ORIGINAL ARTICLE

Sports biomechanical analysis of international Standard Dance: Movement techniques in Standard Dance

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ABSTRACT

As a principal discipline within International Standard Dance, Standard Dance requires dancers to possess strong body control capabilities and a profound understanding of sports biomechanics due to the complexity of its technical movements and the demands for artistic expressiveness. This study adopts a sports biomechanical perspective, employing expert surveys, video analysis, and interdisciplinary research methods to investigate the fundamental techniques of Standard Dance—specifically rise and fall, weight transfer, contra body movement, swing, inclination, and rotation—with the aims of exploring the biomechanical principles underlying these techniques and their practical application in dance movements. The research findings indicate that the movement techniques of Standard Dance adhere to the fundamental principles of sports biomechanics. Specifically, the "*S*"-shaped kinetic chain transmission sequence in rise-and-fall techniques optimizes energy transfer efficiency, the dynamic balance control mechanism in weight transfer enhances dancers' stability, the conservation of angular momentum in contra body movement provides a mechanical foundation for rotational actions, the regulation of muscular torque in inclination techniques maintains dynamic equilibrium, the conversion between potential and kinetic energy in swing techniques enhances dance fluidity and artistic expressiveness, and the transfer of angular momentum in rotation techniques offers mechanical support for the execution of complex rotational movements. This study employs sports biomechanical principles to analyse the six core techniques of Standard Dance, revealing the biomechanical mechanisms underlying movement efficiency and artistic expressiveness, thereby providing a crucial theoretical foundation for the scientific refinement and precision-oriented optimization of technical training.
Keywords: Biomechanics, International Standard Dance, Sports biomechanics, Movement techniques.

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INTRODUCTION

International Standard Dance is a standardized and procedural athletic discipline performed by male-female couples. It requires the precise demonstration and application of physical techniques and skills within defined musical and rhythmic parameters, combined with artistic expression to create a cohesive performance (Li, 2015). As a sport that integrates artistic and competitive elements, International Standard Dance adheres to the principles of human biomechanics. It achieves its unique movement dynamics through the harmonious coordination of body actions, music, and spatial trajectories (Sofron & Tifrea, 2022). As a principal discipline within International Standard Dance, Standard Dance encompasses five distinct styles: Waltz, Tango, Viennese Waltz, Foxtrot, and Quickstep (World Dance Sport Federation, 2023). Its technical execution necessitates not only intricate neuromuscular coordination and dynamic equilibrium control but also requires dancers to sustain refined artistic expression amidst high-velocity movement sequences.

Driven by the continuous elevation of competitive benchmarks and groundbreaking advancements in human movement science, research in International Standard Dance pedagogy and training methodologies is undergoing a paradigm shift toward interdisciplinary integration. Examples include employing sports biomechanical principles to analyse and optimize movement mechanics (Chang et al., 2019; Hanks et al., 2024; Song et al., 2020), utilizing exercise physiology metrics to refine training load management (Li et al., 2022; Zhang et al., 2022; Zhou et al., 2024), leveraging digital information technology to develop virtual reality-assisted training systems (Liu et al., 2023; Ni & Yao, 2021), and integrating medical theories to enhance sports injury prevention and assessment protocols (Liu et al., 2024; Liu et al., 2025). Collectively, these studies provide innovative perspectives for deconstructing technical principles, optimizing movement performance, and advancing technical proficiency.

Sports biomechanics, as a discipline that investigates the mechanical characteristics and laws governing living organisms during motion or under external forces, encompasses the study of human movement principles as one of its pivotal research domains. By analysing mechanical factors under diverse movement states, it provides a scientific foundation for enhancing athletic performance, optimizing training methodologies, and mitigating sports injuries. In recent years, the application of biomechanical principles in dance training has emerged as a prominent research focus. Relevant studies concentrate on movement optimization, energy efficiency enhancement, and injury prevention, with notable advancements achieved in dance genres such as ballet (Chung et al., 2023; Li et al., 2022; Thullier & Moufti, 2004) and modern dance (Farmer & Brouner, 2025; Torrents et al., 2013; Wilson & Kwon, 2008). Research on the application of sports biomechanics principles in standard dance training has also demonstrated a trend of increasing depth. Some scholars have conducted studies focusing on biomechanical analysis of standard dance techniques. For instance, Standard Dance practitioners rely more heavily on coordinated hip-knee-ankle movements during weight transfer (Yoshida et al., 2022). In the basic Waltz step, male dancers must withstand vertical ground reaction forces approximately 1.2 times their body weight to maintain the stability of the partner hold (Li, 2015). The correlation between dynamic stability and energy efficiency is particularly pronounced during dance step transitions (Kulis et al., 2023). Additionally, some scholars have investigated how to prevent sports injuries through the optimization of movement techniques. For instance, rise and fall movements rely on the coordinated flexion and extension of the knee and ankle joints, while requiring core muscle engagement to stabilize the torso. Excessive knee flexion increases patellofemoral joint pressure, leading to sports injuries (Premelč et al., 2019). Assessments of fall risk during rotational movements reveal that dancers exhibit significantly increased lateral displacement of the centre of pressure, which correlates with dynamic balance control capabilities (Yoshida et al., 2022).

Fundamental techniques represent the most characteristic and essential elements of Standard Dance, serving as the foundation for executing complex movements and demonstrating advanced dance skills. Although existing research has achieved notable progress in the biomechanical analysis of fundamental Standard Dance techniques, and scholars have widely acknowledged the critical importance of these foundational skills, the majority of studies remain confined to fragmented investigations of individual techniques. These studies lack a holistic analysis of the technical system and have yet to develop a coherent theoretical framework. Furthermore, existing research predominantly focuses on biomechanical analyses of techniques such as weight transfer (Chang et al., 2019; Liu & Deng, 2012), rise and fall (Shioya, 2016; Wang, 2021), and rotation (Prosen et al., 2013；Yoshida et al., 2022), while studies on contra body movement, inclination, and swing remain relatively scarce. Therefore, an in-depth exploration of the biomechanical principles underlying Standard Dance techniques is critical for understanding dancers' dynamic postural control, energy transfer efficiency, and multi-joint coordinative movements, while also providing theoretical support for coaches in the context of dancer training to optimize technical execution with precision, enhance competitive performance and artistic expression. This research offers direct scientific evidence and practical guidelines for the pedagogy and training of Standard Dance, thereby facilitating the transformation of International Standard Dance training from traditional experience-driven approaches to modern scientific paradigms.

METHODOLOGY

Expert survey method

Data sources

To comprehensively understand the fundamental technical system of Standard Dance, we systematically reviewed technical materials from the World DanceSport Federation (WDSF), as well as relevant literature and books on Standard Dance teaching and training. The study primarily relies on the technical classification outlined in the World DanceSport Federation Technique Books, which categorizes Standard Dance figures into three levels: Gold, Silver, and Bronze. The fundamental techniques consist of 12 elements, including weight transfer, rise and fall, swing, contra body movement, inclination, rotation, shoulder leading, extension, heel turn, twist, heel pull, and pivot (World Dance Sport Federation, 2013).

Analysis methods

To precisely define the scope of this study and further clarify the core content of Standard Dance fundamental techniques, a questionnaire survey was conducted with 10 authoritative experts in the field of International Standard Dance. The experts included university International Standard Dance instructors and certified judges. All university instructors held associate professor or higher positions with over 15 years of teaching experience, while the judges held international-level certifications. Each expert evaluated the inclusion of each technique as either "*approved*" or "*not approved*", with data recorded in binary format (1 for "*approved*", 0 for "*not approved*").

Additionally, to further assess the consistency of expert opinions, this study employs Gwet's AC1 coefficient for statistical analysis. Gwet's AC1 is a statistical method suitable for evaluating agreement among multiple raters across multiple categorical items, effectively measuring the level of consensus among experts regarding the recognition of Standard Dance fundamental techniques. The calculation of the Gwet's AC1 coefficient is based on the evaluation results of each technique by the experts, with data processing and analysis conducted using R language (Kappaetc package).

Video analysis method

Video sources

This study selected official competition videos from the World DanceSport Federation (WDSF) and publicly available footage from international top-tier events such as the Blackpool Dance Festival as primary analysis materials.

Selection criteria

The videos were filtered based on the following conditions:

(1) High video resolution, enabling clear capture of dancers' joint angles, body posture, and weight transfer;
(2) Coverage of major Standard Dance styles (e.g., Waltz, Tango, Quickstep, Foxtrot, Viennese Waltz);
(3) Appropriate video duration, allowing complete demonstration of the initiation, intermediate, and concluding phases of technical movements.

Video observation and movement analysis

The videos were analysed frame-by-frame to meticulously document the performance characteristics of each technical movement. Qualitative analysis was conducted in conjunction with sports biomechanics principles to summarize the mechanical laws governing fundamental Standard Dance techniques.

Interdisciplinary research method

Drawing on relevant research findings from sports biomechanics, this study analyses the dynamic characteristics and mechanical key points of fundamental Standard Dance techniques based on Standard Dance technical theory and biomechanical principles, aiming to uncover the mechanical laws inherent in these techniques.

RESULTS

Selection of fundamental standard dance techniques

As a highly standardized dance form, Standard Dance comprises a technical system built upon various fundamental techniques. These techniques not only form the foundation of dance movements but also serve as the core support for dancers' expressiveness and competitive performance. The five Standard Dance styles—Waltz, Tango, Quickstep, Foxtrot, and Viennese Waltz—each possess distinct characteristics, with their technical movements adhering to specific biomechanical principles. Based on the classification of Standard Dance techniques by the World DanceSport Federation, the techniques are categorized into 12 elements: weight transfer, rise and fall, swing, contra body movement, inclination, rotation, shoulder leading, extension, heel turn, twist, heel pull, and pivot. These techniques collectively form the technical framework of Standard Dance, serving as the foundation for dancers to execute complex movements and demonstrate advanced dance skills.

Expert approval rate statistics

Table 1 presents the expert approval rates for each fundamental technique (calculated as the number of approvals divided by the total number of experts). Among these, the approval rates for rise and fall, weight transfer, contra body movement, swing, inclination and rotation are all 100%, indicating unanimous expert consensus that these techniques constitute the core foundation of Standard Dance. The approval rates for extension and shoulder leading are 80% and 70% respectively, while pivot, heel turn, twist, and heel pull each demonstrate 50% approval rates, indicating these techniques hold comparatively lesser importance in the foundational framework of Standard Dance and reflecting discernible divergence among expert assessments.

Table 1. Expert approval rate statistics for fundamental Standard Dance techniques.

No.	Fundamental technique	Expert approval rate
1	Rise and Fall	100%
2	Weight Transfer	100%
3	Contra Body Movement	100%
4	Swing	100%
5	Inclination	100%
6	Rotation	100%
7	Extension	80%
8	Shoulder Leading	70%
9	Pivot	50%
10	Heel Turn	50%
11	Twist	50%
12	Heel Pull	50%

Gwet's AC1 coefficient analysis

To further evaluate the consistency of expert opinions on the recognition of fundamental Standard Dance techniques, Gwet's AC1 coefficient was employed for statistical analysis.

(1) Data organization

The evaluation results from each expert were recorded, and the total number of approvals for each technique was calculated.

(2) Calculation of observed agreement (*Pa*)

The observed agreement (*Pa*) represents the actual rate of agreement among experts, calculated using Formula (1).

$$P_a = \frac{a(a-1)+d(d-1)}{N(N-1)} \quad (1)$$

a is the number of experts approving the technique;
d is the number of experts disapproving the technique;
N is the total number of experts ($N = a+d$).

(3) Calculation of chance agreement (*Pe*)

The chance agreement (*Pe*) represents the rate of agreement among experts under random conditions, calculated using Formula (2).

$$P_e = \frac{1}{k-1}\sum p_c(1-p_c) \quad (2)$$

p_c is expert approval rate for technique *c* (number of approving experts / total number of experts) ;
k is the number of rating categories (2 categories: approved or not approved).

(4) Calculation of Gwet's AC1 coefficient

Gwet's AC1 coefficient is calculated using Formula (3).

$$AC1 = \frac{Pa-Pe}{1-Pe} \tag{3}$$

The AC1 coefficient ranges from [−1,1], and its interpretation is as follows:
AC1 ≤0: Agreement is lower than chance;
0< AC1 ≤0.20: Slight agreement;
0.20< AC1 ≤0.40: Fair agreement;
0.40< AC1 ≤0.60: Moderate agreement;
0.60< AC1 ≤0.80: Substantial agreement;
AC1 >0.80: Almost perfect agreement.

(5) Result analysis
Based on the expert survey data, Gwet's AC1 coefficients were calculated for each technique, with the results presented in Table 2.

Table 2. Analysis of expert consensus on fundamental standard dance techniques.

Fundamental technique	Observed agreement (*Pa*)	Chance agreement (*Pe*)	Gwet's AC1 coefficient	Agreement level
Weight transfer	1.00	0.00	1.00	Almost perfect agreement
Rise and fall	1.00	0.00	1.00	Almost perfect agreement
Contra body movement	1.00	0.00	1.00	Almost perfect agreement
Swing	1.00	0.00	1.00	Almost perfect agreement
Inclination	1.00	0.00	1.00	Almost perfect agreement
Rotation	1.00	0.00	1.00	Almost perfect agreement
Extension	0.644	0.16	0.575	Moderate agreement
Shoulder leading	0.533	0.21	0.410	Moderate agreement
Pivot	0.444	0.25	0.259	Fair agreement
Heel turn	0.444	0.25	0.259	Fair agreement
Twist	0.444	0.25	0.259	Fair agreement
Heel pull	0.444	0.25	0.259	Fair agreement

By calculating Gwet's AC1 coefficients for the 12 fundamental techniques, the results indicate that the level of expert consensus ranges from 0.259 to 1.00. Among these, six techniques—weight transfer, rise and fall, contra body movement, swing, inclination, and rotation—all achieved Gwet's AC1 coefficients of 1.00, indicating the highest level of expert consensus. This demonstrates that these techniques hold a central position in Standard Dance and should form the core of foundational training. In contrast, heel pull, twist, heel turn, pivot, shoulder leading, and extension showed Gwet's AC1 coefficients between 0.259 and 0.575, reflecting relatively lower expert consensus. These techniques are considered less critical in foundational Standard Dance training compared to the aforementioned six techniques.

Expert survey results
Experts unanimously agree that fundamental techniques are the most characteristic and essential elements of Standard Dance, serving as the foundation for executing complex movements and demonstrating advanced dance skills. Among the 12 fundamental techniques, weight transfer, rise and fall, swing, inclination, contra body movement, and rotation are identified as the core of Standard Dance foundational training. Based on these findings, this study focuses on in-depth analysis and research of these six techniques.

Biomechanical principles of fundamental standard dance techniques

The "S"-shaped kinetic chain conduction sequence principle

Standard Dance is a coordinated and continuous full-body movement, characterized as a flowing dance style that exhibits various dynamic attributes driven by force. The source of force and its scientifically efficient application are fundamental to Standard Dance teaching and training. In swing-based dances (excluding Tango), the rise technique, particularly the upward movement, better demonstrates the dancer's control over music and expression through body language, thereby enhancing artistic expressiveness. The International Dance Teachers Association (IDTA) Dance Technique Book describes the rise and fall as follows: "*The rise is achieved by the lifting action of the leg muscles, straightening of the knees, and upward extension of the body, typically accompanied by the lifting or raising of the heels; the fall involves lowering from the toes to the heel of the supporting foot, followed by the relaxation of the knees in preparation for the next step*" (Horward, 1976).

The rise and fall technique involves the movement of multiple joints, including the ankle, knee, hip, torso, cervical spine, and head, as well as the activation of associated muscles. During movement, the body's joints form an "*S*"-shaped full-body coordinated kinetic chain (as shown in Figure 1), adhering to the principle of joint activation sequence. Energy is generated through the driving force of the lower limb's large muscle groups and transmitted upward layer by layer. Through the coordinated efforts of the torso and distal limb's small muscle groups, combined with lateral rotation and longitudinal spatial extension, the artistic presentation of the dance is achieved. Initially, the downward movement is generated by utilizing body gravity, causing the centre of gravity to lower. The bending of the ankle and knee joints forms an "*S*"-shaped posture, where the buffering force generated by energy storage counteracts the deformation force resulting from the stretching of leg muscles. Subsequently, the release of muscular elastic force and the contraction of thigh muscles drive the body's centre of gravity to rise from a low to a high position through knee extension. This is accompanied by the extension of the knee, ankle, and toes, transmitting energy upward through the body's joints. Ultimately, the energy reaches the torso and extends to the distal limbs and head, expanding into the surrounding space and creating an energy conduction curve (as shown in Figure 2), thereby producing a mesmerizing artistic effect in dance.

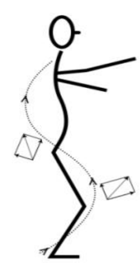


Figure 1. Chain transmission of joint forces during rise and fall.

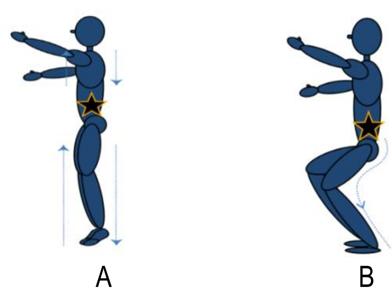
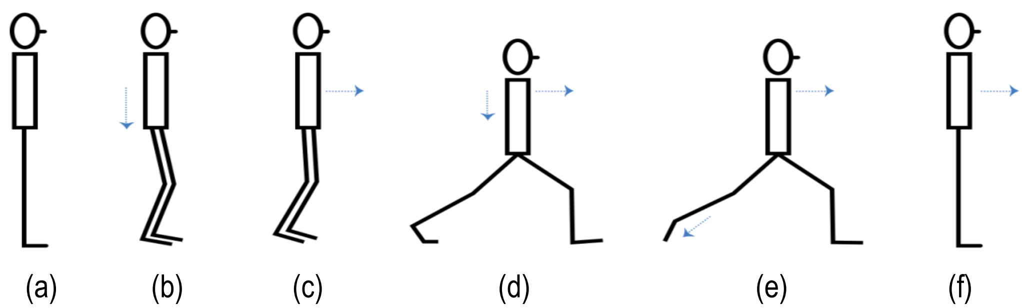


Figure 2. In-place rise and fall movement.

The principle of the "*S*"-shaped force conduction sequence is maximally utilized in the training of rise and fall techniques. These techniques are particularly crucial for beginners. Through descent practice, dancers can develop floor awareness, utilizing the gradual bending of the upper body, hip joints, knee joints, and ankle joints to create driving movements. By applying body gravity to the floor, a reactive force is generated, providing significant driving power. Ascent practice enables the coordinated and orderly transmission of force throughout the body, enhancing the dancer's stability and coordination.

Principle of central balance control in weight transfer

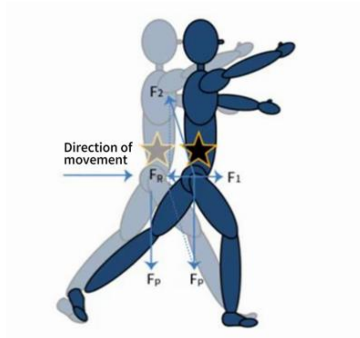
The technique of Standard Dance is essentially the technique of weight transfer. The fundamental skill of Standard Dance steps lies in the continuous shifting of the body's centre of gravity, making it the "*skill within skills*". The weight transfer in Standard Dance can be categorized into forward movement, backward movement, and side movement, each involving a continuous exchange and alteration of the weight-bearing points between the legs and feet. Weight transfer generally encompasses five movement phases: descent, resistance, control, propulsion, and recovery (as shown in Figure 3). Each phase requires dancers to possess a high level of dynamic balance maintenance ability, which is crucial for the fluidity and artistic expression of the dance.



Note. (a) Preparation; (b) Descent: Centre of gravity moves downward; (c) Resistance: Buffering and energy storage; (d) Control: Central balance position; (e) Propulsion: Rear foot propels to reach the front foot's centre of gravity position; (f) Recovery: Rising to the highest point.

Figure 3. Movement phases of weight transfer.

In the continuous flow of Standard Dance, weight transfer involves breaking the existing balance and establishing a new one. The tension generated by muscle contraction and the momentum of the body during movement must be controlled at specific positions to achieve stable balance. At this moment, the dancer's weight is F_P, the braking force of the driving leg is F_2, and the forward momentum is F_1. The resultant force F_R, formed by gravity and the braking force, is equal in magnitude and opposite in direction to the forward weight F_1, cancelling each other out. This creates a controllable balanced movement, referred to as "*central position balance*" (as shown in Figure 4). Taking forward movement as an example: The "*S*"-shaped bending of the body's joints during the buffering descent provides the driving force for movement. Before moving, the centre of gravity lowers to the ball of the supporting foot. When the driving foot reaches the maximum stride, the body's centre of gravity is positioned between the heel of the front foot and the ball of the rear foot, achieving "*central position balance*". As the front foot fully contacts the floor, the ball of the rear foot pushes naturally and smoothly, allowing the body's centre of gravity to transfer quickly and harmoniously to the front foot, followed by closing the feet and rising to recovery. This process occurs in the dynamic movement of each dance step, enabling the dance to continuously flow in balance.



Caption: The equilibrium condition is (F1+FR = 0). FP: Dancer's weight. F1: Forward momentum. F2: Braking force. FR: Resultant force of the balance system.

Figure 4. Force diagram of central position balance control.

Principle of conservation of angular momentum in contra body movement

During walking, the human body retains a contralateral movement pattern to maintain the stability of the torso and head relative to the body's longitudinal axis. The arms swing in opposition to the legs, forming a "*contra body movement*" (as shown in Figure 5). The swinging motion of the upper limbs helps counteract the rotational effect of the lower limbs' angular momentum during walking, adhering to the mechanical law of conservation of angular momentum: $M \cdot \Delta t = I\omega_2 - I\omega_1$. $M \cdot \Delta t$ represents the impulse moment, and $I\omega$ is the angular momentum of a rotating object, referred to as the moment of momentum. Standard Dance effectively applies this principle, termed "*contra body movement*".

Figure 5. Contra body movement.

Contra body movement refers to the motion where one leg moves forward or backward while the corresponding side of the body moves in the same direction. This dynamic is often used in the preparatory phase of turning or rotational movements in dance. In moving dance steps, taking a right turn as an example, when advancing or retreating, the movement of the stepping foot is accompanied by the rotation of the shoulder and hip on the opposite side of the body, creating a cross-power mechanism. The angular momentum generated by the contra body movement counteracts the angular momentum of the freely swinging lower limbs (as shown in Figure 6), maintaining a stable positional relationship between the wrist, elbow, shoulder, and hip joints on the partner's side. This not only ensures the stability of the partner's frame but also allows for an expansive and graceful posture during complex dance movements. In rotational movements, the contra body movement serves as an essential mechanical condition for turning. Before initiating a rotational step, the body moves in the opposite direction, generating a reactive force through the internal twisting of the body. This not only ensures the balance of the body's forward motion during the leading step but also provides the turning force for the rotation. By utilizing the contra technique, dancers achieve a flawless and fluid rotation.

Caption: Angular momentum conservation: $M \cdot \Delta t = I\omega_2 - I\omega_1$. M: Torque. Δt: Time interval. I: Moment of inertial. ω_1, ω_2: Initial and final angular velocities. (a) Preparation phase: Left hip forward, weight on the left foot, with the corresponding left shoulder slightly behind; (b) Twist phase: Right hip and left shoulder rotate toward each other, right leg swings forward, reaching the central balance position; (c) Final phase: The left foot pushes to generate driving force, acting on the left shoulder and the left side of the body, achieving the maximum amplitude of the contra body movement.

Figure 6. Phases of contra body movement during a standard dance right turn.

Principle of kinetic-potential energy conversion in swing

The term “*swing*” originates from physics, referring to the periodic pendulum motion of a freely moving object around a fixed point. Swing resembles the motion of “*swinging on a swing*”, with its most fundamental dynamic characteristic being the mutual conversion of gravitational potential energy and kinetic energy. According to the law of conservation of energy, the total mechanical energy of an object remains constant during the swing process. This means that the mutual conversion between kinetic and potential energy adheres to the principle of energy conservation. Specifically, at the highest points of the swing (points A and B), the object possesses maximum potential energy and zero kinetic energy. At the lowest point (point C), the object has maximum kinetic energy and minimum potential energy. As the swing position rises, kinetic energy gradually converts into potential energy, and the speed decreases. Conversely, as the swing position lowers, potential energy converts into kinetic energy, and the speed increases (as shown in Figure 7). This periodic energy conversion is the core characteristic of swing motion.

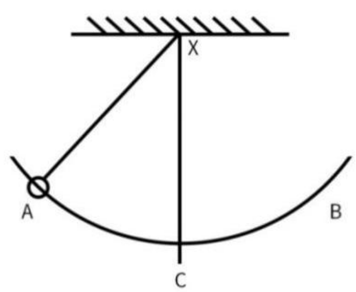


Figure 7. Principle of swing.

Swing is the fundamental movement mode of Standard Dance, characterized by the mutual conversion of kinetic energy and gravitational potential energy. The effective utilization of this energy conversion significantly enhances dancers’ training efficiency and competitive performance. Waltz, Viennese Waltz, Quickstep, and Foxtrot share the technical commonality of generating swing through gravitational potential energy, which is why these dance styles are collectively referred to as "*swing dances*" (Liu & Wu, 2012).

From a kinematic perspective, swing technique provides an efficient method of energy replenishment. Taking the Waltz sidestep as an example: the dancer begins at the highest point (point A) by relaxing the knees and lowering the centre of gravity through a knee-bending buffering motion, generating movement speed and lateral momentum. Simultaneously, the leg swings with the hip joint as the pivot point, reaching the central balance position at the lowest point (point C) and attaining maximum speed. The supporting leg then pushes, completing the rise of the centre of gravity through a swinging motion, converting kinetic energy into potential energy, and reaching the highest point (point B) (as shown in Figure 8). This cyclical process continuously generates the dynamic rhythm of dance swing. Throughout the entire process, the effects of gravity and motion inertia are fully utilized, creating a captivating dance rhythm that combines acceleration and control, movement and stillness. By understanding the principles of swing, dancers learn to better harness external forces and utilize motion inertia to complete dance movements in a passive manner. This approach makes the movements more effortless, lighter, and less fatiguing, enhancing the efficiency of the actions and allowing the dance to appear more relaxed, natural, and graceful.

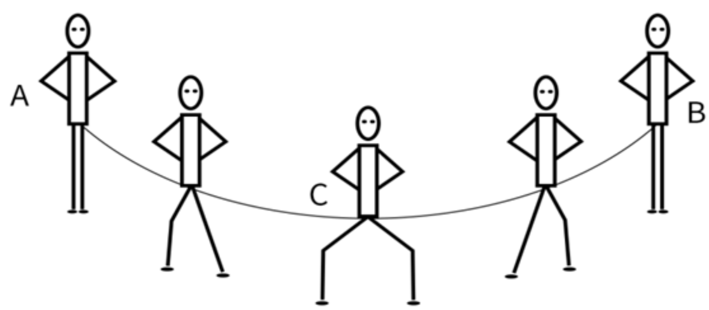


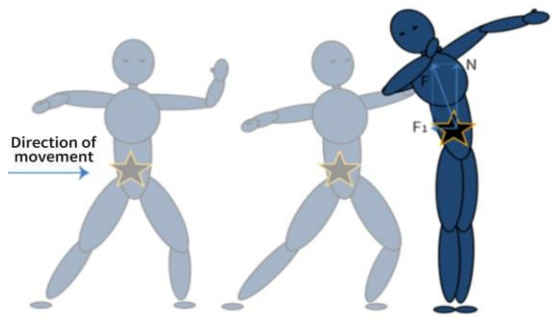
Figure 8. Schematic diagram of swing motion.

Maintaining balance in inclination – muscular torque

In Standard Dance, body inclination occurs during rise-and-fall and turning movements. Inclination is generated by swing, with swing being the cause and inclination the result. Inclination is a unique aesthetic feature of Standard Dance, a form of body line expression, and an essential component of dance technique and artistic expression.

Inclination is a dynamic posture, and maintaining this posture requires the coordinated involvement of muscles throughout the body, achieved through the regulation of different muscular torques to achieve balance. In dance, when the centre of gravity swings laterally to the opposite side, the vertical line of the centre of gravity in the sagittal plane tends to extend beyond the base of support due to motion inertia, leading to a loss of balance. To decelerate and maintain balance, it is necessary to create mechanical conditions that sustain balance on the toes. Through visual and proprioceptive feedback, the body generates internal muscular torques to counteract the motion, thereby maintaining posture and achieving a stable equilibrium. Thus, the inclination movements in Standard Dance align with the requirements of mechanical balance. Driven by the movement of the centre of gravity and through the swing, the centre of gravity remains above the pivot point of the single supporting foot. The pivot point and the ground generate a frictional force F_1. As the body's centre of gravity is braked during movement, the motion inertia acts in the opposite direction to the braking force. The gravitational force and the ground reaction force produce an elastic deformation force

N. The combined effect of the frictional force and the elastic force results in a muscular pulling force *F*. On the side of the moving foot, muscle stretching creates an elongated and relaxed line, while on the opposite side, the latissimus dorsi contracts. Under the combined action of gravitational torque and muscular torque, the body's vertical axis tilts relative to the centre of gravity's vertical line, causing the vertical plane to rotate around the sagittal axis. This results in a stable upward and diagonal movement of the body's centre of gravity, showcasing the dancer's graceful body lines and posture (as shown in Figure 9).



(a) (b) (c)

Caption. N: Elastic Force. F1: Frictional Force. F: Muscular Pulling Force. (a) Central balance position; (b) Lateral foot centre of gravity position; (c) Inclination balance position.

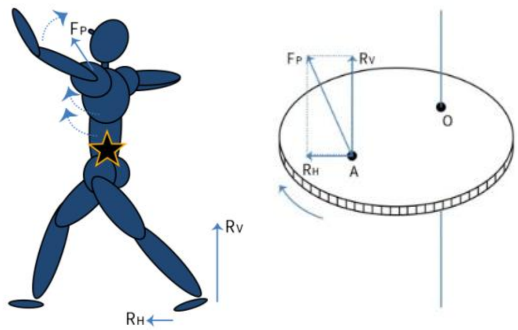
Figure 9. Formation of inclination balance through muscular torque in standard dance.

From a biomechanical perspective, tilting the centre of gravity causes the body's longitudinal axis to deviate from the vertical ground coordinate, counteracting centrifugal and forward momentum forces. This creates a dance posture where the chest, waist above the diaphragm, and head extend upward, aiding deceleration and maintaining a new state of balance. From a ballet aesthetic perspective, the characteristics of "*straightness, uprightness, and elongation*" are perfectly expressed. "*Straightness*" refers to the midsection of the body (typically the torso) maintaining a perpendicular alignment with the floor at all times. "*Uprightness*" involves lifting the hips and engaging the lower back, with the hip joints and midsection of the body tightened and pushed upward. "*Elongation*" emphasizes the upward lift of the diaphragm driven by the midsection, achieving both vertical lengthening of the entire body and horizontal extension of the frame. Particularly, the muscles on one side of the ribcage expand and stretch outward, generating muscular tension. This is accompanied by the dynamic opening of the chest and waist, creating a line that extends from the ankles, legs, and hip joints through the spine, chest, waist, and head, all the way to the hands and gaze, reaching upward and outward. This results in a beautifully artistic effect.

Transfer of angular momentum in rotational techniques

According to sports biomechanics, the rotational movements performed by the human body can generally be divided into two major categories: rotational movements of the body in a supported state and rotational movements in an unsupported (aerial) state (Sports Biomechanics Writing Group, 2019). In Standard Dance, rotation is an action that revolves around the vertical axis of the body with the foot as the pivot point. It is also a type of rotation performed while moving. Based on the angle of rotation and the amount of movement in the steps, it can be categorized into three types: pivot, spin, and natural turn (ADTV German Dance Teachers Association, 2014). Rotation is a core technique in Standard Dance, adhering to the mechanical principles of human body rotation. Whether it is a natural turn or a pivot, there must be an application of angular momentum relative to the axis of rotation (as shown in Figure 10). During the push-off phase of the leading step (left foot), the dancer is subjected to a vertical component force R_V and a horizontal component force

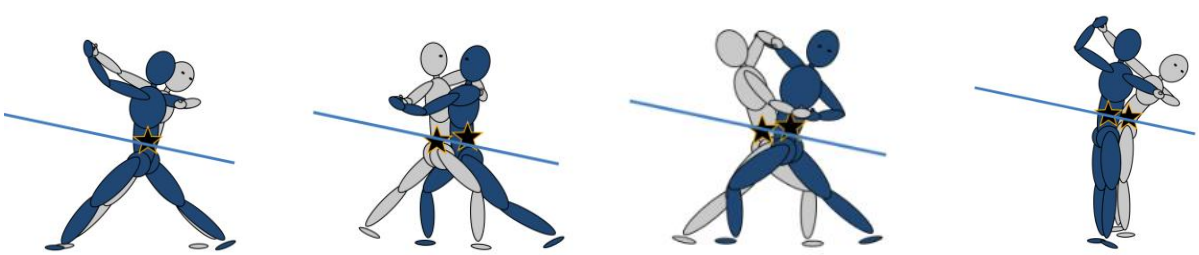
R_H, which combine to form a resultant force F_P acting on the same-side shoulder and torso of the dancer. The centre of gravity of the body shifts to the side of the resultant force's point of application, generating rotation in the horizontal plane around the supporting leg (right foot) as the axis.



Caption. RV: Vertical component force. RH: Horizontal component force. FP: Resultant force. O: Centre of gravity pivot point. A: Eccentric force pivot point.

Figure 10. The role of eccentric force in the contra body movement of Standard Dance.

The complete rotational technique in Standard Dance is typically broken down into three phases: the "*Contra Body Movement*" phase, the "*Rotation*" phase, and the "*Conclusion*" phase (as shown in Figure 11). Using a forward or backward step as the reverse lead, the dancer generates coordinated movement of the upper and lower limbs through the push-off of the supporting foot against the floor and the twisting of internal body forces. Subsequently, the moving foot lands and cushions, creating a braking effect. Due to the presence of motion inertia, the opposite side of the body retains its movement speed during braking. The rotation of the upper body forms an eccentric braking force, which generates angular momentum. This angular momentum is transferred within the body, driving the lower body to rotate around the pivot point of the braking foot and the vertical axis of the body's centre of gravity. Due to the generation of rotational inertia during the rotation phase, after the completion of the rotational movement, the dancer regulates the stretching and contraction of the muscles across various joints through internal bodily forces, demonstrating infinite spatial extensibility and dance tension.



(d) (c) (b) (a)

Note. (a) Preparation phase: Left foot moves forward; (b) Contra body movement phase: eccentric braking generates angular momentum, body rotates 1/4 to the right; (c) Rotation phase: Momentum transfer, utilizing muscle tension to complete an additional 1/8 right turn of the body; (d) Conclusion phase: Supporting leg pushes, body rises and swings, extending with inclination.

Figure 11. Transfer of angular momentum in the contra body movement of a right turn in Standard Dance.

Rotation technique is one of the core skills that Standard Dance dancers must master. It is widely applied in the movement combinations of various dance styles, not only serving to connect movements but also enhancing the aesthetic appeal of the dance through smooth rotations, fully showcasing the dancer's physical control and artistic expression. To improve the effectiveness of rotations, dancers can optimize their performance through the following approaches:

(1) Maximize the utilization of muscular strength to generate greater driving force:
The existence of torque is a prerequisite for body rotation. According to the torque formula $M = F·r·\sin\theta$, it is evident that during the contra body movement, the conservation of momentum between the upper and lower limbs plays a crucial role. The greater the muscular torque generated by the body, the higher the angular velocity produced during rotation. The magnitude of muscular torque depends on both the strength of the muscles and the length of the muscle arm. Therefore, to enhance rotational power in dance, dancers need to engage in training that increases muscle strength and expands the range of motion of the body.

(2) Adopting appropriate body movements to reduce the moment of inertia and achieve greater angular acceleration:
According to the principles of mechanics, the angular acceleration of a rigid body's rotation depends on the torque and the moment of inertia, as expressed by the formula: $\beta = M/J$. In Standard Dance routines, to achieve greater rotational speed and optimal spinning performance, dancers can increase their rotational speed by reducing the moment of inertia while maintaining a constant muscular torque. For instance, during spinning training, both the male and female dancers are required to tighten their bodies, maintain a fixed partnership frame, and keep their body posture stable while rotating around a common axis. During pivot turns, dancers should keep their bodies compact, engage the inner muscles of both legs, and control the working leg to stay close to the supporting leg, thereby reducing the rotational radius and achieving greater angular velocity.

DISCUSSION

This study, grounded in the theoretical framework of sports biomechanics, systematically investigates the mechanical principles underlying fundamental Standard Dance techniques and their application in dance movements. The research focuses on elucidating the mechanical characteristics of Standard Dance techniques through biomechanical principles, while also uncovering the mechanisms through which these characteristics influence dancers' performance. Through a comprehensive analysis of techniques such as rise and fall, weight transfer, contra body movement, swing, sway, and rotation, the study further reveals the biomechanical laws governing Standard Dance movements. Specifically, the findings indicate that the "*S*"-shaped kinetic chain transmission sequence in the rise and fall technique optimizes energy transfer efficiency, the dynamic balance control mechanism in weight transfer enhances dancers' postural stability, the conservation of angular momentum in contra body movement establishes a biomechanical foundation for rotational dynamics, the conversion between potential and kinetic energy in swing technique amplifies dance fluidity and artistic expressiveness, the regulation of muscular torque in sway technique sustains dynamic equilibrium, and the transfer of angular momentum in rotation technique provides mechanical support for the execution of complex axial rotations.

In contrast to existing studies that predominantly focus on the biomechanical relationships of partner interaction in Standard Dance or technical differences across dance styles, this study systematically deconstructs the mechanical pathways of individual fundamental techniques in Standard Dance. It provides an in-depth analysis of key issues such as energy transfer efficiency and movement economy, offering new theoretical foundations for the refinement of Standard Dance technical training. Standard Dance practitioners rely more heavily on the coordinated movement of the hip, knee, and ankle (Yoshida et al., 2022), a finding that aligns with this study's conclusion that weight transfer requires multi-joint coordinated control. However, their research primarily focused on technical differences across dance styles and did not delve deeply into the universal fundamental techniques of Standard Dance. Chang et al. (Chang et al., 2019), in their research, emphasized the central role of biomechanics in optimizing dance movements and proposed that "*joint coordination directly influences movement fluidity*", which resonates with the "*S-shaped kinetic chain transmission sequence*" theory proposed in this study. Nevertheless, Chang's research remained largely theoretical and did not analyse the mechanical pathways of specific technical movements in depth. Wu et al. (Wu et al., 2023) supported the view in this study that "*weight transfer requires dynamic balance control*", but their research mainly analysed the mechanical characteristics of partner interaction, whereas this study places greater emphasis on the systematic interpretation of the biomechanical principles of individual techniques. Chang et al. (Chang et al., 2019) and this study both revealed the central role of joint coordination in movement stability and economy, but this study further explains how coordination is achieved through mechanical pathways, providing more specific theoretical tools for technical training.

However, this study still has certain limitations. For instance, it does not delve deeply into the individual differences among dancers, such as age, gender, training experience, and body morphology. Additionally, the research focuses on a general framework of Standard Dance techniques and does not systematically compare the differences in mechanical mechanisms across different dance styles, such as Waltz, Tango, and Quickstep. Furthermore, the biomechanical mechanisms of partner interaction in Standard Dance remain an area for further exploration.

CONCLUSION

Based on expert surveys, literature analysis, and statistical methods, the research identified six core techniques of Standard Dance (weight transfer, rise and fall, swing, contra body movement, sway, and rotation) as research subjects and systematically explored their biomechanical principles and applications in dance movements. The research found that the "*S*"-shaped kinetic chain transmission sequence in the rise and fall technique optimizes energy transfer efficiency, the dynamic balance control mechanism in weight transfer enhances dancers' stability, the conservation of angular momentum in contra body movement provides a mechanical foundation for rotational actions, the regulation of muscle torque in sway technique maintains dynamic balance, the conversion between potential and kinetic energy in swing technique enhances the fluidity and artistic expression of dance, and the transfer of angular momentum in rotation technique provides mechanical support for the execution of complex rotational movements. These findings offer new biomechanical theoretical foundations for Standard Dance technical training.

The research addresses the gap in existing literature regarding the biomechanical analysis of fundamental techniques in Standard Dance. Although previous studies have explored joint coordination and dynamic balance in dance, research on the mechanical characteristics and synergistic effects of Standard Dance techniques remains limited. The research provides new perspectives and contributions for Standard Dance training research, and its outcomes will help dancers more efficiently improve their technical skills and artistic expression, further promoting the scientific and systematic development of Standard Dance training.

The research adopted an interdisciplinary research approach, combining sports biomechanics theory and video analysis methods to conduct a comprehensive biomechanical analysis of Standard Dance techniques, laying a scientific theoretical foundation for the innovation of training content and methods in Standard Dance. Future research can further expand on this basis by incorporating motion capture technology, electromyography, and energy metabolism testing to achieve more precise quantitative analysis of the mechanical characteristics of Standard Dance techniques. Additionally, in-depth exploration of the impact of individual differences among dancers on technical movements, as well as the biomechanical mechanisms of different dance styles and fundamental techniques in partner interaction, will contribute to a deeper understanding of the movement principles of Standard Dance and further advance the scientific development of International Standard Dance training.

AUTHOR CONTRIBUTIONS

Conceptualization, TW and PF; methodology, TW; software, PF; formal analysis, PF; investigation, TW; resources, TW; data curation, PF; writing—original draft preparation, TW; writing—review and editing, PF; visualization, TW and PF; project administration, TW and PF. All authors have read and agreed to the published version of the manuscript.

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