repeated execution of sport-specific techniques as a direct effect of the applied intervention.

In contrast, the control group showed limited progress. In the case of VRMG, a decrease in performance was observed, suggesting the absence of relevant functional adaptations in the lack of a targeted training program. These differences support the notion that the development of repetition speed depends on specific stimuli aimed at neuromuscular control, intersegmental coordination, and technical execution efficiency.

The integration of athletics-based exercises into the structure of Kempo-specific training proved to be an effective strategy for optimizing repetition speed in both analyzed techniques. Speed runs, acceleration drills, jumps, and strength–speed exercises contributed to improving the capacity for rapid motor unit activation. They also supported the maintenance of a high execution rhythm throughout the 10-second test duration.

The differences observed between the two testing moments indicate that the intervention had a more pronounced impact on VRMG. This technique involves larger body segments and requires a higher level of intersegmental coordination and neuromuscular control. This finding underscores the need for a differentiated approach to striking techniques in the training of junior athletes, depending on the specific biomechanical and neuromotor demands of each action.

Overall, the study results provide scientific support for the systematic inclusion of athletics-based elements in the training of junior Kempo athletes. This approach represents an effective means of developing repetition speed and sport-specific technical performance. These conclusions may contribute to the optimization of training programs and to increasing the efficiency of striking technique execution in combat sports.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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This research received no external funding.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Use of Artificial Intelligence Tools

During the preparation of this manuscript, the authors used the artificial intelligence based tool ChatGPT (OpenAI) to obtain linguistic suggestions, synonyms, reformulations, translations, and guidance toward publicly available web resources. Artificial intelligence tools were not used for data analysis, statistical processing, interpretation of results, or the generation of original scientific content. All suggestions were critically reviewed and adapted by the authors. The authors assume full responsibility for the final content of the manuscript.

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