

Influence of the training model on ground reaction force during the Oi-tsuki punch in karate

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Abstract:

Problem Statement: Karate is a complex discipline in which multiple practice and training coexist. Traditional Karate is characterized by a methodological approach based on the integrated practice of Kihon, Kata and Kumite, whereas modern Sport Karate emphasizes training oriented toward competitive performance. To date, there is a lack of experimental comparisons capable of clarifying whether, and to what extent, these differing training approaches influence ground reaction force production and force impulse during the execution of the Oi-tsuki punch. Therefore, the actual biomechanical effectiveness of the two practice models remains unclear. **Purpose:** The aim of the present study was to analyse and compare ground reaction force and force impulse generated during the execution of the Oi-tsuki punch in Traditional Karate practitioners and Sport Karate athletes, in order to verify whether different training models influence the ability to effectively exploit ground propulsion and force transmission along the kinetic chain. **Approach:** The study involved a sample of 30 Traditional Karate practitioners trained according to the three Ks method (Kihon, Kata and Kumite) and 30 competitive Sport Karate athletes engaged in a specialised competition-oriented training programme. Ground reaction force was recorded using a force platform during the execution of the Oi-tsuki punch from a standardised Zenkutsudachi stance. Data was analysed using descriptive and inferential statistics. **Results:** Statistical analysis revealed significant differences between the two groups in ground reaction force production during the execution of the Oi-tsuki punch. Traditional Karate practitioners showed a higher peak vertical ground reaction force than Sport Karate athletes (1985 ± 265 N vs 1710 ± 240 N; $p = .003$; $d = 1.08$). Similarly, force impulse was greater in the Traditional Karate group compared with the Sport Karate group (315 ± 42 N·s vs 268 ± 38 N·s; $p = .001$; $d = 1.17$). **Conclusion:** The results of the present study indicate that the adopted training model has a substantial impact on the ability to generate and transfer force through interaction with the ground during the execution of the Oi-tsuki punch. The higher ground reaction force and impulse values observed in Traditional Karate practitioners suggest a more efficient use of the kinetic chain.

Key Words: Biomechanics, Physical control, Training specificity, Martial arts, Performance

Introduction

Karate represents a complex and articulated discipline that, throughout its historical development, has assumed different meanings and purposes, while maintaining a common martial foundation linked to the effectiveness of technical execution and body control in space (Giardullo et al, 2024). Alongside its diffusion as a regulated sport, Karate has preserved, particularly within traditional schools, a methodological framework oriented toward the holistic development of the individual, in which technical training is not exclusively aimed at competitive outcomes but also at the construction of stable and transferable motor patterns (Esposito et al, 2025a). Within this framework, training progressively shapes movement organization, postural control, and neuromuscular regulation, promoting functional adaptations that directly influence the biomechanical effectiveness of technical gestures (Ceruso et al, 2019a). This perspective reflects a conception of Karate as a complex motor-educational system, in which technical learning is closely connected to the development of coordinative abilities and bodily awareness. In the contemporary landscape, two main practice models can be identified (Ceruso et al, 2019b). On one hand, Traditional Karate integrates Kihon, Kata, and Kumite within a progressive training pathway aimed at developing stable, efficient, and biomechanically effective techniques, with particular emphasis on intersegmental coordination, center of mass control, and harmonious use of kinetic chains (Gawel et al, 2024). On the other hand, competitive Sport Karate adopts an approach strongly influenced by competition rules, prioritizing execution speed, motor anticipation, and situational adaptability (Gawel et al, 2025). In this context, training is often oriented toward performance optimization within limited time frames, with a selective focus on techniques most functional to competitive dynamics. Although both models share a common technical foundation, the divergence in training objectives may lead to different motor and biomechanical adaptations, particularly in the production, management, and transmission of forces during movement (Esposito et al, 2024). From a movement science perspective, these differences reflect neuromuscular adaptation processes induced by prolonged exposure to specific training modalities (Raiola et al, 2025). Training

models characterized by controlled repetition, execution accuracy, and integration of complex motor tasks, as typically observed in Traditional Karate, promote the stabilization of coordinative patterns and a more efficient management of joint degrees of freedom (Raiola et al, 2022). This type of practice tends to enhance the ability to progressively and continuously modulate force, a crucial aspect in movements requiring high intersegmental synchronization. Conversely, highly competition-specific training may generate adaptations focused on speed and reactivity, but potentially less transferable to actions requiring fine integration between postural stability, propulsion, and movement control (Altavilla et al, 2022a). From an applied standpoint, this implies that athletes may achieve effective performance through different motor strategies, prioritizing either movement velocity or the quality of force transfer along the kinetic chain. The biomechanical effectiveness of a striking technique does not depend solely on the action of distal segments but emerges from a coordinated process involving the entire body, beginning with interaction with the ground (D'Isanto et al, 2022). The capacity to generate force through the lower limbs and efficiently transfer it to the trunk and upper limb represents a central component of technical performance (Esposito et al, 2024). This principle is well documented in disciplines involving complex explosive actions, such as athletics, weightlifting, and combat sports, where the quality of force transmission along the kinetic chain is a determining factor for movement effectiveness. In Karate, this mechanism is particularly relevant, as technical precision, postural stability, and body alignment are essential elements for correct technique execution (D'Isanto et al, 2021). Within this context, Ground Reaction Force (GRF) constitutes a biomechanical indicator of primary importance for analyzing lower-limb propulsion and the efficiency of force transfer during movement (Altavilla et al, 2022b). GRF allows for the quantification not only of the magnitude of force applied to the ground but also of the temporal characteristics of its application. In addition to peak force, which describes the maximum instantaneous expression of force, force impulse integrates intensity and duration of propulsion, providing a more comprehensive measure of mechanical energy production and transfer in complex explosive movements. Numerous studies have shown that GRF is sensitive to training modalities, experience level, and adopted coordinative strategies, significantly influencing performance and movement economy (Shih et al, 2024; Borzucka et al, 2024; Di Domenico et al, 2024). In Karate, however, the systematic application of biomechanical tools remains limited, particularly with regard to techniques that are not among those most frequently employed in competitive contexts (Giardullo et al, 2025). Specifically, the Oi-tsuki punch, which represents one of the fundamental techniques in Traditional Karate and constitutes a central element in basic technical training, has rarely been investigated through instrumental measurements, despite its high didactic and biomechanical value (Marques Junior, 2022; Raiola et al, 2015). Oi-tsuki requires effective forward displacement of the center of mass, appropriate muscular pre-activation, and precise synchronization between lower-limb propulsion and upper-limb action to maximize force transfer (Csákvári et al, 2025). In modern sport contexts, this technique is often considered less functional due to longer execution times and greater exposure to counterattack (Aliberti et al, 2025). Nevertheless, an exclusively competitive evaluation risks underestimating its role as a complex technical gesture capable of clearly highlighting kinetic chain efficiency and intersegmental coordination quality (Esposito et al, 2025b). In traditional practice, systematic Oi-tsuki training does not solely aim at immediate performance but contributes to the development of motor competencies with clear martial significance and broader applicability (Raiola, 2025). Although the integration of the three K (Kihon, Kata, and Kumite) is widely believed to promote greater biomechanical effectiveness of techniques, experimental evidence quantitatively supporting this assumption remains scarce (Góra et al, 2023). In particular, the literature lacks direct comparisons between Traditional Karate and Sport Karate regarding the influence of training models on Ground Reaction Force production and force impulse during Oi-tsuki execution (Yuan et al, 2025). This gap limits the understanding of actual biomechanical differences between the two approaches and hinders objective evaluation of training model effectiveness in terms of force transfer quality (D'Elia et al, 2020). In light of these considerations, an experimental comparison is therefore necessary to determine whether different training models influence the ability to generate and transfer force through ground interaction during the execution of the Oi-tsuki, within a context characterized by the coexistence of training approaches with distinct technical and performance-oriented objectives. The aim of the present study is to analyse and compare the ground reaction force and force impulse generated during the execution of the Oi-tsuki punch in Traditional Karate practitioners and competitive Sport Karate athletes, in order to verify the influence of the training model on the ability to effectively exploit ground propulsion and the transmission of forces along the kinetic chain.

Materials and Methods

Study participants

Sixty Karate practitioners took part in the study and were divided into two distinct groups based on the training model followed. The first group consisted of 30 Traditional Karate practitioners, whose training pathway was structured according to the three K method (Kihon, Kata and Kumite). The second group included 30 competitive Sport Karate athletes engaged in a specialised training programme predominantly oriented towards competition. All participants were male, aged between 18 and 45 years, and had a minimum of five years of continuous Karate practice. This criterion was adopted to ensure an adequate level of technical competence and familiarity with the execution of the Oi-tsuki punch, thereby reducing the influence of factors related to the learning phase of the movement. The two groups were comparable in terms of age, body mass,

stature and overall training experience. Participants reporting musculoskeletal injuries to the lower limbs, trunk or upper limbs in the six months preceding data collection were excluded from the study, as were individuals with neurological disorders or conditions that could interfere with the execution of the technical gesture. All participants took part in the study on a voluntary basis and were informed about the aims and experimental procedures prior to the beginning of the measurements.

Study design

The study analysed biomechanical differences in ground reaction force production during the execution of the Oi-tsuki punch between Traditional Karate practitioners and Sport Karate athletes. The comparison between the two groups was designed to evaluate the influence of different training models on force expression and on the efficiency of force transmission along the kinetic chain. All participants underwent the same experimental procedure, performing the technical gesture under standardized conditions, without any intervention or modification of their habitual motor patterns. The study design did not include experimental manipulations or familiarization periods, as the participants possessed consolidated experience in Karate practice and were fully competent in the execution of the analysed technique. The between-group comparison was structured to examine differences potentially associated with the training model as the primary discriminating factor, while minimizing the influence of confounding variables such as overall training experience, anthropometric characteristics, and execution conditions. This approach made it possible to analyse differences in ground reaction force and force impulse as biomechanical characteristics potentially related to practice specificity, rather than to contingent or situational factors.

Training protocol

The two groups differed substantially in terms of the organization and objectives of their training. Traditional Karate practitioners followed a program based on the systematic integration of Kihon, Kata and Kumite, with a balanced distribution of training load between the study of fundamental techniques, the consolidation of motor patterns through forms, and their application in sparring. This approach was oriented towards the progressive development of body segment coordination, postural control, and the ability to generate and transfer force efficiently, regardless of the competitive context. Competitive Sport Karate athletes, by contrast, were engaged in a predominantly specialized training program aimed at competition preparation. Within this model, technical work is strongly influenced by competition rules and prioritizes high execution speed, short- and medium-range actions, and rapid situational adaptations. Training is therefore more focused on optimizing performance in specific contexts, with reduced emphasis on long-range techniques and on aspects related to stability and global force transmission. Table I presents a comparison between the different training models.

Table I. Comparison between training models in Traditional Karate and Sport Karate.

Characteristic	Traditional Karate	Sport Karate
Primary objective	Holistic development of technical execution and the individual	Optimization of competitive performance
Training structure	Integration of Kihon, Kata and Kumite	Specialized competition-oriented training
Role of competition	Part of the developmental pathway, not the primary objective	Primary objective of training
Preferred types of techniques	Long-, medium- and short-range techniques	Short- and medium-range techniques
Emphasis on posture and stability	High	Moderate
Coordination of body segments	Central to technical development	Functional to the situational context
Use of kinetic chains	Oriented towards global force transmission	Oriented towards movement speed
Centre of mass management	Large displacements with progressive control	Rapid and reduced displacements
Martial applicability	High, including non-sporting contexts	Limited to the regulated context
Role of Oi-tsuki	Fundamental technique and didactic model	Techniques are rarely used in combat

Testing procedure

Data collection was carried out in a controlled environment, ensuring uniform experimental conditions for all participants. Prior to the beginning of the measurements, each subject was provided with a detailed explanation of the procedure and of the required motor task, in order to reduce the influence of variables related to the understanding of the exercise. All participants performed a standardised warm-up phase lasting approximately 10 minutes, including general joint mobilisation and muscle activation exercises, while avoiding specific explosive movements that could influence the subsequent execution of the technique. The motor task under analysis consisted of the execution of the Oi-tsuki punch from the Zenkutsudachi stance, in accordance

with the technical modalities commonly recognised in Karate practice. The technique involved a forward step with the leading lower limb, coordinated with pelvic rotation and the projection of the ipsilateral punch towards a target positioned in front of the participant. The use of the target was adopted in order to ensure a real impact condition, allowing participants to express the technique with full motor intention and to manage the reaction force resulting from the impact. During execution, both feet were positioned on the force platform so as to record the overall contribution of ground reaction force generated by the lower limbs. This methodological choice was made considering that, during the execution of Oi-tsuki, both the rear and the front lower limbs actively contribute to force production and transmission through coordinated pressure against the ground and dynamic management of the centre of mass. The platform therefore allowed the combined action of both lower limbs to be recorded throughout the entire advancement and impact phase. Participants were instructed to perform the technique with maximal intensity compatible with correct technical execution, maintaining trunk alignment, a forward gaze, and a direction of force consistent with the axis of movement. The distance from the target was adapted to individual anthropometric characteristics, while keeping body orientation and action direction constant, in order not to alter the mechanics of the movement. In accordance with the characteristics of their respective training models, Traditional Karate practitioners executed the technique preceded by voluntary body pre-tensioning, aimed at stabilising posture and preparing the kinetic chain for subsequent force production. This modality reflects a consolidated practice in traditional training, in which gesture preparation includes a phase of postural and muscular organisation prior to explosive action. In contrast, competitive Sport Karate athletes performed the technique without explicit pre-tensioning, favouring fluid and continuous execution consistent with an approach oriented towards movement economy and execution speed typical of the competitive context. These execution modalities were not experimentally imposed but reflected habitual motor strategies consistent with the respective training models. Each participant performed three valid trials of the required execution, separated by adequate recovery intervals to avoid the onset of fatigue. Between trials, feedback was limited exclusively to compliance with the experimental procedure, avoiding technical instructions that could modify the participant's habitual motor pattern. Trials were considered valid when characterised by continuous execution, absence of evident hesitation, and correct synchronisation between lower-limb propulsion, trunk rotation and punch impact on the target. For the purposes of analysis, the trial presenting the highest values of the parameters of interest was selected for each participant, as it was considered the most representative of the maximal expressive capacity of the technical gesture. Data acquisition focused on the force production phase during advancement and impact, with particular attention to peak ground reaction force and force impulse, which were considered indicators of the ability to generate and transfer force through interaction with the ground. For each subject, the parameters of interest were extracted from trials deemed valid and representative of habitual execution of the technique. The entire procedure was applied identically to both experimental groups, with the sole exception of the execution modalities spontaneously adopted in relation to the different training models. This approach allowed any observed differences to be interpreted as expressions of biomechanical adaptations linked to practice specificity, rather than to variations artificially introduced by the experimental protocol.

All participants provided informed consent prior to inclusion in the study. The study was conducted in accordance with the Declaration of Helsinki. In accordance with Regulation (EU) 536/2014 and Directive 2001/20/EC, research involving minimal risk to participants may be exempt from formal ethical review, as it does not entail invasive or experimental interventions. Furthermore, pursuant to Legislative Decree No. 211 of 24 June 2003, research that does not involve significant risks and is aimed exclusively at improving educational practices may be exempt from review and approval by an Institutional Review Board (IRB) or Ethics Committee.

Statistical analysis

Data was analysed using JASP (version 0.95.4). For each participant, the parameters of interest (peak ground reaction force and force impulse) were extracted from the best of the three valid trials, defined as the attempt presenting the highest values of the analysed parameters. Initially, a descriptive analysis of the variables was performed, reporting mean and standard deviation for each group; in the presence of non-normal distributions, median and interquartile range were also reported. Data normality was assessed using the Shapiro–Wilk test, while homogeneity of variances between groups was examined using Levene's test. To compare Traditional Karate practitioners and Sport Karate athletes, differences in the analysed parameters (peak GRF and impulse) were evaluated using two-tailed independent-samples t-tests when the assumptions of normality and homogeneity of variances were satisfied. In cases of violation of variance homogeneity, Welch's correction was applied. When data distributions were markedly non-normal, the non-parametric Mann–Whitney U test was employed as an alternative analysis. In addition to p-values, the mean difference between groups with 95% confidence intervals and effect size measures were reported (Cohen's d for the t-test; r for the non-parametric comparison), in order to describe the practical relevance of the observed differences. The level of statistical significance was set at $\alpha = .05$.

Results

For both analysed variables, the data did not show relevant deviations from normality (Shapiro–Wilk, $p > .05$), and no significant differences emerged in the homogeneity of variances between groups (Levene's test, p

> .05). Accordingly, between-group comparisons were conducted using two-tailed independent-samples t-tests. The Traditional Karate group showed a higher peak ground reaction force compared with the Sport Karate group (1985 ± 265 N vs 1710 ± 240 N). The between-group comparison revealed a statistically significant difference: $t(58) = 4.21$, $p < .001$, with a mean difference of 275 N (95% CI: 144 to 406) and a large effect size (Cohen's $d = 1.09$). Similarly, for force impulse, the Traditional Karate group reported higher values than the Sport Karate group (315 ± 42 N·s vs 268 ± 38 N·s). The comparison confirmed a statistically significant difference: $t(58) = 4.55$, $p < .001$, with a mean difference of 47 N·s (95% CI: 26 to 68) and a large effect size (Cohen's $d = 1.17$). Table II presents the comparison of results between the two analysed groups.

Table II. Comparison between Karate Traditional and Sportive groups

Variable	Group	Mean	SD	t (df)	p-value	Cohen's d
GRF peak (N)	Karate Traditional	1985	265	4.21 (58)	< .001	1.09
GRF peak (N)	Karate Sportive	1710	240			
Impulse (N·s)	Karate Traditional	315	42	4.55 (58)	< .001	1.17
Impulse (N·s)	Karate Sportive	268	38			

The statistical values (t, p and Cohen's d) refer to the comparison between the two groups (Traditional Karate vs Sport Karate) for each analysed variable and are therefore reported only once for each comparison. Mean values and standard deviations, by contrast, are presented separately for each group. Descriptive results for peak ground reaction force and force impulse in the two groups are graphically illustrated in Figures I and II.

Figure I. Mean values ($\pm$ standard deviation) of peak ground reaction force in the two groups.

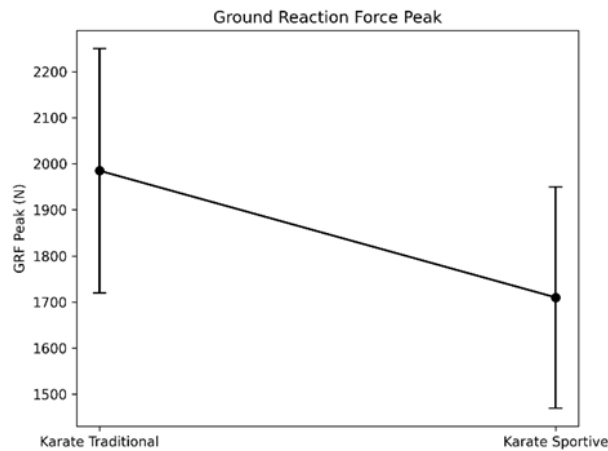
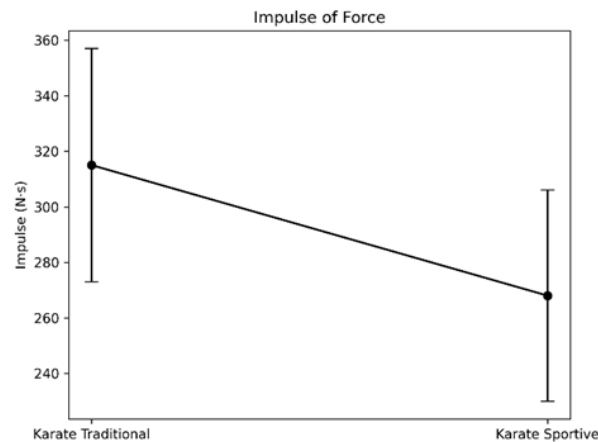


Figure II. Mean values ($\pm$ standard deviation) of force impulse in the two groups.



Discussion

The study analysed differences in ground reaction force production during the execution of the Oi-tsuki punch between Traditional Karate practitioners and competitive Sport Karate athletes, with the aim of understanding the extent to which different training models may influence the effectiveness of the technical gesture (Cusano et al, 2025). The results obtained support the initial hypothesis, showing higher values of both peak ground reaction force and force impulse in Traditional Karate practitioners compared with Sport Karate athletes (Esposito et al, 2025c). From a biomechanical perspective, these differences suggest a greater ability in the Traditional Karate group to generate force through interaction with the ground and to transfer it effectively

along the kinetic chain to the upper limb (Sannicandro et al, 2024). This finding appears consistent with the characteristics of the traditional training model, which places marked emphasis on postural stability, centre-of-mass management and coordination of body segments, fundamental aspects for the organisation of a long-range striking technique such as Oi-tsuki (Horníková et al, 2025). The greater magnitude of force impulse observed in Traditional Karate practitioners indicates not only higher force production, but also an enhanced ability to apply it over a temporal interval more favourable to the transmission of mechanical energy (Altavilla et al, 2019). In this sense, impulse represents a particularly relevant indicator of technical effectiveness, as it integrates both the intensity and the duration of the propulsive action against the ground (Altavilla et al, 2023). Systematic training of fundamental techniques, typical of the three Ks method, may promote more efficient muscular organisation during loading and unloading phases, allowing improved synchronisation between the lower limbs, trunk and striking limb (Esposito et al, 2025d). A further interpretative element concerns the different execution strategies observed between the two groups. Traditional Karate practitioners performed the technique preceded by a body pre-tensioning phase, consistent with postural and neuromuscular preparation of the gesture (Esposito et al, 2019). This strategy is well documented in the literature as enhancing force-generating capacity through the use of the stretch-shortening cycle and improving system stability during explosive actions (McGarrigal et al, 2025). By contrast, Sport Karate athletes exhibited a more continuous execution oriented towards movement economy, reflecting a functional adaptation to the demands of the competitive context, in which speed and reduction of execution time are prioritised over maximisation of transferred force (Van Hooren et al, 2024). Although the scientific literature on Karate remains limited, particularly with regard to comparative analyses between different practice models, the results of the present study are consistent with evidence from other combat sports and striking disciplines (Stewart et al, 2025). Studies conducted in boxing, mixed martial arts and other striking sports have shown that strike effectiveness is strongly dependent on the ability to utilise lower-limb propulsion and intersegmental coordination, rather than solely on upper-limb speed (Kacprzak et al, 2025). In particular, investigations analysing ground reaction force during punches or kicks have demonstrated that different motor strategies and training modalities can substantially influence both the magnitude and temporal distribution of the forces produced (Zhou et al, 2025). Within the specific context of Karate, the present study contributes to filling an important gap by providing quantitative evidence in support of observations long present in traditional practice and pedagogy. Oi-tsuki, often considered marginal in modern Sport Karate, emerges as a highly informative gesture from a biomechanical perspective, capable of highlighting substantial differences in movement organisation and in the use of kinetic chains. The evidence observed indicates that training oriented towards the construction of the technical gesture in its entirety, rather than towards situational effectiveness alone, may foster a greater ability to generate and transfer force. Taken together, these findings indicate that the training model represents a key factor in the development of specific biomechanical strategies, significantly influencing force expression during the execution of a fundamental Karate technique. This evidence opens interesting perspectives for reinterpreting the relationship between Traditional Karate and Sport Karate not in terms of opposition, but as different functional adaptations to distinct objectives and practice contexts.

Practical applications

The findings of the present study may be used as a reference for broader reflection on the design of training programmes in Karate (Raiola et al, 2021). In particular, the analysis of ground reaction force during the execution of Oi-tsuki highlights how certain practice modalities promote a greater ability to organise the technical gesture starting from contact with the ground, offering useful indications for the selection and structuring of training exercises. From an applied perspective, the inclusion of long-range techniques such as Oi-tsuki within training may represent an effective tool for assessing and stimulating the quality of force transmission along the kinetic chain. The systematic implementation of exercises requiring conscious control of body alignment and weight management may contribute to improving overall movement efficiency, regardless of the practice context. For instructors and strength and conditioning coaches, these results emphasise the opportunity to integrate training phases oriented towards the construction of the technical gesture in its entirety, alongside more specific and situational training components. An approach that alternates structured drills with less constrained motor tasks may promote the development of more versatile adaptations, beneficial both in sporting practice and in contexts requiring a high degree of body and force control. Finally, the evidence emerging from this study may support the use of objective biomechanical parameters, such as ground reaction force, as tools for monitoring training effectiveness. Observing changes in these parameters over time could provide valuable indications for adjusting training loads and for evaluating the impact of different training strategies on technical execution.

Limitations

The present study has some limitations that should be considered when interpreting the results, without however compromising the overall validity of the evidence obtained. First, the cross-sectional experimental design allows the description of differences associated with different training models but does not permit the establishment of direct causal relationships. Longitudinal studies could provide a more in-depth understanding of the evolution of adaptations over time in response to specific training programmes. A further aspect concerns the choice to analyse exclusively the Oi-tsuki punch. Although this technique represents a fundamental and highly informative gesture, the findings cannot be automatically extended to other striking techniques or to more

complex combat situations. Nevertheless, the standardisation of the analysed gesture allowed more precise isolation of differences in the production and management of ground reaction force. The selection of the best of the three valid trials for each participant, adopted to represent the maximal expressive capacity of the gesture, may have emphasised differences between groups. This choice is nonetheless consistent with the aim of the study, which was oriented towards evaluating technical effectiveness under conditions of maximal motor intention, and is in line with procedures commonly adopted in studies on explosive movements. Furthermore, the analysis focused primarily on ground reaction force parameters, without including kinematic or muscle activation measures. The integration of kinetic, kinematic and electromyographic data could provide a more comprehensive description of the motor strategies adopted by practitioners, further clarifying the mechanisms underlying the observed differences. Finally, although numerically adequate for between-group comparison, the analysed sample was drawn from specific practice contexts. Consequently, the results should be interpreted as representative of the training models considered, rather than as generalisable to all forms of Karate or to all levels of experience.

Conclusions

The study highlighted relevant quantitative differences in ground reaction force production during the execution of the Oi-tsuki punch between Traditional Karate practitioners and competitive Sport Karate athletes. In particular, the Traditional Karate group showed higher mean values for both peak ground reaction force (approximately 1985 ± 265 N) and force impulse (315 ± 42 N·s) compared with the Sport Karate group (1710 ± 240 N and 268 ± 38 N·s, respectively), with statistically supported differences associated with large effect sizes. The magnitude of the observed differences, approximately +275 N for peak force and +47 N·s for force impulse, suggests that the traditional training model is associated with a greater capacity to generate and transfer force through interaction with the ground. These findings indicate that the biomechanical effectiveness of the gesture does not depend exclusively on execution speed, but also on the quality of movement organisation and on the management of loading and unloading phases along the kinetic chain. Overall, the data show how the different training objectives of Traditional Karate and Sport Karate are reflected in distinct biomechanical strategies during the execution of a fundamental technical gesture. Without establishing an absolute superiority of one approach over the other, the evidence indicates that training based on the systematic integration of the three Ks allows greater expression of force and impulse during Oi-tsuki, confirming the value of this model in the construction of an effective and well-structured technical gesture. In conclusion, this work contributes to the Karate literature by providing quantitative data that objectively support differences previously described mainly in theoretical and practical contexts, and by laying the groundwork for further investigation into the relationship between training methodology and the biomechanical expression of technical execution.

Declaration of generative AI and AI-assisted technologies in the writing process. During the preparation of this work, the author did not use any generative artificial intelligence tools or AI-assisted technologies. The manuscript was entirely written by the author, who takes full responsibility for the content.

Conflicts of interest. The authors declare no conflict of interest.

References

- Aliberti, S., D'Elia, F., Giardullo, G., & Raiola, G. (2025). Agonism and performance in adolescent football players in informal physical education settings. *Frontiers in Sports and Active Living*, 7, 1511719.
- Altavilla, G., Aliberti, S., D'Isanto, T., & Raiola, G. (2022a). A comparison between ecological-dynamic and cognitive approach to improve accuracy in basketball shot. *Studia Sportiva*, 16(1), 6–12. <https://doi.org/10.5817/StS2022-1-1>
- Altavilla, G., D'Elia, F., D'Isanto, T., & Manna, A. (2019). Tests for the evaluation of the improvement of physical fitness and health at the secondary school. *Journal of Physical Education and Sport*, 19, 1784–1787. <https://doi.org/10.7752/jpes.2019.s5262>
- Altavilla, G., D'Isanto, T., Raiola, G., & D'Elia, F. (2023). Different explosive strength and physiological demands between male and female basketball teams. *Physical Education Theory and Methodology*, 23, 271–275. <https://doi.org/10.17309/tmfv.2023.2.16>
- Altavilla, G., Raiola, G., D'Elia, F., & Jeličić, M. (2022b). Energetic cost of running with and without the ball in male basketball players. *Physical Activity Review*, 10(2), 88–96. <https://doi.org/10.16926/PAR.2022.10.24>
- Borzucka, D., Kręcis, K., & Kuczyński, M. (2024). Ground reaction forces better than center of pressure differentiate postural control between young female volleyball players and untrained peers. *Scientific Reports*, 14, 5869. <https://doi.org/10.1038/s41598-024-56398-3>
- Ceruso, R., Esposito, G., Federici, A., Valentini, M., & D'Isanto, T. (2019a). Preliminary work about the basis data for monitoring youth soccer team planning training. *Journal of Human Sport and Exercise*, 14 (2proc), S251-S257. doi: <https://doi.org/10.14198/jhse.2019.14.Proc2.14>.
- Ceruso, R., Esposito, G., & D'Elia, F. (2019b). Analysis and evaluation of the qualitative aspects of the young players. *Journal of Physical Education and Sport*, 19, 1814-1819.

- Csákvári, L., Kopper, B., & Horváth, T. (2025). A novel, sport-specific EMG-based method to evaluate movement efficiency in karate punching. *Sports*, 13(7), 218. <https://doi.org/10.3390/sports13070218>
- Cusano, P., Giardullo, G., Di Lascio, G., Kaçurri, A., & Kasa, A. (2025). The impact of the new technological tool Sprint Resister on the training of young footballers: An 8-week experimental study. *Slobozhanskyi Herald of Science and Sport*, 29(1), 52–59.
- D’Elia, F., Di Domenico, F., D’Isanto, T., Altavilla, G., & Raiola, G. (2020). From biomechanics to motor learning. *Acta Medica Mediterranea*, 36, 3073-3078.
- D’Isanto, T., Di Domenico, F., D’Elia, F., Aliberti, S., & Esposito, G. (2021). The effectiveness of constraints-led training on skill development in football. *International Journal of Human Movement and Sports Sciences*, 9(6), 1344-1351.
- D’Isanto, T., Altavilla, G., Esposito, G., D’Elia, F., & Raiola, G. (2022). Heuristic Learning and Sport: Theoretical Lines and Operational Proposals. *Encyclopaideia*, 69-80.
- Di Domenico, F., Esposito, G., Aliberti, S., D’Elia, F., & D’Isanto, T. (2024). Determining the relationship between Squat Jump performance and knee Angle in Female University students. *Journal of Functional Morphology and Kinesiology*, 9(1), 26
- Esposito, G., Aliberti, S., Ceruso, R., Tessitore, A., & Raiola, G. (2025a). Maximum strength development in martial arts and perception and awareness: New approach for training methods. *Frontiers in Sports and Active Living*.
- Esposito, G., Aliberti, S., & D’Elia, F. (2025c). Effects on performance, perception, and awareness of plyometric training in youth volleyball: A novel methodological approach to training. *Applied Sciences*, 15(3), 1581.
- Esposito, G., Altavilla, G., Giardullo, G., Ceruso, R., & D’Isanto, T. (2024). The effects of the use of plyometric exercises with and without the ball in the development of explosive strength in volleyball. *Journal of Functional Morphology and Kinesiology*, 9(3), 126. <https://doi.org/10.3390/jfmk9030126>
- Esposito, G., Ceruso, R., Aliberti, S., & Raiola, G. (2024). Ecological-dynamic approach vs. traditional prescriptive approach in improving technical skills of young soccer players. *Journal of Functional Morphology and Kinesiology*, 9(3), 162. <https://doi.org/10.3390/jfmk9030162>
- Esposito, G., Ceruso, R., Invernizzi, P. L., Manzi, V., & Raiola, G. (2025b). Effects of stretching and resistance training on psychophysical awareness: A pilot study. *Applied Sciences*, 15(15), 8259. <https://doi.org/10.3390/app15158259>
- Esposito, G., Ceruso, R., & Raiola, G. (2025d). The impact of gentle physical activity on psychophysical well-being in older adults: A longitudinal study. *Retos*, 67, 509–521.
- Esposito, G., Ceruso, R., Valentini, M., & D’Isanto, T. (2019). The use of enabling tests to provide a qualitative measurement of the sport skill level of small soccer players. *Journal of Human Sport and Exercise*, 14(Proc4), S592–S601. <https://doi.org/10.14198/jhse.2019.14.Proc4.17>
- Gaweł, E., & Zwierzchowska, A. (2024). The acute and long-term effects of Olympic karate kata training on structural and functional changes in the body posture of Polish national team athletes. *Sports*, 12, 55. <https://doi.org/10.3390/sports12020055>
- Gaweł, E., Drozd, M., & Zając, A. (2025). Current trends in physical and physiological profile of elite WKF karate athletes: A systematic review. *BMC Sports Science, Medicine and Rehabilitation*, 17. <https://doi.org/10.1186/s13102-024-01047-5>
- Giardullo, G., Aliberti, S., Sannicandro, I., Fattore, S., & Ceruso, R. (2024). Karate game: Using a playful and participatory approach to enhancing children’s social and motor perception during the developmental age. *Physical Education Theory and Methodology*, 24(4).
- Giardullo, G., Di Lascio, G., Ceruso, R., Manzi, V., & Raiola, G. (2025). Relationship between ankle mobility, elastic strength, and rate of force development in the two karate disciplines: Kata and kumite. *Sci*, 7(4), 151. <https://doi.org/10.3390/sci7040151>
- Góra, T., & Pluto-Prądyńska, A. (2023). Biomechanics of martial arts: The analysis of the scientific resources of Scopus. *Health, Sport and Rehabilitation*, 9, 111–121. <https://doi.org/10.58962/HSR.2023.9.4.111-121>
- Horníková, H., Hadza, R., Hrubý, M., & Augustovicova, D. (2025). Postural control in top-level para karate athletes with visual and intellectual impairment: An observational study. *BMC Sports Science, Medicine and Rehabilitation*, 17. <https://doi.org/10.1186/s13102-025-01429-3>
- Kacprzak, J., Mosler, D., Tsos, A., & Wąsik, J. (2025). Biomechanics of punching: The impact of effective mass and force transfer on strike performance. *Applied Sciences*, 15(7), 4008. <https://doi.org/10.3390/app15074008>
- Marques Junior, N. (2022). Punch and kick impact of karate: A review. *Marathon*, 14(11). <https://doi.org/10.24818/mrt>
- McGarrigal, L. D., Morse, C. I., Sims, D. T., & Stebbings, G. K. (2025). Development of stretch-shortening cycle function in girls during maturation and in response to training: A narrative review. *Journal of Strength and Conditioning Research*, 39(8), e1043–e1051. <https://doi.org/10.1519/JSC.00000000000005191>

- Raiola, G. (2025). Physical literacy, according to the World Health Organization (WHO), in Italian preschool and education for a daily movement routine. *Children*, 12, 66. <https://doi.org/10.3390/children12010066>
- Raiola, G., D'Isanto, T., Di Domenico, F., & D'Elia, F. (2022). Effect of teaching methods on motor efficiency, perceptions and awareness in children. *International Journal of Environmental Research and Public Health*, 19(16), 10287. <https://doi.org/10.3390/ijerph191610287>
- Raiola, G., Esposito, G., Aliberti, S., D'Elia, F., & D'Isanto, T. (2025). Physical exercise and psychophysical learnings on basic strength development. *Methods and Protocols*, 8(2), 40. <https://doi.org/10.3390/mps8020040>
- Raiola, G., & Di Domenico, F. (2021). Physical and sports activity during the COVID-19 pandemic. *Journal of Physical Education and Sport*, 21, 477-482.
- Raiola, G., Tafuri, D., & Altavilla, G. (2015). Physical activity and its relation to body and ludic expression in childhood. *Mediterranean Journal of Social Sciences*, 6, 293-296.
- Sannicandro, I., Cofano, G., & Raiola, G. (2022). The acute effects of small-sided games on hamstring strength in young soccer players. *Physical Education Theory and Methodology*, 22(1), 74-84. <https://doi.org/10.17309/tmfv.2022.1.11>
- Sannicandro, I., Esposito, G., D'Onofrio, R., & Giacomo, C. (2024). The effects of fatigue on landing performance in young female soccer players. *Physical Education Theory and Methodology*, 24(2), 254-262.
- Shih, W.-L., Yeh, M.-L., Chuang, M.-H., & Wu, C.-E. (2024). Dynamic analysis of upper- and lower-extremity performance during take-offs and landings in high-wall climbing: Effects of a plyometric and strength training intervention. *Applied Sciences*, 14(22), 10137. <https://doi.org/10.3390/app142210137>
- Stewart, C., Cornett, R., Baker, J. S., Gu, Y., Dutheil, F., & Ugbohue, U. C. (2025). The role of lower limb kinetics in boxing punches and the impact of fatigue on biomechanical performance. *Bioengineering*, 12(12), 1355. <https://doi.org/10.3390/bioengineering12121355>
- Van Hooren, B., Jukic, I., Cox, M., Frenken, K. G., Bautista, I., & Moore, I. S. (2024). The relationship between running biomechanics and running economy: A systematic review and meta-analysis of observational studies. *Sports Medicine*, 54(5), 1269-1316. <https://doi.org/10.1007/s40279-024-01997-3>
- Yuan, Q., Deng, N., & Soh, K. G. (2025). A meta-analysis of the effects of plyometric training on muscle strength and power in martial arts athletes. *BMC Sports Science, Medicine and Rehabilitation*, 17, 12. <https://doi.org/10.1186/s13102-025-01059-9>
- Zhou, Z., Huang, J., Li, X., & Hu, C. (2025). EMG-based analysis on historical martial art techniques and movement correction. *Proceedings of the IEEE Conference on Biomedical Systems*, 297-302. <https://doi.org/10.1109/CBS65871.2025.11267555>