JOURNAL OF SPORTS AND PHYSICAL ACTIVITY
2025.VOL 1, NO 1, (38-46)
https://www.jospa.spdfharmony.com/index.php/jospa/index
DOI: https://doi.org/10.64268/jospa.v1i1.10

Analysis of *gyaku tsuki* in Karate: Injury risk and fitness implications

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ABSTRACT

Background: Karate, a traditional martial art, involves various techniques that require a deep understanding of biomechanics to optimize performance and minimize injury risks. One such technique, gyaku tsuki (reverse punch), is frequently used in competitive kumite. However, limited biomechanical analysis focuses on this technique. **Aims:** This study aims to analyze the biomechanics of gyaku tsuki, identifying the key movement phases, potential injury risks, and the necessary physical fitness components. It also explores the implications of biomechanical optimization for performance and injury prevention. **Methods:** A qualitative approach was employed using video analysis of one elite karate athlete, BK, a specialist in the -55 kg kumite category. Data was collected from the official YouTube page of the athlete on October 29, 2021. The video was analyzed using Kinovea software for biomechanical motion analysis. Triangulation was performed by comparing the video analysis with interviews from the coach and direct observation of the athlete during competition. **Results:** The study identified critical factors such as proper foot alignment and body rotation that influence punch effectiveness. Incorrect foot positioning and misalignment of the knee during execution were found to increase injury risk. The analysis also highlighted the importance of physical fitness, particularly power, speed, and coordination, for executing an optimal gyaku tsuki. **Conclusion:** The findings emphasize the need for biomechanically informed training methods to improve performance and reduce injury risks. Training should focus on optimizing body alignment, strength, and flexibility to enhance the effectiveness of gyaku tsuki.

To cite this article: Rozi, F., Nasir, M. Z. M., & Hasan, S. N. (2025). Analysis of *gyaku tsuki* in Karate: Injury risk and fitness implications. *Journal of Sports and Physical Activity, 1*(1), 38-46. https://doi.org/10.64268/jospa.v1i1.10

ARTICLE HISTORY

Received: March 15, 2025
Revised: April 24, 2025
Accepted: May 18, 2025

KEYWORDS

Biomechanics;
Gyaku Tsuki;
Injury Prevention;
Physical Fitness;

INTRODUCTION

The dynamic and high-intensity nature of Karate exposes athletes to significant injury risks, particularly in the joints and soft tissues, highlighting the urgent need for biomechanically informed injury prevention strategies (Panchal et al., 2025; Wang et al., 2024). Given the frequency and intensity of striking techniques like *gyaku tsuki*, improper execution or poor body mechanics can significantly increase the likelihood of acute or chronic injuries, particularly in high-level competition settings. Karate is a martial art that requires physical capability, technical precision, and movement efficiency. Both upper and lower limb techniques must be executed tactically. Success in Karate is significantly influenced by various motor abilities, including coordination, explosive strength, and speed, all of which are essential for technical execution and combat efficiency, particularly in

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performing effective *gyaku tsuki* punches (Gallaher, 2013; Ionete et al., 2011; Venkatraman & Nasiriavanaki, 2019).

Additionally, physical fitness components such as strength, speed, and endurance play a vital role in enhancing technical effectiveness and overall performance (Almas et al., 2023; Gurín & Podmajerský, 2025; Maqbool et al., 2024; Martínez de Quel et al., 2020). In *kumite* matches, athletes are required to execute techniques swiftly, powerfully, and accurately (Almas et al., 2023), to score points in a very limited time. One of the most frequently used and reliable scoring techniques is the *gyaku tsuki* (reverse punch). Mastery of *gyaku tsuki* significantly contributes to achieving optimal performance in competition. This technique relies not only on arm strength but also on coordinated hip rotation (Gallaher, 2013; Ionete et al., 2011), postural stability, and the coordination of large muscle groups to generate maximum force within a short time. Therefore, a thorough understanding of the biomechanical foundations of this technique is crucial for optimizing both its effectiveness and safety in high-level competition.

Previous studies have emphasized the importance of a biomechanical approach to analyzing techniques in Karate. Hip rotation supports energy efficiency and generates greater force during *gyaku tsuki* compared to movements without rotation (Venkatraman & Nasiriavanaki, 2019). Punches in martial arts are heavily influenced by intersegmental coordination and core strength (Gurín & Podmajerský, 2025), both of which are critical in Karate. Moreover, optimizing linear punch mechanics and synchronizing impulse with acceleration are crucial to improve mass transfer and strike performance (Kacprzak et al., 2025). *Gyaku tsuki* is a striking technique used for attack, interception, or counterattack, executed from the zenkutsu dachi stance, where the punching hand is opposite the front leg. Body weight distribution and momentum transfer play major roles in strike effectiveness, with efficient use of body momentum enhancing both punch power and speed (VencesBrito et al., 2011).

Physical fitness components are a primary focus for coaches to ensure the future success of karate athletes (Martínez de Quel et al., 2020) and to reduce injury risks. Injuries cannot be entirely prevented due to impact forces that exceed the mechanical capacity of bodily tissues during karate combat, especially in *kumite* simulations, which result in higher cardiovascular stress and lower blood lactate responses than official matches. Biomechanical analysis also helps identify movement patterns associated with high injury risk (Payton & Bartlett, 2008; Pal et al., 2020). While most karate-related injuries are minor, making it a relatively safe competitive sport (Pal et al., 2020), preventive measures remain essential. Therefore, a comprehensive understanding of the *gyaku tsuki* movement from a biomechanical perspective is necessary for performance enhancement and injury prevention.

Although numerous studies have examined the biomechanics of karate techniques (Beránek et al., 2023; Blanco Ortega et al., 2022; Ervilha, 2017; Gavagan & Sayers, 2017; Rinaldi et al., 2018), there remains a significant gap in research that integrates software-based video analysis with contextual observations of elite athletes in real training environments. Most biomechanical studies are conducted in laboratory settings or under controlled conditions, which may not accurately reflect the dynamic nature of actual training or competition scenarios (Adams et al., 2020; Harris et al., 2020; Stellingwerff et al., 2025; Verheul et al., 2020). In contrast, direct observation during authentic training sessions can provide deeper insights into movement patterns, bodily adaptations, and athletes' responses to specific technical demands, such as the *gyaku tsuki*.

Furthermore, there is a notable scarcity of research focusing on Indonesian athletes, particularly those from regional clubs that have made substantial contributions to national achievements. This lack of attention leaves an important gap in understanding the technical characteristics and potential of local athletes. In addition, there has been limited development of research frameworks that simultaneously integrate motion analysis, injury risk evaluation, and identification of key physical fitness components. Such a comprehensive approach is essential for the design of more effective, evidence-based training programs tailored to the needs of high-performance athletes. To date, no study has holistically combined motion analysis, injury risk assessment, and physical fitness profiling to examine the *gyaku tsuki* technique specifically among elite Indonesian karate athletes, making this research a novel contribution to the field.

Given the importance of the *gyaku tsuki* technique in *kumite* competition, a deeper understanding of its biomechanical execution is essential, especially among high-level athletes. The

effectiveness of this technique is not only determined by the power of the punch but also by the synchronization of body movements, hip rotation, and postural stability, all of which are integrated with the components of physical fitness. This study aims to analyze the biomechanics of the *gyaku tsuki* technique in Karate by using a qualitative approach through video analysis. The main focus of this research includes three main aspects: movement mechanics, potential injury risk, and identification of the most dominant physical fitness components in executing the technique. By examining how the body moves efficiently during the execution of *gyaku tsuki*, including limb coordination, hip rotation, and postural stability, this study seeks to provide valuable insights for coaches and athletes.

METHOD

This study employed a descriptive qualitative approach with motion video analysis as the primary method. The research focused on the biomechanical analysis of the *gyaku tsuki* technique within the context of karate competitions. A comprehensive analysis was conducted using visual documentation in the form of video recordings, supported by in-depth interviews with coaches and athletes, as well as direct observation during training sessions. This approach enabled the researcher to understand movement patterns, technical efficiency, and potential injury risks from both practical and theoretical perspectives. The participant in this study is an elite karate athlete from Central Java, an active member of the Great Warrior club, who specializes in the -55 kg *kumite* competition category. The selection of this athlete was based on a consistent record of achievements at both regional and national levels, demonstrating a high degree of skill and competitive experience. Moreover, the athlete is known for the frequent and effective use of the *gyaku tsuki* technique during matches, making them an ideal subject for advanced biomechanical analysis within the context of karate performance.

The population of this study consists of elite-level karate athletes from Central Java, with a focus on athletes actively competing in the *kumite* category. A purposive sampling method was employed, with the following criteria: athletes actively participating in the *kumite* category, with a high frequency of using the *gyaku tsuki* technique in competitions, and with available official video documentation of their matches. Additionally, consent from both the athletes and their respective clubs was required for participation. This process ensures that the selected sample represents characteristics relevant to the research objectives and facilitates the collection of accurate and reliable data.

The primary instruments used in this study include: video recordings of the *gyaku tsuki* movement from samples uploaded on the official YouTube channel of the Great Warrior club; semi-structured interviews with the athlete's head coach; direct observation during competitions; and the motion analysis application, Kinovea, used to perform kinematic analysis of the *gyaku tsuki* movement. Validity and reliability were ensured through source triangulation: video, interviews, and observations were compared to strengthen the validity of the findings (Creswell, 2014). The steps taken in this study include: Data collection from the official Great Warior YouTube channel (October 29, 2021); Initial analysis was conducted using Kinovea software to identify key biomechanical components; Direct observation of the match was carried out during the regional competition session the following month; Semi-structured interviews were conducted with the coach within one week after the observation; The analysis process was carried out over three months, consisting of data coding, interpretation, and triangulation.

The data were analyzed using the qualitative thematic analysis method (Braun & Clarke, 2006). The video data was divided into movement phases: preparation, execution, and follow-through. Each phase was analyzed separately. The kinematic findings from the video were compared with the results from interviews and direct observations. Simple descriptive statistics were used to illustrate the use of the technique. Inferential statistical tests were not employed due to the qualitative nature of the data. This study focused on a single athlete. Thus, the findings cannot be generalized to the entire population of karate athletes. The video-based analysis is limited by the angles from which the footage was captured and its visual quality. EMG (electromyography) measurements or force dynamics were not conducted due to equipment limitations. Although triangulation was applied, data interpretation remains influenced by the researcher's subjectivity.

RESULTS AND DISCUSSION

Results

The movement phases of *gyaku tsuki* in an elite karate athlete from Central Java, BK, who is a member of the Great Warrior club and specializes in the -55 kg *kumite* category, demonstrate a well-structured motion pattern that aligns with the fundamental biomechanical principles in Karate. The movement begins with the athlete assuming a ready stance in a modified zenkutsu dachi position, set higher to enhance preparedness for the competition. This modification aims to increase the athlete's readiness and provide a stable base for executing an effective *gyaku tsuki*. The analysis confirms that each phase of the movement, from preparation to follow-through, adheres to optimal biomechanical principles to generate power and speed in the punch.

Figure 1. *Gyaku tsuki* Movement Stages

The second stage is the punch execution, which reflects the importance of the six technical indicators for scoring points in a karate competition. These indicators include technique form, sportsmanship, spirit (bushido), awareness (zanshin), timing, and distance accuracy. In this stage, the *gyaku tsuki* technique performed by the athlete shows satisfactory achievement in these aspects, which are crucial for optimizing punch effectiveness.

The third stage is the target impact, where the non-punching hand is retracted simultaneously as the punching hand makes contact with the target. This technique adheres to competition rules, especially in the senior category, which only allows skin contact in the head area. This indicates mastery of the technique under highly controlled conditions, minimizing the risk of injury.

The fourth stage is the retraction phase, where the punching hand is immediately pulled back after impact, along with a pushing motion from the non-punching hand. This stage plays a vital role in maintaining movement flow and readiness to face counterattacks.

The final stage is returning to the ready position, which reflects the recovery of body posture and preparedness for the next move. However, a minor flaw was identified in the video analysis, where the back foot was turned outward upon impact. This misalignment with hip rotation may lead to ankle and knee injuries. Ideally, the foot position should follow proper biomechanical principles, similar to a short-distance sprint start position, to enhance push power and stability.

The movement of *gyaku tsuki* in Karate represents an integrated work of the anatomical system, involving various parts of the body from bottom to top. Starting with the feet, this movement engages bones such as the os tarsalia and os metatarsalia, as well as important ligaments like the

anterior and posterior talofibular ligament. The talocrural joint, or the ankle joint, plays a crucial role in providing stability and supporting both vertical and rotational movements of the body.

Large bones such as the femur, tibia, and coxal bone actively support force production and stability in the lower limbs and pelvis. Major muscles such as the quadriceps, gluteus maximus, and hamstrings work together, while the hinge joint in the knee and ball-and-socket joint in the pelvis facilitate body rotation and provide the thrust needed to generate a powerful punch. These components are essential for creating fast and accurate movements.

In the upper body, bones such as the sternum, scapula, and clavicle, along with back and abdominal muscles, play vital roles in maintaining body stability and optimizing rotation during the punch. The abdominal and back muscles help maintain correct posture during the execution of the movement. In the arms and hands, bones like the humerus, radius, ulna, and metacarpals work synergistically with muscles such as the triceps, biceps, deltoids, and flexor carpi to generate maximum punch force. Common injuries associated with this movement include sprains (ligament tears), dislocations, muscle spasms, and tendon lacerations. These injuries most commonly occur in the ankle, knee, lower back, and wrist, particularly due to improper posture or excessive tension.

The analysis reveals that several physical fitness components play a crucial role in the success of the *gyaku tsuki* technique. Endurance is essential to sustain the intensity of the technique throughout the match, allowing the athlete to perform attacks with optimal force. Power, particularly in the legs and arms, is necessary to generate strong and fast punches. Speed and agility enhance mobility, aiding in both attacking and evading opponents' strikes. Hand-eye and foot-eye coordination are critical in determining the accuracy and rhythm of the movements, which in turn enhances punch effectiveness. Balance is vital during both the execution of the punch and when returning to the ready stance to maintain body stability. Flexibility, especially in the legs and arms, supports an optimal range of motion in performing the technique. Core strength plays a significant role in stabilizing the body and facilitating efficient energy transfer from the lower body to the upper body, thus optimizing the force of the punch. The findings of this analysis underscore that the *gyaku tsuki* technique is a harmonious integration of biomechanical principles, physical preparedness, and tactical awareness in the context of karate competition.

Discussion

Implication

The biomechanical analysis of the *gyaku tsuki* technique reveals that the effectiveness of the punch is significantly influenced by balance, coordination, flexibility, and arm muscle strength, as well as reaction time (Almas et al., 2023; Goethel et al., 2023). Additionally, body structure, leg explosiveness, flexibility, and arm length have a notable impact on the effectiveness of the *gyaku tsuki* (Doder et al., 2023). This emphasizes the importance of developing training programs that focus not only on enhancing reaction speed and arm muscle strength but also on improving the overall technical performance of the *gyaku tsuki*. The development of these physical attributes can help athletes optimize their ability to perform this critical technique in competition.

Furthermore, elite karate athletes demonstrate faster reaction times and better neuromuscular control compared to sub-elite athletes (Ervilha et al., 2020; Goethel et al., 2023). This difference is particularly evident during the deceleration phase of the punch, where elite athletes show a higher co-contraction index between the biceps and triceps muscles, contributing to greater movement stability and control. Such advanced neuromuscular coordination allows for precise execution of movements, enhancing both the power and accuracy of the punch. This distinction underscores the importance of neuromuscular training and reaction time improvement in the development of elite-level karate practitioners.

Anatomical alignment during the execution of *gyaku tsuki* is crucial in preventing injuries. Misalignment of the back leg, such as the foot turning outward, can increase the risk of ankle and knee joint injuries. This misalignment results from a mismatch between the direction of the movement and the body's natural anatomical position, placing excessive stress on the joints. Adjusting the technique to ensure that the back foot is aligned with the direction of the punch can reduce injury risk and improve the efficiency of energy transfer during the strike. Proper body alignment is essential not only for injury prevention but also for enhancing the effectiveness of karate

techniques (Venkatraman & Nasiriavanaki, 2019), as well as the overall performance of the athlete (Goethel et al., 2023; Rinaldi et al., 2018).

Figure 2. Potential Injury in *Gyaku tsuki*

The findings of this study emphasize the need for integrated training programs that focus not only on improving strength and speed but also on coordination, balance, and flexibility. The analysis shows that coordination contributes 34.1% (r = 0.341), balance contributes 23.5% (r = 0.235), flexibility contributes 49% (r = 0.490), and arm muscle strength contributes 46.5% (r = 0.465) to the effectiveness of the kizami-*gyaku tsuki* punch. Together, these four physical fitness components contribute a total of 67.4% to the overall punch performance (Almas et al., 2023). This highlights the importance of integrating physical capabilities into training to optimize the performance of punching techniques in Karate. A holistic training approach that incorporates strength, speed, coordination, balance, and flexibility can significantly enhance the overall performance of the technique.

The use of technology, such as motion analysis software (e.g., Kinovea), allows coaches and athletes to conduct in-depth, objective assessments of techniques. Through video analysis, aspects such as speed, articulation angles, and movement patterns can be examined in detail, enabling the identification of areas that require improvement. Advanced biomechanical analysis can uncover significant differences in athletes' neuromuscular control, which can then be used to tailor training focus (Goethel et al., 2023; J. Payton & Bartlett, 2008; Kacprzak et al., 2025).

The results of this study have direct implications for coaches and those involved in the development of karate training programs. By understanding the biomechanical and physiological factors that influence the effectiveness of the *gyaku tsuki* technique, coaches can design more specific and focused training programs. For example, exercises targeting the improvement of hand reaction speed and arm muscle strength can be incorporated into training routines to enhance punch performance. Additionally, emphasizing correct technique and utilizing motion analysis technology can help prevent injuries and improve movement efficiency. As a result, this research provides valuable insights for improving training regimens and ensuring that athletes are well-prepared for competition while minimizing the risk of injury.

Research Contribution

This study makes a significant scientific contribution to the field of sports science and martial arts training, particularly in Karate. It offers an in-depth biomechanical analysis of the *gyaku tsuki* technique, which has not been extensively examined in the context of Indonesian Karate. Furthermore, the study identifies the dominant components of physical fitness associated with this technique, providing a valuable foundation for developing sport-specific training programs for karate athletes. Additionally, the research presents anatomical insights and injury risk assessments related to the movement, offering practical benefits for physiotherapists, coaches, and athletes in designing injury prevention programs based on technical execution. By integrating visual motion analysis, anatomical theory, and fitness principles, this study enriches the body of literature in sports science, especially within the domain of martial arts performance and injury management. The findings also support evidence-based approaches in coaching and conditioning strategies tailored to the biomechanical demands of elite karate competition.

Limitations

Although the findings of this study are relatively comprehensive, several limitations should be acknowledged. First, the study involved only a single subject (an elite athlete identified as BK), which limits the generalizability of the results to the broader karate athlete population. Second, the analysis was purely qualitative; no quantitative biomechanical measurements, such as punch velocity, force, or joint angles, were conducted, which could have provided stronger objective validity. Third, this study did not experimentally examine the direct relationship between physical fitness variables and the effectiveness of the *gyaku tsuki* technique, leaving a gap in understanding their causal connection.

Suggestions

Several recommendations can be proposed for future research and practical application. First, involving a larger sample of athletes across different skill levels (beginner, national, and international) is essential to compare variations in technique and their effectiveness. Second, the use of biomechanical measurement tools such as motion capture systems and force plates is recommended to obtain quantitative data on speed, force, and movement efficiency. Third, preventive training programs targeting the knee, ankle, and lower back joints should be integrated into karate practice routines, based on biomechanical findings, to reduce injury risk. Lastly, longitudinal studies are needed to examine how specific components of physical fitness influence the long-term development and refinement of *the gyaku tsuki* technique.

CONCLUSION

This study explores the *gyaku tsuki* technique in Karate from a multidisciplinary perspective, incorporating biomechanical analysis, anatomical considerations, and physical fitness components. The findings reveal that the effectiveness of this technique is highly dependent on the coordination of segmental body movements (particularly pelvic rotation, trunk torsion, and arm extension). Proper synchronization of these segments contributes to optimal force generation and punching speed. Notably, misalignment of the rear foot relative to the direction of attack was observed to negatively impact punch efficiency and increase the risk of injury, especially to the knee and ankle joints, due to excessive torsional stress. From an anatomical standpoint, technical errors such as overextension or unstable posture can result in undue strain on the shoulder, elbow, and wrist joints, potentially leading to acute or chronic injuries. Moreover, several physical fitness components (including body composition, motor coordination, balance, upper limb muscular strength, and hand reaction speed) were identified as critical factors that support the acceleration and impact force of the *gyaku tsuki* punch. Therefore, the development of this technique should be supported by targeted strength training, flexibility enhancement, and structured postural conditioning. Overall, this research contributes to the scientific understanding of fundamental karate techniques, particularly within the domains of sports science and injury prevention. The findings are intended to inform coaches, athletes, and sports practitioners in designing evidence-based training programs aimed at improving athletic performance while minimizing the risk of injury.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to the Great Warrior Karate Club for granting permission to access and utilize the training footage, which became an essential source of data for this study. Special appreciation is also extended to BK, the elite athlete featured in the video, whose technical performance provided valuable insight for the biomechanical and anatomical analysis of the *gyaku tsuki* technique. Their support has significantly contributed to the depth and relevance of this research.

AUTHOR CONTRIBUTION STATEMENT

The author, Fatkhur Rozi, was responsible for the design, data collection, and analysis of the study. The research methodology, including the video analysis of *gyaku tsuki*, was developed by Muhammad Zulqarnain Mohd Nasir. The manuscript was written and revised by Siti Nursyahiirah Hasan. All authors have read and approved the final manuscript.

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