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Original Article

The impact of psycho–neuro–motor exercises on enhancing karate technical proficiency

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Abstract
Martial arts are a structured system of combat traditions and tactics practised for various purposes such as self-defence, competitive sports, leisure, and overall physical, mental, and psychological development. Achieving technical proficiency involves deeply understanding and internalising techniques through consistent practice. Our body processes both external and internal stimuli, requiring heightened attention. This study explores the effectiveness of psycho–neuro–motor exercises in improving a specific karate technique, mawashi-geri. Ten karate athletes from Rapid Karate Sports Club participated in the study during a training camp in Poiana Marului, Brasov, Romania. Over seven days, athletes performed three sets of slow-motion mawashi-geri kicks after warm-up routines each morning. These exercises aimed to enhance neuromuscular coordination, potentially refining performance and reducing injury risks. Statistical analysis of pre- and post-training camp assessments of mobility (side and front splits) and speed (maximum repetitions of mawashi-geri in 10 s) revealed significant improvements ($p < 0.05$) in four pairs of variables. **Results:** When comparing the initial and final assessments, the most significant improvement in split mobility was 10 cm (a 6.28% increase), with the group averaging an improvement of 5.26 cm (2.58%). Similarly, the most significant improvement in kicking speed was evidenced by 5 additional kicks (a 41.66% improvement), while the group's average reflected an increase of one extra kick (a 7.78% increase). **Conclusions:** These findings underscore the importance of integrating slow-motion practice into karate training, suggesting its potential to enhance complex movement execution such as mawashi-geri. However, the study acknowledges the need for future experiments to include a control group, isolate psycho–neuro–motor training, and introduce a fourth set of kicks at normal speed to enhance participants' awareness of exercise effects.
Keywords: karate, training, neuromuscular, motor skills

Introduction

Achieving peak performance in karate and generally, in martial arts, depends on the athlete's physical condition, technical–tactical skills, and mental state (Georgios, 2016; Przybylski et al., 2021; Dwojaczny et al., 2021; Kunszabo et al. 2024). Published research highlights the pivotal role of speed development in karate, enhancing the athlete's overall technical and tactical training proficiency (Vorozheikin, Tarasov & Volkov, 2020; Romanova et al., 2022). Karate is a vital tool for maintaining and optimising daily abilities (Lima et al., 2017; Doder et al., 2021), proving beneficial for individuals with disabilities (Stefano et al., 2022; Greco & de Ronzi, 2020; Mischenko et al., 2020), and as an effective means of combatting school bullying (Greco et al., 2019). Moreover, karate training correlates with high levels of self-control and cognitive abilities, potentially contributing to increased life satisfaction (Potoczny et al., 2022). Regarding martial arts training methodologies, Swanson (2017, p. 17) delineates the traditional Japanese approach, where instructors demonstrate techniques, and students, often lacking a thorough understanding of the nuances, begin to emulate them. In this model, students receive visual guidance and occasional verbal or tactile corrections from instructors, yet they may lack internal comprehension of the technique's execution. Consequently, after numerous repetitions, they may develop imperfect techniques. According to the World Karate Federation (WKF) regulations, a competitor can secure victory in kumite matches by either achieving an 8-point difference during the match or by having more points than their opponent at the end of the match. In a tie, the victor is determined based on who scores the first point, and if neither competitor scores, the referees make the decision (International Olympic Committee [IOC], 2021).

According to official rules, points are awarded as follows (World Karate Federation [WKF], 2022, p. 23):

- Ippon (3 points) is awarded for kicks connecting with the opponent's head and arm strikes to the opponent when they are on their back on the ground as a result of a sweep or fall;
- Waza-ari (2 points) is granted for kicks targeting the opponent's torso;
- Yuko (1 point) is earned for kicks or arm strikes directed at the head, face, neck, abdomen, chest, back, or side.

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Alinaghipour (2019) notes that the mawashi-geri technique ranks third in the frequency of match scoring (7.6%). Despite ranking among the top three most utilised strikes, its usage lags behind arm techniques such as "kizami zuki" (44.2%) and "oi zuki" (32.6%). Athletes tend to favour arm strikes over leg strikes owing to the faster speed of technique execution by upper limbs and the perceived risk associated with leg strikes. Engaging in leg strikes compromises stability, exposing athletes to potential arm counterattacks (quicker than leg strikes) or sweeps (favourable because of the opponent's unstable position).

However, the mawashi-geri strike, being equivalent in points to three arm strikes, allows athletes to widen the score gap, recover from a 3-point deficit, or secure victory in the final moments of a match when trailing. Building on this observation, in this study, we investigate the effectiveness of psycho–neuro–motor exercises in optimising the mawashi-geri technique.

The human brain processes a continuous stream of external and internal stimuli, serving as a repository of information that influences daily psychological behaviours and adaptive responses to new environmental cues. As the complexity of physical exercises in motor skill development increases, they serve as "the main driving force in the development and perfection of neural structures" (Dănăilă, 2000, p. 33).

Optimising a technique requires internalisation and understanding its mechanics, coupled with repetition until mastery is achieved. This process is viewed from a "neuropsychological or psychoneurological perspective, where the focus is on revealing and explaining the concrete mechanisms through which a psycho-behavioural act or another is realised at the brain level. Each mechanism includes the physiological (biochemical or electrical) component that ensures the production of the respective behaviour, and the morphological component (type of neurons, synapses, and neural circuits) supports the physiological manifestation" (Dănăilă, 2000, p. 11). While a neurosurgeon may find muscle omission in technique optimisation understandable, coaches or physical education instructors view the absence of muscles in technique description differently. To them, muscles are the movement generators, an essential component bridging the gap between neurons and biochemistry, facilitating actual movement (cf. Hillerin, 2024).

Research indicates that "multisensory and attentional mechanisms control the flow of information through partially distinct neural circuits" (Gau, 2020). Consequently, "anticipation could be improved using visual-perceptual, visuomotor, and motor model [structure/pattern – n.a.] training, isolated or combined, and the transfer of benefits of improvement in different contexts" (Brenton, 2018).

Considering the assertion that "separate regions of the cerebellum are connected to distinct cerebral areas, forming a complex topography ['map' – n.a.]" (Buckner, 2011), it becomes feasible to develop predictive models that "could depend on the degree of motor development" (Camenidis, 2020) of individuals. These processes could facilitate real-time estimation of "the sense [in the meaning of order, sequence of – n.a.] of multiple joint positions" (Baumann, 2015) and identification of differences between anticipated outcomes and actual command execution.

Sherrington's investigation into proprioceptive field neuronal activity reveals that the excitation of proprioceptive receptors, unlike those in the exteroceptive field, is primarily associated with bodily actions. Proprioceptors are stimulated by actions such as muscle contractions, which are primary reactions. These primary reactions often stem from the excitation of exteroceptive field receptors, which are rich in both number and variety. Reflexes triggered by proprioceptive organs typically complement and enhance reflexes initiated by exteroceptive organs (Sherrington, 1906, p. 130).

According to Fleishman, proprioception's role in motor behaviour extends beyond regulatory functions (providing feedback for observable responses); it serves "as a mechanism of time perception S [the subject/participant – n.a.] in anticipating temporal regularities in stimulus events" (Fleishman, 1963).

Functionally, the nervous system converts environmental stimuli into defensive or adaptive movements based on the nature and intensity of excitations, facilitating engram formation, memorisation, learning, and refinement (Ifrim, 1988, p. 147). Engram memorisation by the cerebral cortex enables the generation of "stereotypical effects, for usual situations, as well as novel, creative responses, for new situations" (Epuran, 2011, p. 73).

Furthermore, Marin et al. (2016) underscore the importance of psycho–neuro–motor exercises in enhancing human performance. Their findings indicate that exposure to diverse stimuli or environmental conditions, with or without visual feedback or mental training, yields benefits, particularly in sports performance (Marin et al., 2016). The educational impact of these exercises manifests in psycho–neuro–motor functions, recognising that "the organ of psychic activity is the central nervous system, with psychic processes having nervous processes as their substrate, without being confused with them" (Epuran, 1980, p. 15). The authors employ the term "psycho-neuro-motricity" to emphasise the interconnectedness of the psyche, neuronal pathways (signal transmission and processing), and motricity, thereby highlighting the organism's functional unity.

The school curriculum for physical education lacks a specific competence targeting proprioceptive ability. Consequently, programs focusing on psycho-neuro-motor exercises prove beneficial for enhancing proprioceptive capacity, particularly if implemented early in physical education classes. Such initiatives have the potential to positively influence future attentional improvements towards stimuli from both external and internal environments, as well as neural representations, thereby contributing qualitatively to children's athletic performance (Camenidis et al., 2024). It has been demonstrated that the implementation of psycho-neuro-motor programs aimed at enhancing proprioceptive capacity within school physical education classes can improve children's motor performances. Assessment of the level of awareness regarding motor representations can be conducted using the scaling from the Wheel of Awareness questionnaire (Camenidis & Geantă, 2022).

Therefore, exercises integrating passive and active movements, incorporating proprioceptive and sensorimotor information, with and without visual feedback, seem to yield the most favourable outcomes (Aman, 2015). Additionally, preliminary findings suggest that such practice "induces cortical reorganisation," supporting the notion that programs targeting proprioceptors are "a viable method for improving motor function" (Aman, 2015). In light of these insights, this research aimed to investigate the efficacy of a method involving repetitive practice of karate techniques at slow-motion speeds and assess its impact on specific parameters of sports training.

Materials and Methods

Research Subjects

Within the framework of the pedagogical experiment, the research sample comprised high-performance athletes affiliated with a sports club in Bucharest (n = 10, 4 males and 6 females; M(y) 19 ± 2.9 years; M(h) 171.6 ± 10.2 cm; M(w) 62.9 ± 10.0 kg). In addition to anthropometric assessments, participants underwent evaluations focusing on their proficiency in executing specific technical elements or procedures in martial arts.

Research Methods Used:

- Literature review – conducted through the examination of specialised books, scientific articles, and reputable websites;
- Longitudinal pedagogical experiment – involved administering initial and final tests to a cohort of 10 karate athletes affiliated with the Rapid Bucharest Sports Club, spanning 7 days from August 7th to August 15th, 2023.

Experimental Program

The athletes were instructed to perform 3 sets of mawashi-geri kicks targeting the head level for each leg, adhering to the following protocol:

- Set 1: Athletes executed 10 kicks at a significantly reduced speed, each taking 10 s to complete.
- Set 2: Athletes executed 5 kicks at a significantly reduced speed, with each kick requiring 30 s for execution.
- Set 3: Athletes executed a single kick at a significantly reduced speed, with the entire execution lasting 60 s.

Mawashi-geri Technique

When utilising the mawashi-geri effectively in a match, athletes require flexibility, balance, coordination, speed, control, precision, and timing. El-Daly (2010) outlines the sequential steps necessary for accurate execution of the mawashi-geri technique as follows:

- From a fighting stance (on guard), the back foot pivots outward at approximately a 150-degree angle to the rear.
- The front leg's knee elevates, establishing a direct path toward the opponent's head.
- The pelvis rotates backwards at an angle of 164–178 degrees, accompanied by twisting the front leg's shin until it aligns parallel to the ground.
- The raised leg extends until the front part of the foot connects with the opponent's head.
- Following the strike, the raised leg retracts by bending and returning to the initial position.

Recognising the significance of initial and final measurements in gauging subjects' responses to training (McGuigan, 2017, pp. 4-5), our study proceeded in two stages: an initial assessment and a final evaluation. In our research, we aimed to diversify exercises to enhance subjects' motor skills, focusing on proprioception. This approach aligns with the understanding that stimulating proprioceptors to execute movements depends on five key aspects of brain function: information processing, signal transmission, modules and connections, individuality, and plasticity (Carter, 2019, pp. 38-39).

Through this methodology, we aimed to determine whether implementing psycho–neuro–motor exercises could enhance the execution speed and repetition rate of the mawashi-geri strike, along with improving joint mobility and soft tissue flexibility in athletes. To assess joint mobility and soft tissue flexibility, measurements were taken using a measuring tape:

- The length of the frontal plane opening of the lower limbs - "split" (Sp - see Morcovescu, 2021).
- The opening in the sagittal plane of the lower limbs, facing left (Sf-left - idem Morcovescu, 2021).
- The opening in the sagittal plane of the lower limbs, facing right (Sf-right - Morcovescu, 2021).

Additionally, to assess execution speed and repetition rate, we utilised a stopwatch to measure the number of "Mawashi-Geri jodan" (head-level kick strikes) executed within a 10-s interval. This assessment was conducted separately for both the left leg (Mawashi-left) and the right leg (Mawashi-right).

Statistical–Mathematical Method

This approach entailed utilising descriptive statistical parameters and the paired t-test, with a significance threshold set at $p < 0.05$ and a confidence interval (C.I.) of 95%.

The obtained results were analysed to determine whether significant differences existed between the two measurements, offering insights into the training program's impact on athletes' performance.

Results

Among the observations gleaned from the repetition of karate procedures at a deliberately slow speed, the following results were noted:

- Practicing at a reduced speed allows karateka to focus on details and correct any errors in technique, improving the technique and precision of movements.
- Practicing at a reduced speed aids in developing motor control and coordination. This fosters the precision and effectiveness of movements in a deliberate and controlled manner, which is crucial in combat scenarios where swift response and control are paramount for overcoming an opponent.
- The reduced speed provides karateka the opportunity to focus on their breathing and develop control over it during movements. This aspect is important in karate for sustaining strength and focus.
- Slow repetition is a form of mental training, allowing karateka to mentally visualise and imagine each movement. This practice reinforces motor memory and enhances performance during practice at faster speeds.
- Practicing at a reduced speed can mitigate the risk of accidents and injuries, enabling karateka to concentrate on refining techniques without the pressure of reacting to rapid opponent movements.

Table 1. Data presented with the mean and SD

Variable	Initial	Final
n = 10		
Age (y)	19.2 ± 2.9	
Height (cm)	171.6 ± 10.2	
Weight (kg)	62.9 ± 10.0	
Sp (cm)	187 ± 13.2	189.9 ± 11.5
Sf-Left (cm)	203.5 ± 14.0	207.4 ± 12.2
Sf-Right (cm)	201.6 ± 15.5	206.9 ± 15.5
Mawashi-Left (s)	13 ± 1.2	14.4 ± 2.0
Mawashi-Right (s)	13.8 ± 1.9	14.8 ± 1.7

Note: Sp - the frontal plane opening length of the lower limbs, Sf-Left - the sagittal plane opening of the lower limbs, facing left, Sf-right - the sagittal plane opening of the lower limbs, facing right, Mawashi-Left - the number of executions of the "Mawashi-Geri jodan" technique, for 10 s, with the left leg, Mawashi-Right - the number of executions of the "Mawashi-Geri jodan" technique, for 10 s, with the right leg.

Table 1 presents descriptive statistics for the variables examined in our observational study based on a sample of 10 subjects. During the initial stage of the research, each variable was assessed as follows: Sp (frontal opening length) - 187 ± 13.2 cm, Sf-left (lateral opening to the left) - 203.5 ± 14.0 cm, Sf-Right (lateral opening to the right) - 201.6 ± 15.5 cm, Mawashi-Left (Mawashi-geri strikes with the left leg in 10 s) - 13 ± 1.2 s, Mawashi-Right (Mawashi-geri strikes with the right leg in 10 s) - 13.8 ± 1.9 s.

Following the implementation of the experimental program, significant enhancements were observed upon final evaluation, particularly in the length of segments (Sp - 189.9 ± 11.5 cm; Sf-left - 207.4 ± 12.2 cm; Sf-Right - 206.9 ± 15.9 cm). Notably, significant improvements were also evident in the execution speed of the Mawashi Geri strike, as indicated by the increased number of strikes for both the left leg (Mawashi-Left - 13.0 ± 1.2 s) and the right leg (Mawashi-Right - 14.8 ± 1.7 s) achieved within the same 10-s interval.

Furthermore, to visually depict the average values at the initial and final stages for the measured variables, the opening length (Figure 1) and the variables quantifying the number of strikes within a preset time interval (Figure 2) were graphically represented.

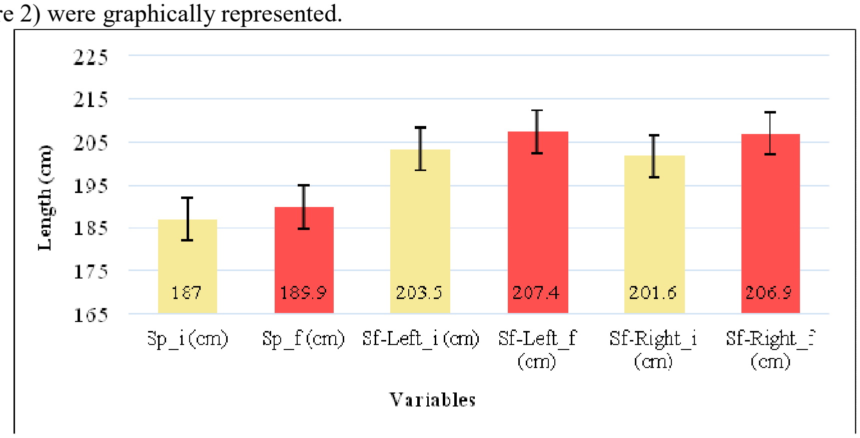

Figure. 1. The initial and final evaluation results for the variables Sp and Sf

From a statistical perspective, Figure 1 shows that the variable Sp_i had an average value of 187 ± 13.2 cm during the initial assessment. Upon final evaluation, a noteworthy improvement in the opening length was observed, with a value of 189.9 ± 11.5 cm.

Similarly, significant progress can be observed in the average values for the variable Sf-left. In the initial stage, it measured 203.5 ± 14.0 cm, and by the final stage, it showed improvement, reaching 207.4 ± 12.2 cm.

Additionally, significant changes were observed for the same movement involving the opposite leg, Sf-right, owing to the training's effects. The initial values for this variable were 201.6 ± 15.5 cm, which increased to 206.9 ± 15.9 cm by the final evaluation. Thus, a dynamic progression of results for each measured variable is highlighted from the perspective of average values, as graphically represented in Figure 1.

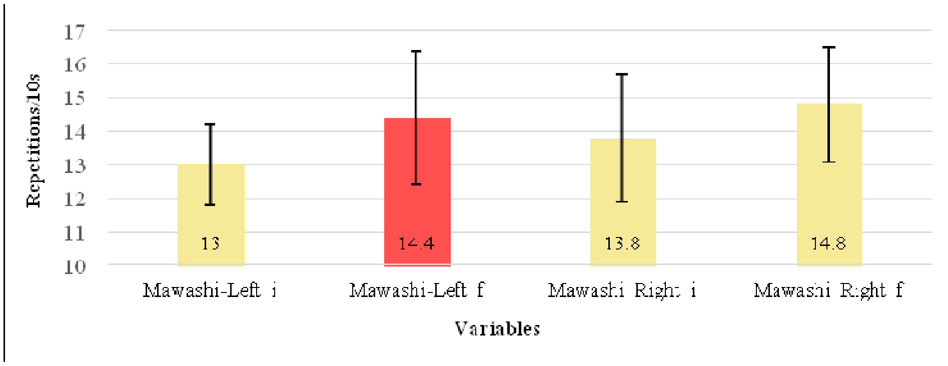

Figure. 2. The initial and final evaluation results for the Mawashi-Geri strike

From a statistical standpoint, Figure 2 illustrates enhancements in the repetition speed of the Mawashi-Geri strike for both lower limbs. Notably, there is an improvement of approximately 1.4 additional strikes within the 10-s period for the left leg. In contrast, the right leg shows an increase of approximately 1 additional strike within the same timeframe.

Considering the dynamic nature of these results, we can confidently conclude that our seven-day psycho–neuro–motor training regimen has yielded positive results on the targeted variables.

Furthermore, to assess the statistical significance of the differences between the initial and final evaluations, we conducted a paired sample t-test for each variable in the initial and final stages presented in Table 1 using a significance threshold alpha of <0.05 (Table 2).

Table 2. The comparative results of the variables in the two testing stages (initial and final) analysed using the dependent t-test

		n	M	SD	S.E. mean	95% Confidence interval		Paired *t*-test		
Variable						Lower	Upper	*t value*	*df*	Sig (two-tailed)
Pair 1	Sp_i Sp_f	10	−2.60	3.39	1.07	-6.09	0.89	−2.42	9	0.039
Pair 2	Sf-Left_i Sf-Left_f	10	-3.90	6.75	2.13	-10.84	3.04	-1.82	9	0.101
Pair 3	Sf-Right_i Sf-Right_f	10	-5.30	2.58	0.81	-7.95	−2.64	-6.48	9	0.000
Pair 4	Mawashi-Left_i Mawashi-Left_f	10	-1.40	1.89	0.6	-3.35	0.55	−2.33	9	0.045
Pair 5	Mawashi_Right_i Mawashi_Right_f	10	-1.00	1.24	0.394	−2.28	0.28	−2.53	9	0.032

Note: Sp_i - frontal plane opening length of the lower limbs in the initial testing, Sp_f - frontal plane opening length of the lower limbs in the final testing, Sf-Left_i - sagittal plane opening of the lower limbs facing left in the initial testing, Sf-Left_f - sagittal plane opening of the lower limbs facing left in the final testing, Sf-Right_i - sagittal plane opening of the lower limbs facing right in the initial testing, Sf-Right_f - sagittal plane opening of the lower limbs facing right in the final testing, Mawashi-Left_i - number of executions of the "Mawashi-Geri jodan" technique within 10 s with the left leg in the initial testing, Mawashi-Left_f - number of executions of the "Mawashi-Geri jodan" technique within 10 s with the left leg in the final testing, Mawashi-Right_i - number of executions of the "Mawashi-Geri jodan" technique within 10 s with the right leg in the initial testing, Mawashi-Right_f - number of executions of the "Mawashi-Geri jodan" technique within 10 s with the right leg in the final testing

Following the statistical analysis using the dependent t-test (Table 2), we confirm that among the five pairs of variables examined, only four exhibit statistically significant differences in the final stage at a confidence interval of $p < 0.05$. Specifically, significant differences were observed for the split tests (SP = 189.9 ± 11.5; t(9) = −2.42, p = .039), the Mawashi Geri strike with the left leg (Mawashi-Left = 14.4 ± 2.0; t(9) = −2.33, p = .045), and the Mawashi Geri strike with the right leg (Mawashi-Right = 14.8 ± 1.7; t(9) = −2.53, p = .032). Moreover, at a confidence threshold of $p < 0.001$, significant differences were noted in the lateral split with the right leg in front (Sf-Right = 206.9 ± 15.5; t(9) = −6.48, p = .000).

While the average values for the lateral split with the left leg in front indicate positive increases in the opening length (Sf-Left = 207.4 ± 12.2, t(9) = 1.82, p = .101), the results of the dependent t-test do not confirm statistical significance. Nonetheless, these findings demonstrate statistically significant improvements within a relatively short period regarding the athletes' movement structure from the perspective of psycho–neuro–motor skills for four out of the five pairs subjected to statistical analysis.

Discussions

Our study aimed to analyse the impact of psycho–neuro–motor exercises on a specific karate technique: mawashi-geri. By employing these exercises, we aimed to assess their influence on enhancing the execution of this technique, thereby contributing significantly to understanding the interconnectedness of psychological, neurological, and motor elements in martial arts training.

In optimising the mawashi-geri strike, efficient and rapid recovery, as emphasised by Arovah & Putri (2024), emerges as a critical dimension of performance. Rapid recovery capability profoundly affects the effectiveness and precision of the strike, enabling practitioners to quickly regain balance and correct positioning for successful execution. Thus, the comprehensive integration and training of this aspect in mawashi-geri practice can significantly enhance the overall performance of this technique in martial arts. Oktavian et al. (2022) explored the relationship between agility, speed, and accuracy in the mawashi-geri strike in karate, identifying a negative relationship between agility and speed and a positive relationship between lower limb muscle power and dynamic balance concerning strike precision. Their study recommends regular exercises or movements to enhance agility, speed, lower limb strength, and dynamic balance. Given these findings, implementing psycho–neuro–motor training becomes imperative. Such training enhances general motor capacity and human functioning at an "informational" level.

In exploring the literature, we have identified various studies designed to enhance karate performance through different methodologies. For instance, Yulfadinata et al. (2022) studied the effectiveness of high-intensity interval training (HIIT), while Sari et al. (2021) investigated the impact of circuit training on enhancing the muscular strength of karate athletes. Rovniy et al. (2017) examined the benefits of training under hypoxic conditions, and Kabadayı et al. (2022) explored the effects of core training. Furthermore, the research conducted by Goethel et al. (2023) significantly contributes to our understanding of karate athlete performance, particularly in terms of neuromuscular control indicators and perception and reaction abilities during the Gyaku Tsuki strike execution. Their study sheds light on elements such as faster reaction times and efficient wrist acceleration, subtly influencing technique effectiveness and unpredictability to opponents. Jeknić et al. (2022) compared involuntary neuromuscular responses induced by lower limb muscle stimulation in karate athletes. Their findings, based on tensiomyographic measurements, underscore the sensitivity of this method in detecting neuromuscular adaptations resulting from specific karate training regimens.

Furthermore, Enkamp (n.d.) suggests that many karate practitioners, while striving to perfect techniques, often unconsciously adapt them for easier execution, potentially reinforcing incorrect movement patterns. Rapid execution of techniques may mask errors such as imbalance or excessive tension, preventing their detection by the central nervous system (CNS). Repetition under such conditions solidifies these flawed patterns.

Slowing down execution speed allows the CNS to detect and address these errors that would go unnoticed. This heightened error awareness enables athletes to refine their techniques, enhancing combat efficiency.

Ox (2016) supports this notion, stating that practising at reduced speeds benefits Olympic athletes, martial artists, and soldiers performing firearm drills. Operating at an extremely slow speed allows the brain to focus on intricate details and eliminate unnecessary movements.

Moreover, to enhance the study's objectivity and eliminate potential causal interferences, the training camp primarily emphasised improving movements, sweeps, and arm strikes, intentionally omitting leg strike exercises during specific sessions. This approach aimed to maintain experimental coherence and clarity while minimising external influences.

Conclusions

Our study focused on comparing the technical advancements of the Mawashi-Geri technique through personalised psycho–neuro–motor exercises. We emphasised the qualitative impact of implementing this exercise regimen on karate practitioners, particularly in enhancing the targeted technique.

Following the experimental program, significant statistical disparities between initial and final test results were observed in 4 out of 5 conducted tests. Notably, there were significant improvements in hip joint mobility, along with increased striking speed, underscoring the efficacy of the prescribed exercises.

By reducing execution speed, athletes can notice and correct technical details, thereby refining muscle control and optimising the interplay between agonist and antagonist muscle contractions.

During training, athletes respond differently to external feedback from a coach, peer, or mirror. The pace of reception and correction varies based on the type and delivery channel of the feedback: auditory, visual, or kinesthetic. Similar dynamics apply to internal feedback generated by the exercises implemented in this experiment. Athletes with a heightened kinesthetic awareness may experience significant enhancements in strike speed, whereas others may not detect technical flaws at slower speeds and thus may not show notable improvement. Evaluating the insights gleaned from motor actions specific to a sport is crucial, considering psycho–neuro–motor attributes across the entire motor chain, from brain commands to muscle responses and vice versa (Geantă & de Hillerin, 2023).

Coaches and physical trainers can leverage these findings in their tailored training regimens for athletes. Integrating such approaches into training programs could yield advantages in terms of technique execution speed, enhanced joint mobility facilitating technique application, and reduced injury risks through muscle and joint strengthening. Moreover, our study results can lay the groundwork for the early development of more effective and personalised training methodologies among karate practitioners. Future studies could investigate the feasibility of integrating these psycho–neuro–motor exercises into specific training protocols for other martial arts or combat sports, aiming to optimise athletic performance and reduce injury susceptibility. Subsequent studies may explore these concepts, enriching the understanding of physical preparation and athletic performance.

These considerations advocate for a comprehensive approach encompassing various aspects of psycho–neuro–motor training and recovery, which offers significant advantages to martial arts practitioners.

However, the study's limitation is the absence of a reference group. Future investigations could incorporate a control group to compare the progress attained through experimental training against that achieved through conventional training methodologies in similar training environments. In future experiments, incorporating training sets performed at normal speed within psycho–neuro–motor training sessions may enhance the awareness of neuro–motor adaptations. Maintaining an emphasis on movements, sweeps, and arm strikes will prevent interference with exercises targeting leg strikes. The findings of our study pave the way for future investigations that could advance the understanding of how psycho–neuro–motor processes influence technical performance in martial arts. A comprehensive understanding of these dynamics could foster the development of more sophisticated and effective training methodologies, potentially improving athletes' performance levels in prestigious competitions.

Therefore, coaches and physical training specialists should recognise the benefits of these methodologies and integrate them into their athletes' training regimens.

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Authors Contributions

All authors have made equal contributions to the completion of this work.

Conflicts of Interest:

The authors declare that there are no conflicts of interest.

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