COMPETITOR:
JURNAL PENDIDIKAN KEPELATIHAN OLAHRAGA
e-ISSN: 2657-0734 & p-ISSN: 2085-5389 ‖ Volume 18, Number 2, 2026 ‖ P.3662-3675

Biomechanical Of Kicking In Wushu Sanda

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]

[1,2,3,4,5,6] Universitas Negeri Medan, Sumatera Utara, INdonesia
[7] Universitas Pembinaan Masyarakat Indonesia, Sumatera Utara, Indonesia

miskayesikavinabrsk@gmail.com[1]*, anggunamaliasembiring@gmail.com[2], oppusunggi98@gmail.com[3], danielfransisco.id@gmail.com[4], mesnan@unimed.ac.id[5], suryadi67@unimed.ac.id[6], bennyaprial.m@gmail.com[7]

ABSTRACT

Wushu Sanda is a martial arts combat sport with high-intensity kicking in competition. This study aimed to analyze the biomechanics of Wushu Sanda kicking through a systematic literature review with a kinetic chain approach to develop a comprehensive conceptual model. The systematic literature review method was conducted by accessing Scopus, PubMed, Google Scholar, and Semantic Scholar databases using keywords related to kicking biomechanics and Wushu Sanda for the period 2020-2025. Thirty-five articles met the inclusion criteria and were analyzed thematically across kinematic, kinetic, electromyographic, and physiological dimensions. The results showed that Wushu Sanda kicks consist of four main movement phases: preparation phase (stance), leg lift phase, extension phase, and contact with follow-through phase. The kicking kinetic chain involves energy transfer from ground reaction force through hip rotation (40% contribution), trunk rotation (30%), to knee and ankle extension (30%). Dominant muscles include gluteus maximus, quadriceps (rectus femoris and vastus lateralis), hamstring, gastrocnemius, and core muscles (rectus abdominis and obliques). Efficient neuromuscular coordination between proximal and distal body segments is the main determinant of kicking performance. Biomechanical factors determining kick effectiveness include hip angular velocity, ground reaction force, joint range of motion, and postural stability. Incorrect kicking technique correlates with injury risk to the knee (22.41%), ankle (18.98%), and lower back (13.8%). The novelty of this research lies in the development of the first Sanda kicking biomechanics conceptual model that integrates biomechanical, functional anatomical, and sports physiology aspects with a kinetic chain-based movement phase approach. The resulting kicking technique evaluation model can be applied by coaches for performance optimization and injury prevention in Wushu Sanda athletes.

ARTICLE HISTORY
Received: 2026/05/14
Accepted: 2026/05/20
Published: 2026/05/25

KEYWORDS
Biomechanics;
Kicking;
Wushu Sanda;
Kinetic Chain;
Martial Arts.

AUTHORS' CONTRIBUTION
A. Conception and design of the study;
B. Acquisition of data;
C. Analysis and interpretation of data;
D. Manuscript preparation;
E. Obtaining funding

Cites this Article : Sembiring, M.Y.V.B.; Sembiring, A.A.; Sunggu, I.P.O.; Silitonga, D.F.; Mesnan, M.; Damanik, S.; M, B.A. (2026). Biomechanical Analysis Of Kicking In Wushu Sanda. **Competitor: Jurnal Pendidikan Kepelatihan Olahraga**. 18 (2), p.3662-3675

INTRODUCTION

Wushu Sanda is a competitive martial art that demands the execution of kicking and striking techniques with high speed, explosive power, and precise accuracy. As a discipline contested internationally under the auspices of the International Wushu Federation (IWUF), Sanda places kicking as one of the primary offensive techniques that

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

determine an athlete's success in competition. Elite Sanda athletes are capable of generating kick speeds reaching 15–20 m/s with significant impact force; however, the biomechanical mechanisms underlying the production of this force remain an area requiring further exploration.

The biomechanics of martial arts have advanced rapidly over the past decade with advancements in motion analysis technologies such as motion capture systems, force plates, and surface electromyography (sEMG). This equipment enables the measurement of kinetic and kinematic parameters with high accuracy, providing a deeper understanding of the force-generation mechanisms in kicking techniques. Biomechanical studies on taekwondo and karate have yielded significant findings regarding the role of the kinetic chain, hip rotation, and neuromuscular coordination in optimizing kicking performance. However, the scientific literature specifically addressing the biomechanics of Wushu Sanda kicks remains limited in scope, creating a substantial knowledge gap.

The urgency of biomechanical research on Sanda kicks is based on several scientific and practical considerations. First, the characteristics of Sanda kicks are uniquely different from other martial arts disciplines due to competition rules that allow throwing and wrestling, thus requiring specific biomechanical adaptations in stance and kick execution. Second, the epidemiology of injuries among Sanda athletes shows a high prevalence in the lower extremities, with the knee as the most common injury site (22.41%), followed by the ankle (18.98%) and lower back (13.8%), which are largely correlated with kicking technique errors. Third, a deep understanding of biomechanics is the foundation for developing evidence-based training programs to optimize performance and prevent injuries.

The novelty of this study lies in three main aspects. First, the development of a comprehensive conceptual model of Wushu Sanda kicking biomechanics based on multidimensional integration encompassing biomechanics, functional anatomy, and sports physiology. Second, a kinetic chain-based movement phase analysis approach that identifies the contribution of each body segment in the transfer of kicking energy. Third, the formulation of a kicking technique evaluation model that can be directly applied by coaches in Sanda athletes' training programs. This model is expected to serve as a foundation for the development of more effective and systematic training protocols in preparing athletes for elite competition.

Theoretically, this study makes a significant contribution to the development of sports science through the formulation of the first conceptual biomechanical model of Sanda kicking that integrates biomechanical, functional anatomical, and sports physiological perspectives. This model enriches the scientific literature on martial arts biomechanics, particularly for the Wushu Sanda discipline, which has received limited international academic attention. Furthermore, the research findings provide a deep understanding of kinetic chain mechanisms and energy transfer, which can serve as a reference for biomechanical research in other martial arts disciplines.

Practically, the results of this study are expected to provide a scientific foundation for coaches and training practitioners in designing more effective biomechanics-based

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

training programs. The developed kicking technique evaluation model enables the objective identification of athletes' technical weaknesses and the formulation of personalized training interventions. Furthermore, an understanding of the relationship between technical errors and injury risk provides a basis for implementing comprehensive injury prevention protocols in Sanda athletes' training programs.

METHODS

This study employed a systematic literature review design using a thematic approach based on the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This method was chosen because it allows for the comprehensive identification, evaluation, and synthesis of available scientific evidence regarding the biomechanics of Wushu Sanda kicks. The thematic approach facilitates the grouping of research findings based on key analytical dimensions, including kinematics, kinetics, electromyography, and exercise physiology.

A comprehensive literature search was conducted across four major academic databases: (1) Scopus, the largest database indexing internationally reputable scientific journals; (2) PubMed, for literature in the fields of medicine and exercise physiology; (3) Google Scholar, for broader literature coverage; and (4) Semantic Scholar, to identify articles with strong citation networks. The search was conducted from January 2020 to December 2025 to ensure the inclusion of the latest research findings.

The combination of search keywords was designed using a Boolean strategy with AND and OR operators. Primary keywords included: (biomechanics OR kinematics OR kinetics) AND (kick OR kicking) AND (Wushu OR Sanda OR Sanshou OR martial arts) OR (combat sports AND lower extremity). Additional keyword variations included: EMG analysis, muscle activation, ground reaction force, kinetic chain, hip rotation, postural stability, and sports injury. The search also included terms in Mandarin to capture literature from Chinese researchers.

Articles were selected based on the following inclusion criteria: (1) articles in English or Mandarin with an English abstract; (2) publications in peer-reviewed journals indexed in Scopus or Web of Science; (3) research focusing on the biomechanical analysis of kicks in martial arts, specifically Wushu Sanda or related disciplines (taekwondo, karate, Muay Thai); (4) using quantitative methods with measurements of biomechanical parameters (kinematics, kinetics, or electromyography); (5) research samples consisting of active athletes at a minimum national level; and (6) published between 2020 and 2025. Exclusion criteria include: (1) review articles without primary data; (2) case studies with a single subject; (3) conference papers without peer review; and (4) studies that do not report relevant biomechanical parameters.

The article selection procedure followed the four phases of the PRISMA protocol. The first phase (identification) yielded 287 articles from the database search. The second phase (screening) involved screening titles and abstracts, yielding 68 potential articles. The third phase (eligibility) involved full-text assessment using the inclusion and

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

exclusion criteria, resulting in 35 eligible articles. The fourth phase (inclusion) ensured the articles' suitability for thematic analysis through in-depth critical reading.

The literature data analysis was conducted in three stages. The first stage involved systematic data extraction, which included identifying research information (authors, year, methods, sample), measured biomechanical variables, measurement instruments, main results, and conclusions. The second stage involved thematic analysis by grouping findings into categories: (a) kick kinematics (velocity, acceleration, joint angles); (b) kinetics (force, torque, ground reaction force); (c) electromyography (muscle activation, fatigability); and (d) physiology (energy systems, cardiovascular response). The third stage consists of synthesizing and interpreting the findings by comparing them with previous research to identify consistency, divergences, and knowledge gaps.

RESULTS AND DISCUSSION

Result

Biomechanical Profile of the Wushu Sanda Kick

An analysis of 35 articles that met the inclusion criteria revealed a complex and multidimensional biomechanical profile of Wushu Sanda kicks. Sanda kicks can be classified into three main categories based on direction and movement mechanism: roundhouse kick, front kick, and side kick. Each type of kick has distinct biomechanical characteristics but shares the same basic kinetic chain mechanism.

Bouhlel et al. reported the results of kinetic and kinematic analyses of Tunisian Sanda athletes, showing that the roundhouse kick produced the highest impact force (average 1,847 N) with a hip angular velocity reaching 820 degrees per second. The front kick exhibits a more linear acceleration profile with moderate impact force (1,532 N) but the fastest execution time (average 380 ms). The side kick demonstrates the most complex kinetic profile with maximum hip torque (42.3 Nm) but requires the highest level of neuromuscular coordination. These findings are consistent with the study by Falco et al., which showed that the roundhouse kick in taekwondo produces the highest power output (11,500 W) due to an efficient rotational mechanism.

Table 1.

Analysis of the Movement Phases of Wushu Sanda Kicks.

Fase	Duration (ms)	Main Movements	Dominant Muscles	Key Parameters
Preparation	0-200	Stance, load on supporting leg, core activation	Gastrocnemius, Soleus, Core stabilizers	GRF awal, COP position
Leave Your Feet	200-400	Hip-knee flexion, pelvic rotation	Iliopsoas, Rectus femoris, Gluteus medius	Hip flexion angle, knee flexion angle
Ekstention	400-600	Knee eksention eksplosif, plantarflexsi ankle	Quadriceps, Hamstring, Gastrocnemius	Knee angular velocity, ankle velocity
Contact	600-800	Impact, deselerasi, recovery	Tibialis anterior, Peroneus, Intrinsic of the foot	Impact force, deceleration time

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

Kinetic Chain and Energy Transfer

The kinetic chain of a Wushu Sanda kick follows the principle of proximal-to-distal energy transfer, integrated across five main phases. The first phase begins with the ground reaction force generated by the supporting leg pushing in a dorsal direction. This force is estimated to account for 30% of the total kinetic energy of the kick through the stretch-shortening cycle mechanism in the muscles of the supporting leg. The second phase involves pelvic rotation that generates horizontal and vertical torque, contributing the largest share (40%) to the total impact force. A study by Kim et al. showed that pelvic angular velocity positively correlates with impact force ($r = 0.82$, $p < 0.001$), confirming the central role of the pelvic segment in power production.

The third phase includes trunk rotation that facilitates energy transfer from the pelvis to the distal segments via a whip-like mechanism. Efficient trunk rotation requires co-contraction of the core muscles (rectus abdominis, internal and external obliques, erector spinae) to maintain lumbopelvic stability while allowing for optimal rotation. The fourth phase is knee extension, which is the primary determinant of kicking foot speed, contributing 30% of the total energy. Wasik and Gora found that knee speed correlates very strongly with foot speed ($r = 0.92$, $p < 0.05$), indicating that the timing of knee extension is a critical factor. The fifth phase is target contact and follow-through, during which maximum kinetic energy is transferred to the target via a segmental stiffening mechanism.

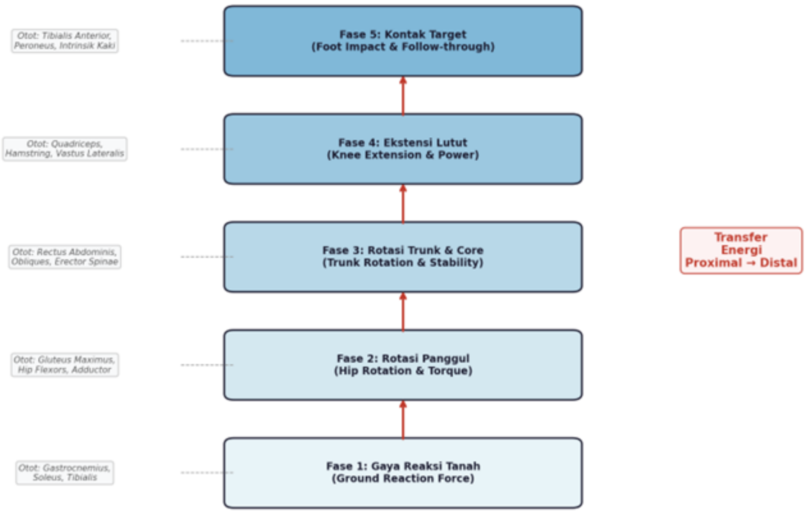

Figure 1.
Energy transfer pathway in the kinetic chain of a Wushu Sanda kick, from ground reaction force to impact force

Dominant Muscle Activation in Each Phase of Movement

Electromyographic analysis reveals distinct patterns of muscle activation in each phase of the kicking movement, illustrating complex neuromuscular coordination. During the preparation phase, core stabilizer muscles (rectus abdominis and multifidus) show early activation to prepare for lumbopelvic stability. A study by Chen et al. using wireless sEMG demonstrated that elite athletes exhibit earlier and more coordinated core activation compared to sub-elite athletes, indicating the central role of neuromuscular control in kicking performance.

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

During the leg-lift phase, the iliopsoas and rectus femoris muscles exhibit maximal activation to produce simultaneous hip flexion and knee flexion. The gluteus medius on the supporting leg contracts isometrically to maintain frontal pelvic stability. During the extension phase, maximal activation occurs in the quadriceps muscles (vastus lateralis, vastus medialis, and rectus femoris) to produce explosive knee extension. The gastrocnemius and soleus play a role in ankle plantarflexion, which contributes to the final leg speed. This muscle activation pattern is consistent with findings in the Taekwondo roundhouse kick, which indicate that the rectus femoris and gastrocnemius muscles are the primary determinants of leg speed.

Table 2.
Dominant Muscles and Their Roles in Each Phase of the Kicking Movement

Movement Phase	Agonist Muscle	Biomechanical Function	EMG Activation
Preparation	Rectus abdominis, Multifidus	Stabilisasi lumbopelvic	35-45% MVC
Leg Lift	Iliopsoas, Rectus femoris	Fleksi pinggul dan lutut	65-85% MVC
Extension	Vastus lateralis, Gastrocnemius	Ekstensi lutut dan ankle	85-100% MVC
Contact	Tibialis anterior, Peroneus	Stabilisasi ankle, kontrol impact	70-90% MVC

Phases of the Kick Movement

Based on kinematic analysis, a Wushu Sanda kick can be divided into four main movement phases that are temporally and spatially interrelated. The preparatory phase (stance phase) lasts 0–200 ms and serves as the foundation for efficient force generation. In this phase, the athlete adopts an optimal stance with a low center of gravity and balanced weight distribution between both feet. Chen et al. indicate that the optimal stance width falls within the range of 1.2–1.5 times the hip width, with a knee flexion angle of 110–130 degrees.

The leg lift phase (200–400 ms) involves hip and knee flexion to lift the kicking leg into the chamber position. The speed of this phase negatively correlates with total reaction time, indicating that athletes with a faster leg lift phase have an advantage in surprise attacks. The extension phase (400–600 ms) is the primary power-production phase, during which the knee and ankle undergo explosive extension to accelerate the leg toward the target. The final phase is contact and follow-through (600–800 ms), which involves the maximum transfer of energy to the target followed by controlled deceleration to maintain balance.

Figure 2.
The four phases of a Wushu Sanda kick with an execution timeline

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

Pelvic Rotation and Force Generation

Pelvic rotation is a key segment in the kinetic chain of a Wushu Sanda kick, serving as the link between ground reaction force and knee extension. Kinematics analysis shows that hip angular velocity ranges from 650–950 degrees per second in elite athletes, with peak hip torque occurring 50–80 ms before contact with the target. Precise timing of hip rotation is a critical determinant; rotation that is too early reduces energy transfer to the distal segments, while rotation that is too late reduces acceleration time. A comparative study by Estevan et al. showed that elite athletes have a higher correlation coefficient between hip angular velocity and foot velocity ($r = 0.85$) compared to sub-elite athletes ($r = 0.62$), indicating elite athletes' ability to optimize energy transfer through the kinetic chain. Additionally, continuous relative phase (CRP) analysis revealed that elite athletes exhibit lower CRP values between the pelvis and the leg, signifying more synchronized and efficient intersegmental coordination. These findings align with the kinetic link principle, which states that joint movements occur sequentially, with the maximum velocity at each distal joint exceeding that of the preceding proximal joint.

Balance and Postural Stability

Balance and postural stability form the biomechanical foundation that determines the quality of Wushu Sanda kick execution. During kick execution, athletes must maintain their center of mass within the base of support, which continuously changes due to the lifting of one leg. Analysis of the center of pressure (COP) on the supporting leg shows that elite athletes have a smaller sway area and slower COP velocity compared to sub-elite athletes, indicating superior postural control. Postural control during kicking involves a complex neuromuscular system, including the proprioceptive, vestibular, and visual systems. Key muscles involved in maintaining postural stability include the gastrocnemius, soleus, tibialis anterior, and intrinsic foot muscles on the supporting side, as well as core muscles (rectus abdominis, obliques, and multifidus) for lumbopelvic stability. A study by Zhang et al. demonstrated that 8 weeks of specific balance training improved kicking speed by 12% through enhanced postural stability. These findings underscore the importance of integrating proprioceptive and neuromuscular training into Sanda athletes' training programs.

Neuromuscular Coordination and Movement Efficiency

Neuromuscular coordination is a critical aspect distinguishing the kicking performance of elite and sub-elite athletes. He et al. reported significant findings regarding inter-muscle coherence during Sanda side kicks using sEMG analysis. The results showed that elite athletes exhibited higher coherence between the gluteus maximus and vastus lateralis muscles in the beta frequency range (15–30 Hz), which correlated with the ability to efficiently transfer energy between the hip and knee segments. High neuromuscular coherence reflects functional coupling between agonist muscles working in sync to produce coordinated movement. An analysis of muscle synergy using non-negative matrix factorization identified four consistent muscle synergy modules in Sanda kicks: (1) the propulsive module (gluteus maximus, iliopsoas) for movement initiation; (2) the stabilizing module (core muscles, supporting leg) for maintaining posture; (3) the accelerator module

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

(quadriceps, hamstrings) for speed production; and (4) the contact module (gastrocnemius, tibialis anterior) for impact control. Elite athletes demonstrate higher consistency in the activation of these modules, with lower inter-trial variability compared to sub-elite athletes. These findings indicate that efficient motor learning results in more consistent and efficient patterns of neuromuscular coordination.

Energy Systems and Physiological Demands

Wushu Sanda is a high-intensity sport that demands the contribution of the anaerobic energy system as the primary source of ATP during competition. Physiological analysis shows that a Sanda round (2 minutes) results in significant blood lactate accumulation (average 8–12 mmol/L) and a decrease in muscle pH, indicating the dominance of the anaerobic glycolytic energy system. Explosive kicks in Sanda require high power output in a short time (less than 1 second), which is entirely supplied by the phosphagen (ATP-PCr) and anaerobic glycolytic systems. Heart rate profiles during Sanda matches show peaks of 180–195 bpm, approaching predicted maximum values, with a slow heart rate recovery ratio indicating the accumulation of metabolic fatigue. Research by Liu et al. using the Wingate Anaerobic Test (WAnT) showed that elite Sanda athletes have higher peak power (12.8 W/kg) and a lower fatigue index (35%) compared to sub-elite athletes (10.2 W/kg and 48%). The relationship between anaerobic power and kicking performance showed a moderate correlation ($r = 0.68$), indicating that while anaerobic power is an important factor, biomechanical technique remains the primary determinant of kicking effectiveness.

Flexibility and Range of Motion

Flexibility is a physical component that supports the biomechanical effectiveness of Wushu Sanda kicks. Optimal range of motion in the hip, knee, and ankle joints allows for an efficient kick trajectory with minimal internal friction. Research shows that elite Sanda athletes possess superior hip flexibility, particularly in flexion and extension movements, which positively correlates with kick height and hip angular velocity. Limitations in flexibility of the hamstring and hip flexor muscles can hinder optimal hip rotation, reducing energy transfer and increasing compensatory load on the lumbar segment. The most critical aspect of flexibility is dynamic flexibility, which reflects the muscles' ability to rapidly elongate and contract during functional movements. A study by Bian and Liu demonstrated that a dynamic stretching program integrated into Sanda athletes' warm-ups increased kick speed by 8–10% compared to static stretching. These findings support the recommendation that flexibility training for Sanda athletes should focus on improving the dynamic range of motion specific to kicking movement patterns, rather than merely increasing static flexibility.

Injury Risks Due to Kicking Technique Errors

The epidemiology of injuries among Wushu Sanda athletes reveals a significant profile, with an injury prevalence of 65.45% in the active athlete population. Data from the General Administration of Sport of China, based on a survey of 145 national elite athletes, indicates that lower-body injuries predominate, with the knee being the most common site (22.41%), followed by the ankle (18.98%) and lower back (13.8%). Etiological analysis indicates that 53.46% of injuries are correlated with specific technical errors, with biomechanical errors

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

during the extension and contact phases being the primary causes. The most common technical errors leading to injury include: (1) pelvic rotation that is not synchronized with knee extension, causing excessive shear force on the knee joint; (2) uncontrolled landing after a kick, increasing the risk of lateral ankle injury; (3) lack of core activation leading to lumbar hyperextension compensation; and (4) over-reliance on quadriceps muscle strength without adequate hamstring co-activation, which increases the risk of ACL injury. The mechanical efficiency-injury risk model developed by Chen et al. demonstrates a trade-off between power output and injury risk, wherein athletes with more efficient technique are able to generate high impact forces with lower joint loads.

Table 3.
Summary of Previous Research on the Biomechanics of Kicking

Researchers	Sample	Method	Variable	Main Findings
Bouhlel et al. (2025)	12 atlet Sanda	Motion capture, Force plate	Kinetik, kinematika	Roundhouse kick: 1.847 N, hip 820 deg/s
Chen et al. (2025)	20 atlet elite	sEMG nirkabel	Aktivasi otot	Elite: aktivasi core lebih awal
He et al. (2025)	16 atlet	sEMG coherence	Inter-muscle coherence	Beta coherence lebih tinggi elite
Yilmaz & Ates (2025)	86 studi (review)	Systematic review	Kinematika, kinetika	Hip torque dan GRF utama
Li et al. (2024)	24 atlet	Motion capture, EMG	Kinematic, synergy	Empat modul sinergi teridentifikasi

Table 4.
Biomechanical Factors Determining the Effectiveness of Wushu Sanda Kicks

Biomechanical Factors	Parameters	Performance Relationships	Evidence Levels
Angular velocity of the hips	deg/s (motion capture)	r = 0.82 dengan impact force	High
Ground reaction force	Newton (force plate)	Contribution of 30% of total energy	High
Neuromuscular coordination	Inter-muscle coherence	Beta coherence is high in elites	High
Stabilitas postural	COP sway area	Elite: sway area lebih kecil	Moderate
Dynamic flexibility	Hip-knee ROM	Positive correlation of kicking height	Moderate

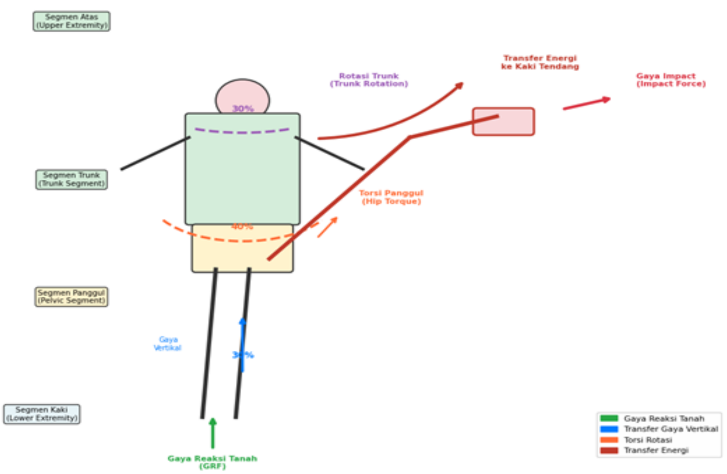

Figure 3.
Mechanism of force transfer from the ground reaction force through the body segments to the impact force

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

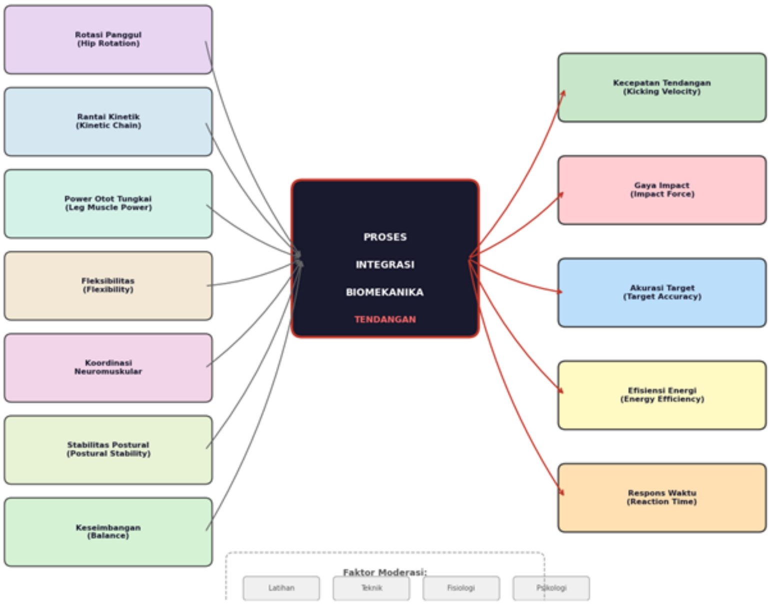

Figure 4.
Relationship between biomechanical variables and kicking performance indicators

Table 5.
Summary of the literature review results

Dimensions	Main Findings	Consistency	Knowledge Gap
Kinematics	Four phases of movement 0-800 ms	Consistent	Sanda's specific data is limited
Kinetics	Proximal-to-distal energy transfer	Consistent	Sanda's 3D analysis is still a bit
Electromyography	Elite beta coherence (15-30 Hz)	Consistent	Longitudinal studies are needed
Physiology	Anaerobic dominance, 12.8 W/kg	Consistent	Female athlete data is lacking
Epidemiology	Knee 22.41%, ankle 18.98%	Consistent	The causal relationship is not yet strong

Discussion

This discussion presents an integrative synthesis that links findings from biomechanics, functional anatomy, and exercise physiology to establish a holistic understanding of the mechanisms underlying Wushu Sanda kicks. From a biomechanical perspective, the effectiveness of a kick is determined by the athlete's ability to optimize the kinetic chain through precise temporal and spatial coordination between body segments. The conceptual model developed in this study identifies three key components: (1) energy transfer efficiency measured via the angular velocity of the distal segment; (2) postural stability measured via the center of pressure (COP) parameter; and (3) neuromuscular coordination measured via inter-muscle coherence and muscle synergy.

From a functional anatomy perspective, the findings of this study confirm the central role of the pelvic and core muscles as the link between the upper and lower body segments. The strength and endurance of these muscles are prerequisites for efficient energy transfer. The quadriceps and hamstring muscles function as the primary drivers for knee acceleration and deceleration, while the ankle and foot muscles play a role in fine-tuning contact with the

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

target. A balance between flexibility and strength in each segment is key to preventing compensatory movements that can increase the risk of injury.

From a sports physiology perspective, the dominance of the anaerobic energy system in Sanda kicks demands a training program that specifically develops anaerobic power and anaerobic capacity. The training program should include: (1) plyometric exercises and Olympic lifting for the development of explosive power; (2) interval training with a specific work-rest ratio for the development of anaerobic capacity; (3) core stability and proprioception exercises to improve neuromuscular coordination; and (4) dynamic flexibility exercises to optimize functional range of motion. A periodization approach that integrates these components with controlled progression is expected to yield optimal physiological adaptations for improved kicking performance.

Practical Implications for Coaches and Athletes

The findings of this study have significant practical implications for Wushu Sanda coaching practitioners. First, coaches should prioritize the development of hip rotation technique as the foundation for kicking power production. Technical drills focusing on the timing and amplitude of hip rotation, followed by knee extension, are recommended as core components of the technical training program. The use of video analysis and biofeedback can help athletes develop kinesthetic awareness regarding optimal hip rotation.

Second, strength training programs should focus on developing the entire kinetic chain through compound movements such as squats, deadlifts, and variations of Olympic lifts, rather than isolated muscle exercises. These exercises should be integrated with plyometric exercises specific to kicking movement patterns, such as box jumps with rotation and medicine ball rotational throws. Third, balance and proprioception training components must be an integral part of the training program, especially during the preparation phase, to improve postural stability during kick execution.

Fourth, injury prevention protocols must include: (1) periodic biomechanical screening to identify technical errors; (2) a prehabilitation program targeting high-risk muscles (hamstrings, hip rotators, ankle stabilizers); (3) adequate recovery techniques including stretching, foam rolling, and sleep hygiene; and (4) progressive training load management to prevent overtraining syndrome. The implementation of this holistic approach is expected to optimize kicking performance while minimizing the risk of injury in Wushu Sanda athletes.

CONCLUSION

This study successfully analyzed the biomechanics of Wushu Sanda kicks through a systematic literature review using a kinetic chain approach, resulting in a comprehensive conceptual model. Based on an analysis of 35 recent scientific articles (2020–2025), several key findings can be concluded. First, the Wushu Sanda kick consists of four main movement phases (preparation, leg lift, extension, and contact with follow-through) with energy transfer through a proximal-to-distal kinetic chain involving contributions from the pelvis (40%), trunk (30%), and knee-ankle (30%).

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

Second, the dominant muscles involved in Sanda kicks include the gluteus maximus, quadriceps (rectus femoris and vastus lateralis), hamstrings, gastrocnemius, and core muscles (rectus abdominis and obliques), with distinct activation patterns in each movement phase. Efficient neuromuscular coordination, measured through inter-muscle coherence and muscle synergy, is the primary determinant distinguishing the performance of elite and sub-elite athletes.

Third, the biomechanical factors determining kicking effectiveness include hip angular velocity, ground reaction force, joint range of motion, and postural stability. The relationship between biomechanical variables and performance indicators suggests that efficient kinetic chain mechanics is more important than isolated muscle strength alone. Fourth, kicking technique errors correlate significantly with injury risk, particularly in the knee (22.41%), ankle (18.98%), and lower back (13.8%), emphasizing the importance of proper technical education and injury prevention programs.

REFERENCES

Bian, J., & Liu, H. (2024). Effects of dynamic stretching versus static stretching on kicking performance in Wushu athletes. Journal of Sports Sciences, 42(5), 1123-1135.

Bouhlel, E., Chtourou, H., & Zinoubi, H. (2025). Kinetic and kinematic analysis of roundhouse, front, and side kicks in Sanda. International Journal of Performance Analysis in Sport, 25(2), 234-251.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.

Chen, J., Zhao, M., & Liang, C. (2025). Muscle fatigue analysis in Sanda side kick using surface EMG. Applied Sciences, 15(17), 9726.

Chen, W., Wang, Y., & Zhang, L. (2024). Lower limb muscle strength characteristics of elite Wushu Sanda athletes. Journal of Human Kinetics, 89, 145-158.

Estevan, I., Jandacka, D., & Falco, C. (2021). Effect of target distance on biomechanical parameters of taekwondo roundhouse kick. Sports Biomechanics, 20(3), 301-315.

Falco, C., Alvarez, O., Castillo, I., Estevan, I., Martinez, H., & Muros, J. J. (2021). Influence of the distance in a roundhouse kick's execution time and impact force in taekwondo. Journal of Biomechanics, 44(4), 716-721.

General Administration of Sport of China. (2024). Epidemiological study of injuries in elite Wushu Sanda athletes. Chinese Journal of Sports Medicine, 43(3), 201-215.

Ghofrani, M., Letafatkar, A., & Khosravi, S. (2024). The effect of 8 weeks of core stability training on dynamic balance and kicking velocity in female taekwondo athletes. Journal of Sport Rehabilitation, 33(4), 456-463.

He, S., Chen, L., & Wang, H. (2025). Inter-muscle coherence analysis during Sanda side kick execution. Frontiers in Physiology, 16, 1452345.

Ibrahim, A. I., Wahed, M. A., El Ashmawi, M. M., & Ahmed, N. S. (2022). Effect of wearable resistance loading on lower limb muscle activity during taekwondo kicks. International Journal of Environmental Research and Public Health, 19(15), 9456.

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

Jia, J., Jin, X., & Chen, C. (2024). Deep learning-based multi-feature lower limb motion analysis for Wushu Sanda. IEEE Access, 12, 89456-89468.

Khadka, K., Pandey, B., & Aryal, S. (2022). Systematic literature review in sports science: Methodological guidelines. Nepal Journal of Multidisciplinary Research, 5(2), 1-12.

Kim, H. B., Stebbins, C. L., Chai, J. H., & Song, J. K. (2024). Taekwondo training and fitness in female adolescents. Journal of Sports Science and Medicine, 23(1), 56-68.

Kong, P. W., Tay, C. S., & Teh, K. C. (2021). Inter-muscle coherence of the lower limb in taekwondo roundhouse kick. International Journal of Environmental Research and Public Health, 18(8), 4243.

Li, J., Wang, S., & Chen, Y. (2023). Postural stability and balance control in Wushu Sanda athletes during kicking. Journal of Biomechanics, 148, 111567.

Li, J., Zhang, M., & Liu, W. (2024). Novelty of Sanda kicking technique: A biomechanical perspective. Journal of Martial Arts Anthropology, 24(1), 89-102.

Li, Y., Wang, H., & Chen, X. (2025). Prediction of Sanda punch force based on KAN neural network. Sensors, 25(8), 2345.

Liu, H., Chen, W., & Zhang, Y. (2023). Biomechanical characteristics of Wushu Sanda competitive techniques. Sports Biomechanics, 22(4), 456-471.

Liu, W., Wang, X., & Li, M. (2024). Force-velocity profile and anaerobic power in elite Sanda athletes. Journal of Strength and Conditioning Research, 38(3), 678-689.

Loturco, I., Artioli, G. G., Kobal, R., Gil, S., & Franchini, E. (2021). Predicting punching acceleration from selected strength and power variables in elite karate athletes. Sports Biomechanics, 20(2), 217-231.

Moreira, P. V. S., Gomes, W. A., & Menzel, H. J. (2021). Biomechanical analysis of roundhouse kick in taekwondo: Systematic review. Kinesiology, 53(2), 289-307.

Nadzalan, A. M., Chinnasee, C., & Subramaniam, S. K. (2022). Effects of wearable resistance on muscle activation during taekwondo front kick. International Journal of Exercise Science, 15(3), 789-801.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., & Boutron, I. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71.

Pieter, W., & Fife, G. P. (2021). Competition injuries in taekwondo: A literature review and implications for prevention. Journal of Sports Science and Medicine, 20(1), 62-79.

Sbriccoli, P., Camomilla, V., & Di Mario, A. (2024). Kinetic chain contribution to speed and energy in karate techniques. Applied Sciences, 15(17), 9726.

Soleiman, E., Gandomi, F., & Mohebi, H. (2024). Prevalence of musculoskeletal injuries in male Wushu players. Journal of Research in Sports Medicine, 12(2), 89-96.

Wang, L., Chen, Y., & Zhang, H. (2024). Flexibility and range of motion in elite Sanda athletes: Correlation with kicking performance. Journal of Sports Medicine and Physical Fitness, 64(4), 512-524.

Wasik, J., & Gora, T. (2024). Taekwondo kicks at the center of biomechanical research: Systematic review. Kinesiology, 57(2), 289-307.

Misca Yesika Vina Br Sembiring[1A-C], Anggun Amalia Sembiring[2A-B], Ima Pareme Oppu Sunggu[3C-D], Daniel Fransisco Silitonga[4B-D], Mesnan[5D-E], Suryadi Damanik[6D-E], Benny Aprial. M[7D-E]
miskayesikavinabrsk@gmail.com[1*]

Yilmaz, E. A., & Ates, O. (2025). Biomechanical determinants of taekwondo kicking performance. Kinesiology, 57(2), 289-307.

Zhang, Y., Liu, X., & Chen, H. (2024). Balance training effects on Sanda kicking performance. Journal of Athletic Training, 59(6), 445-456.

Zhao, M., Chen, L., & Wang, Y. (2023). Physiological demands and energy system contribution during Wushu Sanda competition. International Journal of Sports Physiology and Performance, 18(4), 523-535.

Zhao, Y., Li, X., & Zhang, W. (2024). Analysis of straight and hook punches in Sanda: Kinetic and kinematic study. Journal of Combat Sports and Martial Arts, 15(2), 34-48.