

Visual-motor reaction in Kempo athletes: A comparative analysis based on RVSS and RVSD tests

LUPU ADRIAN VALENTIN¹, MIHĂILESCU LILIANA NICULINA², MIHAI ILIE³

^{1,2,3} National University of Science and Technology Politehnica Bucharest,

Pitești University Center, Faculty of Science, Physical Education and Computer Science, ROMANIA

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Abstract

In combat sports, visuomotor reaction time represents a key determinant of performance, influencing the effectiveness of offensive, defensive, and counterattacking techniques. The scientific literature provides limited data regarding specific interventions targeting Kempo practitioners aged 10–12 years. **Purpose:** The aim of this study was to evaluate the effects of a training program focused on segmental visuomotor reaction by comparing the progression of an experimental group and a control group. **Methods:** The study employed a longitudinal experimental pre-test–post-test design and included 24 junior Kempo athletes (10–12 years), allocated into two groups (experimental, $n = 12$; control, $n = 12$). Reaction time was assessed at baseline (T1) and post-intervention (T2) using the RVSS (left segmental visuomotor reaction) and RVSD (right segmental visuomotor reaction) tests, performed with the OptoJump Next system. Statistical analysis included descriptive indicators and the Mann–Whitney U test to compare Δ differences (T2–T1), with the level of significance set at $p < .05$. **Results:** The experimental group demonstrated reductions in reaction time of -0.111 s for RVSS and -0.064 s for RVSD, whereas the control group showed increases of $+0.022$ s and $+0.053$ s, respectively. Between-group differences were statistically significant for both tests ($p = .002$). **Conclusions:** The implemented program induced significant functional adaptations in visuomotor response among junior athletes, supporting the systematic integration of segmental reaction-oriented exercises into the specific training of Kempo practitioners.

Keywords: neuromuscular latency; reaction time assessment; segmental visual response; combat sports training; junior athletes; experimental design

Introduction

In combat sports, performance is closely associated with the speed and accuracy of visuomotor reaction, as the rapid processing of visual information and its transformation into an effective motor response determine the success of offensive, defensive, and counterattacking actions. In contact sports characterized by a predominance of striking techniques, the time available for decision-making is extremely limited, and execution efficiency depends on the optimal integration between perceptual stimulus analysis and the corresponding neuromuscular activation. The scientific literature indicates that reaction time is influenced by factors such as the level of neuromuscular maturation, training experience, stimulus complexity, and task specificity (Zemková, 2016; Zhang et al., 2022). In combat sports, differences of only a few tenths of a second in reaction time can directly determine the outcome of a bout, influencing anticipation capacity, initiation speed, and counterattacking efficiency. During childhood and early adolescence, nervous system development is characterized by heightened neuronal plasticity and active processes of motor schema consolidation, facilitating rapid adaptation to learning and training experiences (Adolph & Hoch, 2019). In youth Kempo training practice, visuomotor reaction development is predominantly approached empirically, without discipline-specific experimental validation for this age category. This stage represents a particularly favorable period for the development of perceptual–motor capacities, as sensory information integration and motor response organization are highly adaptable. Consequently, structured interventions implemented during this developmental phase may substantially contribute to the optimization of neuromuscular control and to long-term improvements in technical and tactical efficiency. In the context of combat sports such as Kempo, the analysis of left–right segmental reaction provides relevant information regarding potential inter-limb asymmetries, lateral dominance, and neuromuscular balance. Inter-limb asymmetry is frequently observed in disciplines characterized by a predominance of unilateral actions, and elevated asymmetry levels may negatively influence sport-specific performance and constitute potential risk factors during high-intensity dynamic tasks (Ouerghi et al., 2025). At the same time, research on functional asymmetry in athletes indicates that high-level performers tend to exhibit reduced inter-segmental differences, reflecting balanced neuromuscular control and efficient intermuscular coordination (Podrigalo et al., 2023).

The differentiated assessment of lower-limb reaction times enables the identification of neuromuscular imbalances that may influence the efficiency of technical execution and competitive stability, particularly under

repetitive task demands. Segmental visuomotor reaction tests represent valuable tools for monitoring the progress of young athletes and for individualizing training interventions.

The integration of modern optoelectronic measurement systems, such as the OptoJump Next, ensures objective and precise evaluation of biomechanical parameters and has been confirmed in the literature as a valid and reliable method for determining contact time, flight time, and jump height (Glatthorn et al., 2011; Castagna et al., 2013). Owing to its optical sensor-based architecture and high temporal resolution, the OptoJump Next system allows accurate and reproducible measurement of temporal parameters related to reaction and motor execution under controlled experimental conditions. The validity and reliability of such systems have been further supported by recent studies reporting high intraclass correlation coefficients and strong agreement with laboratory-based reference methods (Comyns et al., 2023; Khemiri et al., 2025).

Most existing research has primarily focused on adult samples or on general analyses of agility and reaction time, without discipline-specific contextualization and without systematically investigating segmental differences or potential functional asymmetries (Zemková, 2016; Predoiu et al., 2025). In particular, for the 10–12-year age group, data regarding the comparative analysis of visuomotor reaction within controlled experimental interventions remain limited, thereby justifying further investigation in this area. In this context, the systematic examination of visuomotor reaction performance in junior Kempo athletes is warranted through the use of specific segmental tests such as the left segmental visuomotor reaction (RVSS) and right segmental visuomotor reaction (RVSD). These instruments allow the assessment of lower-limb response latency to visual stimuli and provide insight into bilateral functional balance. Recent developments in combat sport-specific reaction testing have led to the creation of instrumented perceptual–motor tasks designed to replicate striking demands (Faro et al., 2025), further supporting the need for ecologically valid reaction assessments in applied settings. Although international literature confirms the effectiveness of reaction-oriented training programs in other sports, there is no controlled evidence examining bilateral segmental reaction in Kempo within the 10–12-year age group. This gap limits the ability to individualise training and optimise functional balance between the lower limbs during athlete development.

Recent literature highlights that inter-limb asymmetries may influence both physical performance and the efficiency of sport-specific actions in combat sports, where repeated unilateral movements predominate (Bishop, Turner, & Read, 2017). Within martial arts-based combat sports, it has been demonstrated that plyometric interventions can modify the level of functional asymmetries and impact performance in jumping and change-of-direction tasks (Moreno-Azpe et al., 2024).

The comparative analysis of left–right segmental reaction in Kempo extends beyond a simple description of performance and may serve as an applied tool for identifying neuromuscular imbalances and supporting individualized interventions during the athlete development stage. Recent evidence indicates that structured perceptual–motor interventions can lead to significant improvements in reaction time, particularly among adolescent populations (Luo et al., 2025; Wang et al., 2025). Current meta-analyses report moderate to large effects on temporal reaction performance following visual training programs, emphasizing the importance of appropriately calibrating intervention duration and frequency to achieve meaningful neuromuscular adaptations.

The implementation of a structured program based on segmental reaction exercises provides the opportunity to quantify neuromuscular adaptations within a framework applicable to sports club settings. Despite these advances, no controlled experimental studies have specifically investigated the effectiveness of a structured training program targeting segmental visuomotor reaction in junior Kempo athletes aged 10–12 years. The absence of such evidence limits the scientific foundation of interventions implemented during the athlete development stage and reduces the potential for tailoring training according to segmental and lateral characteristics. To address this issue, the study employed a controlled experimental design with pre- and post-intervention assessments, comparing an experimental and a control group over a six-month intervention period. The study hypothesized that the experimental group would demonstrate significantly greater improvements in RVSS and RVSD reaction times compared to the control group following the six-month intervention. The obtained results may contribute to the scientific substantiation of youth Kempo training planning and to the systematic integration of segmental reaction assessment in performance monitoring.

Materials and Methods

Participants

The study was conducted between March 2025 and September 2025 in two sports centers affiliated with the Romanian Kempo Federation: C S Atac Roșiori de Vede (Romania) and C S Tiger Kempo Buftea (Romania). The participants were 24 male junior athletes aged between 10 and 12 years, actively practicing Kempo and officially registered for competitive participation. Group allocation was based on club affiliation, ensuring comparable levels of prior training experience and training volume between the two groups. Group allocation was not individually randomized but performed at club level to avoid contamination of the intervention between participants. All participants had at least one year of specific training experience and had previously competed in official competitions. Training frequency was a minimum of three sessions per week. Prior to the commencement of the study, written informed consent was obtained from parents or legal guardians,

and assent was provided by the participants. The study was conducted in accordance with the principles of the Declaration of Helsinki for research involving human subjects. At baseline, no significant differences were identified between groups regarding age, training experience, or weekly training volume.

Inclusion and Exclusion Criteria

Athletes were eligible for participation if they met the following criteria: age between 10 and 12 years; active Kempo practitioners with a minimum of one year of training experience; participation in official competitions; and general health status permitting engagement in sustained physical effort. Consistent attendance at training sessions and full compliance with the evaluation and intervention protocol were also required.

Athletes presenting neuromuscular disorders, orthopedic conditions, or recent injuries that could limit exercise execution were excluded. Participants concurrently involved in other competitive sports disciplines or other experimental studies were also excluded, as were those unable to adhere to the established schedule.

Study Design and Intervention Protocol

The research adopted a comparative experimental approach, employing a pre-test–post-test design with an experimental group and a control group. Assessments were conducted at two distinct time points: baseline testing (T1) and post-intervention testing (T2), separated by a six-month period. Testing sessions took place in the training halls of each club, on tatami surfaces, under similar environmental conditions (temperature approximately 20–22°C) and within a consistent time interval (17:00–19:00) to minimize circadian influences.

The testing procedures, equipment, and protocol were identical at both locations to ensure data comparability between groups. The selection of a controlled design is supported by recent literature in sport science, which recommends structured interventions and group comparisons according to biological development stage to identify age-specific neuromuscular adaptations (Ramirez-Campillo et al., 2023). Furthermore, the comparative experimental model is widely applied in sport research to evaluate training program effectiveness and quantify differences resulting from systematically planned interventions (Kudryavtsev et al., 2023). The choice of the 10–12-year age range is theoretically grounded in the characteristics of the pre- and peri-pubertal stage, which is associated with an elevated potential for neuromuscular adaptation. The literature indicates that this developmental period represents a favorable window for enhancing strength, speed, and plyometric capacities through predominantly neural mechanisms (Lloyd et al., 2021; Oliver et al., 2024). The intervention lasted six months, with both groups participating in regular weekly training sessions. In the experimental group, 30 minutes of each session (from a total weekly training volume of 180 minutes) were systematically allocated to athletic-specific exercises integrated into the standard Kempo training program.

The experimental group followed a structured athletics-based component integrated into regular Kempo training, with three weekly sessions including approximately 30 minutes dedicated to speed and neuromuscular development. The program focused on short acceleration runs (5–10 m), coordination drills, bilateral and unilateral jumps, basic plyometric exercises, and elastic resistance tasks aimed at enhancing explosive strength and intersegmental control. Selected exercises simulated striking mechanics, particularly lower-limb actions similar to Mae-Geri execution. Training intensity was moderate to high, organized in short repeated efforts with brief recovery periods to maintain execution quality.

Exercise complexity and execution speed were progressively increased throughout the six-month intervention in accordance with age-specific neuromuscular adaptation principles. The control group continued standard Kempo technical training without inclusion of the athletics-based component. The content of the intervention aimed to optimize execution speed, intersegmental coordination, explosive strength, and neuromuscular control through the use of short-distance sprints, acceleration drills, bilateral and unilateral jumps, plyometric exercises, elastic resistance exercises, the hurdling running step, and the pushing movement specific to the final effort phase of the shot put. The structuring of the intervention followed the principles of training progression and specificity, in accordance with current recommendations regarding neuromuscular preparation in junior athletes. The control group followed exclusively the standard Kempo training program, without the inclusion of the additional athletics-based component. Total weekly training volume was similar between groups, with the only difference being the content of the 30-minute athletics-based component.

Instruments

Reaction times for the left segmental visuomotor reaction (RVSS) and right segmental visuomotor reaction (RVSD) tests were assessed using the OptoJump Next optoelectronic system (Microgate, Bolzano, Italy). The system consists of transmitting and receiving bars equipped with LED diodes that continuously communicate with each other, detecting interruptions of the light beam with a temporal resolution of 1/1000 s. This architecture enables precise and reproducible measurement of temporal movement parameters and has been widely used in neuromuscular performance assessment (Rapotan et al., 2023). The validity and reliability of optoelectronic systems based on flight time and contact time measurements have been confirmed in recent literature through comparison with force platforms, considered the gold standard (Silva et al., 2024). Furthermore, studies investigating reaction time measurement using instrumented devices have demonstrated good agreement between portable systems and laboratory-based methods, supporting their application in sport-specific settings (Harper et al., 2022).

The testing protocol aimed to quantify the neuromotor response latency of the lower limb to a visual stimulus. Participants stood upright, with the tested lower limb positioned between the optical bars of the system.

Participants maintained their arms alongside the body, gaze directed forward, and the tested foot centrally positioned between the optical bars at a standardized distance of 1 m. Upon presentation of a random visual stimulus, the athlete was required to lift the foot rapidly and return it to the initial position while maintaining a controlled vertical trajectory, without compensatory movements of the trunk or upper limbs. The visual stimulus was electronically generated at randomized intervals between 2 and 5 seconds to prevent movement anticipation. Total motor reaction time was defined as the temporal interval between the onset of the visual stimulus and the re-interruption of the optical beam, corresponding to the repositioning of the lower limb to the initial stance and completion of the full movement cycle.

Prior to official data collection, participants performed several familiarization trials to ensure correct task understanding and stabilization of motor execution. Subsequently, each athlete completed two valid trials for each test (RVSS and RVSD). Each athlete performed only two valid trials for each lower limb, without additional attempts, in order to avoid learning effects and fatigue-related bias. The mean value of the two recorded trials was used for statistical analysis. Data were automatically recorded through the OptoJump Next system and exported electronically for statistical processing. To ensure measurement accuracy, potential outliers were identified and removed according to the criterion of ± 2 standard deviations from the individual mean. The testing procedure was preceded by standardized instructions to ensure consistent task understanding and uniform execution conditions across all participants. Statistical analysis was performed using JASP software (Version 0.95.3; JASP Team). For each participant, the difference Δ ($T2 - T1$) was calculated. Percentage changes were determined by dividing Δ by the baseline value ($T1$) and multiplying by 100. Between-group comparisons of Δ values were conducted using the Mann–Whitney U test due to the non-parametric distribution of the analyzed variables and the relatively small sample size. The level of significance was set at $p < .05$. Effect size (r) was calculated using the formula $r = Z / \sqrt{N}$, where N represents the total number of observations.

Results

For the RVSS test, the experimental group demonstrated a reduction in mean reaction time from 0.598 ± 0.101 s at baseline ($T1$) to 0.487 ± 0.069 s post-intervention ($T2$), corresponding to a change of $\Delta = -0.111$ s. In contrast, the control group exhibited an increase from 0.473 ± 0.064 s to 0.495 ± 0.039 s ($\Delta = +0.022$ s). The between-group difference in Δ values was statistically significant (Mann–Whitney $U = 20.00$, $p = .002$).

Table 1. Comparative Analysis of Mean RVSS Reaction Times ($T1$ – $T2$)

Group	N	$\bar{x}$ ($T1$)	$\bar{x}$ ($T2$)	Δ ($T2$ – $T1$)
Experimental	12	0.598	0.487	-0.111
Control	12	0.473	0.495	0.022

For the RVSS test (Table 1), the experimental group decreased from 0.598 s at $T1$ to 0.487 s at $T2$ ($\Delta = -0.111$ s; -18.6%), whereas the control group increased from 0.473 s to 0.495 s ($\Delta = +0.022$ s; $+4.7\%$). The baseline between-group difference was 0.125 s and was reduced to 0.008 s at $T2$. A statistically significant difference between groups was identified at baseline ($U = 20.00$, $p = .002$).

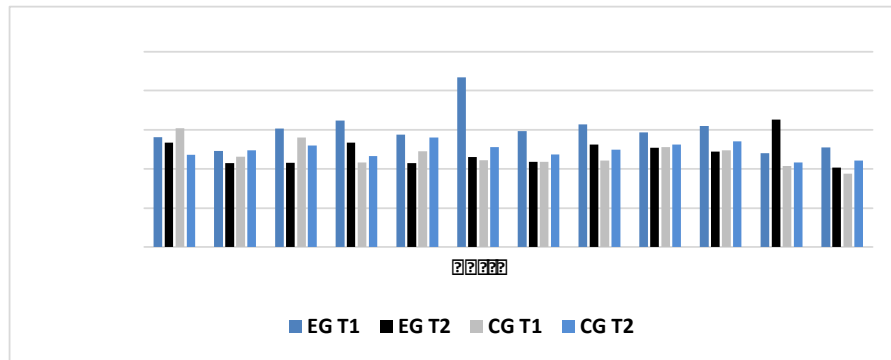


Figure 1. Comparative Graphical Representation of RVSS Results for the Two Groups at $T1$ and $T2$

Figure 1 presents the mean RVSS reaction times at $T1$ and $T2$ for both groups. The experimental group recorded a decrease from 0.598 s to 0.487 s ($\Delta = -0.111$ s), whereas the control group increased from 0.473 s to 0.495 s ($\Delta = +0.022$ s).

Table 2. Descriptive Statistical Variability Indicators for $T1$, $T2$, and Δ

Group	SD ($T1$)	SD ($T2$)	SD (Δ)	SE ($T1$)	SE ($T2$)
Experimental	0.101	0.069	0.130	0.029	0.020
Control	0.064	0.039	0.058	0.018	0.011

Descriptive variability indicators for the RVSS test are summarized in Table 2. In the experimental group, SD values were 0.101 at T1 and 0.069 at T2 ($SD\Delta = 0.130$), while in the control group SD values were 0.064 and 0.039 ($SD\Delta = 0.058$). Standard error values were 0.029 and 0.020 in the experimental group and 0.018 and 0.011 in the control group.

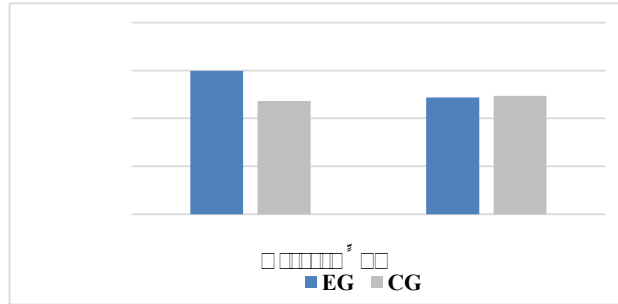


Figure 2. Comparative Graphical Representation of Mean RVSS Values for the Two Groups at T1 and T2

Figure 2 displays the mean RVSS reaction times at T1 and T2 for both groups. At T1, values were 0.598 s (experimental) and 0.473 s (control). At T2, values were 0.487 s and 0.495 s, respectively, with the between-group difference reduced to 0.008 s.

Table 3. Mann–Whitney U Test Results for Between-Group Differences in Δ (T2–T1) for the RVSS Test

U	p	Mean Rank (EG)	Mean Rank (CG)	Sum of Ranks (EG)	Sum of Ranks (CG)	Levene (p)
20.00	.002	8.167	16.833	98.00	202.00	.243

At baseline (T1), statistically significant between-group differences were observed for both RVSS ($U = 20.00$, $p = .002$) and RVSD ($U = 20.00$, $p = .002$). Between-group comparisons of Δ (T2–T1) values for RVSS were performed using the Mann–Whitney U test (Table 3), revealing a statistically significant difference ($U = 20.00$, $p = .002$, $r = 0.63$). Mean ranks were 8.167 for the experimental group and 16.833 for the control group.

Comparative Analysis of RVSD Results

For the RVSD test (Table 4), the experimental group decreased from 0.595 s at T1 to 0.531 s at T2 ($\Delta = -0.064$ s), while the control group increased from 0.482 s to 0.535 s ($\Delta = +0.053$ s). The baseline between-group difference was 0.113 s and was reduced to 0.004 s at T2. Descriptive variability indicators are summarized in Table 5. In the experimental group, SD values were 0.071 at T1 and 0.092 at T2 ($SD\Delta = 0.089$). In the control group, SD values were 0.045 and 0.056 ($SD\Delta = 0.066$). Between-group comparisons of Δ values were conducted using the Mann–Whitney U test (Table 6), revealing a statistically significant difference ($U = 20.00$, $p = .002$, $r = 0.63$). Mean ranks were 8.167 for the experimental group and 16.833 for the control group.

Table 4. Comparative Analysis of Mean RVSD Reaction Times (T1–T2)

Group	N	$\bar{x}$ (T1)	$\bar{x}$ (T2)	Δ (T2–T1)
Experimental	12	0.595	0.531	-0.064
Control	12	0.482	0.535	0.053

Mean RVSD reaction times are presented in Table 4. The experimental group decreased from 0.595 s at T1 to 0.531 s at T2 ($\Delta = -0.064$ s), whereas the control group increased from 0.482 s to 0.535 s ($\Delta = +0.053$ s).

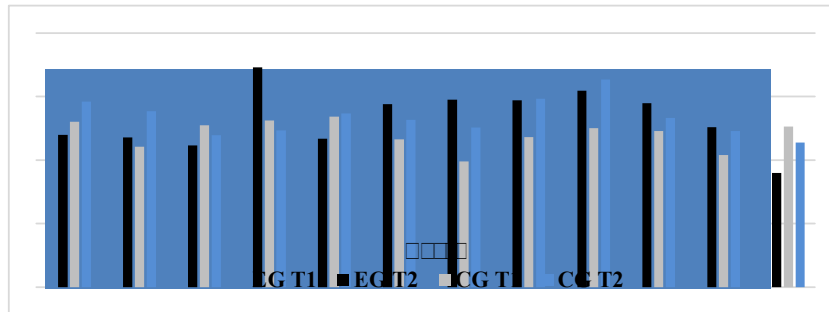


Figure 3. Comparative Graphical Representation of the Two Groups' Results at T1 and T2 for the RVSD Test

Figure 3 presents the individual RVSD reaction time values at T1 and T2 for both groups. In the experimental group, the majority of T2 values are lower than T1. In the control group, T1 and T2 values show minimal variation. The distribution of individual values at both time points is displayed in the figure.

Table 5. Descriptive Statistical Variability Indicators for T1, T2, and Δ

Group	SD (T1)	SD (T2)	SD (Δ)	SE (T1)	SE (T2)
Experimental	0.071	0.092	0.089	0.0206	0.0264
Control	0.045	0.056	0.066	0.0129	0.0162

Variability indicators for the RVSD test are presented in Table 5. In the experimental group, SD values were 0.071 at T1 and 0.092 at T2 ($SD\Delta = 0.089$), while SE values were 0.0206 and 0.0264, respectively. In the control group, SD values were 0.045 at T1 and 0.056 at T2 ($SD\Delta = 0.066$), with SE values of 0.0129 and 0.0162.

Figure 4 displays the mean RVSD reaction times at T1 and T2 for both groups. The experimental group recorded 0.595 s at T1 and 0.531 s at T2 ($\Delta = -0.064$ s), whereas the control group recorded 0.482 s and 0.535 s ($\Delta = +0.053$ s). The between-group difference was 0.113 s at baseline and 0.004 s at T2.

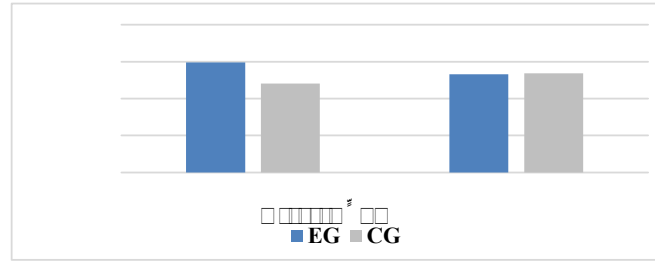
**Figure 4. Comparative Graphical Representation of Mean RVSD Reaction Time Values at T1 and T2 for Both Groups**

Figure 4 presents the mean RVSD reaction times at T1 and T2 for both groups. In the experimental group, T2 values are generally lower than T1. In the control group, T1 and T2 values show minimal variation. The distribution of individual values at both time points is displayed in the figure.

Table 6. Results of the Mann–Whitney U Test for Δ Differences in the RVSD Test

U	p	Mean Rank (EG)	Mean Rank (CG)	Sum of Ranks (EG)	Sum of Ranks (CG)	Levene (p)
20.00	0.002	8.167	16.833	98.0	202.0	0.291

At T1, statistically significant between-group differences were observed for both RVSS and RVSD ($U = 20.00$, $p = .002$). Between-group comparisons of Δ ($T2 - T1$) values for RVSD were conducted using the Mann–Whitney U test (Table 6), revealing a statistically significant difference ($U = 20.00$, $p = .002$, $r = 0.63$). Mean ranks were 8.167 for the experimental group and 16.833 for the control group, with sums of ranks of 98.00 and 202.00, respectively.

Discussion

The purpose of this study was to examine whether a structured intervention focused on segmental visuomotor reaction would produce greater improvements in RVSS and RVSD reaction times compared with standard Kempo training. The hypothesis formulated in the Introduction was confirmed, as the experimental group demonstrated significantly greater reductions in reaction time compared with the control group.

As presented in Table 1 and Table 4, the experimental group recorded reductions of -0.111 s (-18.6%) in RVSS and -0.064 s in RVSD, while the control group showed slight increases in both parameters. The between-group comparisons of Δ values (Tables 3 and 6) revealed statistically significant differences ($U = 20.00$, $p = .002$, $r = 0.63$), indicating a substantial intervention effect. The reduction of the between-group difference from baseline to post-intervention (Figures 2 and 4) further supports the effectiveness of the applied training program. The role of visuomotor reaction in combat sports performance is well documented. Mülhim and Akcan (2021) reported significant reaction-time differences according to performance level in martial arts athletes. Similarly, Williams et al. (2021) and Zhang et al. (2022) demonstrated that neuromuscular and reaction-focused training programs lead to measurable improvements in motor response latency. Intervention-based studies in youth athletes have also confirmed the effectiveness of perceptual–motor training protocols (Theofilou et al., 2022; Bădău et al., 2022). The present findings are consistent with these results while extending them to a controlled experimental context specific to junior Kempo athletes.

The magnitude of improvement observed in RVSS (-18.6%) is relevant in disciplines characterized by rapid exchanges and limited decision-making time. Previous analyses of rapid motor responses indicate that even small reductions in reaction latency may influence performance outcomes in dynamic combat environments (Pojskic et al., 2019; Zemková, 2016). The systematic exposure to visual stimuli integrated into rapid lower-limb tasks may have facilitated neuromuscular adaptations related to improved motor unit synchronization and intersegmental coordination (de Brito & Silva, 2011; Mancini et al., 2024). Differences observed between RVSS and RVSD highlight lateral functional characteristics potentially associated with dominance patterns and technical specificity. Combat sport participation has been shown to induce asymmetric adaptations in neuromuscular control and reaction speed (Del Vecchio et al., 2018; Gao, 2022; Piatysotska et al., 2023). By

separately evaluating left and right segmental responses, the present study provides additional applied value for individualized training design during the developmental stage.

Although variability remained present within the experimental group (Tables 2 and 5), the direction of change was consistent at the group level. The control group did not demonstrate comparable functional improvements, suggesting that standard technical training alone may not sufficiently optimize segmental visuomotor latency in this age category.

If reaction-focused interventions are already supported in the literature, the originality of the present study lies in several aspects:

1. the controlled experimental design applied specifically to junior Kempo athletes aged 10–12 years;
2. the bilateral quantification of segmental reaction (RVSS and RVSD);
3. the integration of athletics-based neuromuscular exercises within regular Kempo training;
4. the use of objective optoelectronic assessment to quantify response latency;
5. the reporting of effect size in addition to nonparametric statistical testing.

From a practical perspective, the findings support the systematic inclusion of unpredictable visual stimuli and time-constrained lower-limb response tasks within youth Kempo training. Structured integration of such exercises may accelerate neuromuscular adaptation during a developmental period characterized by increased plasticity.

The limitations of the study include the relatively small sample size and the absence of complementary neuromuscular measures such as electromyography or kinematic decomposition of latency components. Future research should involve larger samples, multimodal biomechanical assessment, and longitudinal follow-up to determine the persistence of adaptations.

Conclusions

The present study examined the effectiveness of a structured intervention program targeting segmental visuomotor reaction in junior Kempo athletes aged 10–12 years. The findings demonstrate that the systematic inclusion of exercises involving controlled visual stimuli and rapid lower-limb responses leads to statistically significant and practically meaningful improvements in RVSS and RVSD reaction times compared with standard training alone. The experimental group showed clear reductions in motor response latency, supported by significant between-group differences and large effect sizes, confirming that visuomotor reaction is a trainable neuromotor capacity at prepubertal ages. The results validate the study hypothesis and reinforce the concept that perceptual–motor integration can be effectively enhanced through structured, progressive training.

From a theoretical perspective, the study makes an important contribution by providing controlled experimental evidence in a youth Kempo population, a domain insufficiently investigated in the literature. The bilateral assessment of segmental reaction provides additional insight into lateral functional characteristics relevant for individualized training.

From a practical standpoint, the findings support the integration of reaction-based exercises into regular Kempo training. The proposed intervention model is transferable to club settings and offers a measurable, reproducible framework for optimizing neuromuscular responsiveness under time-constrained conditions typical of combat sports. Future research should include larger samples, longitudinal follow-up, and complementary neurophysiological assessments to further clarify the mechanisms underlying visuomotor adaptation.

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Conflict of Interest

The authors declare no conflicts of interest.

Use of Artificial Intelligence Tools

During the preparation of this manuscript, the authors used the AI-based tool ChatGPT (OpenAI) exclusively for language refinement, including wording suggestions, paraphrasing, translation support, and improvement of clarity. Artificial intelligence was not employed for data analysis, statistical calculations, interpretation of findings, or the development of scientific conclusions. All AI-generated suggestions were carefully evaluated, revised where necessary, and validated by the authors. The authors take full responsibility for the integrity and final content of the manuscript.

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