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Article

Long-term dance training alters the likelihood of slips and trips

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Abstract: Prior studies have suggested that dance may mitigate fall risks by enhancing muscular strength; despite its apparent safety, compelling evidence substantiating its efficacy in fall prevention remains scarce. The objective of this study was to examine whether individuals with prolonged dance training demonstrate distinct biomechanical responses to fall risk in contrast to those without dance experience. **Methods:** Thirty-two participants were recruited internally from a university setting (comprising 8 non-dancers, 8 ballet dancers, 8 korean dancers, and 8 modern dancers) for this investigation. Kinematic and kinetic data were scrutinized using Visual-3D software, and subsequent analyses involved data normalization, with One-way ANOVA conducted using SPSS 23.0 software. **Results:** Ballet dancers and modern dancers displayed longer stride lengths, narrower step widths, and quicker walking speeds compared to non-dancers; Korean dancers exhibited shorter stride lengths, narrower step widths, slower walking speeds, and higher gait symmetry. Modern dancers demonstrated the highest MTC during swing phase, while korean dancers showed the smallest HCV, thus yielding the lowest RCOF. **Conclusion:** Korean dancers demonstrated the lower risks of falls and trips; rigorous professional training in dancers fosters distinctive, stable gaits, superior joint control, and robust body balance, all contributing to a decrease of the likelihood of risks of falls and trips. Conversely, while modern dancers similarly showed the reduced risks, the varied styles in modern dance may be introducing some uncertainty in mitigating risks of falls and trips.

Keywords: step length; required coefficient of friction; ratio index; foot clearance; symmetry

1. Introduction

Dance integrates physical activity, musicality, social interaction, and creativity within a joyous and safe environment [1]. Over the years, an extensive body of previous research has illuminated the numerous benefits of dance, particularly its ability to reduce the risk of falls. For both healthy and clinical older adults, dance has proven to be an effective means of enhancing muscle strength, endurance, and balance [2,3]. While improvements in these risk factors contribute to a decreased fall risk, they are not interchangeable with the occurrence of falls themselves [4]. Falls are complex events influenced by a multitude of intrinsic and extrinsic risk factors that interact in intricate ways [5]. Previous assessments of fall risk factors, such as those related to slips or trips, have had limitations. They often failed to incorporate or test the body's responses to gait disturbances, which are significant contributors to the majority of falls. This gap in understanding highlights the need for a more comprehensive approach to studying fall prevention.

Dancers exhibit high levels of motor control and balance ability [6,7]. This is attributed to the specificity of dance training, to attain the requisite extremes of posture demanded by dance, dancers' musculoskeletal systems adeptly adapt through various compensatory mechanisms [8]. The technical movement characteristics of dance dictate that dancers need long and intense training, and the art form places high demands on the human body in terms of muscle and joint flexibility, stability, coordination, strength, and the vestibular system, especially for the lower limbs.

Different dance styles, with their prolonged and intensive training regimens, affect the lower limb muscle groups of dancers in varying ways depending on the specific demands of the movements [9], this can lead to changes in movement patterns [10]. For example, in ballet, the turn-out posture, along with the extension of the knees and ankles, is highly prominent. This is accompanied by frequent tiptoe movements [11]. Additionally, the lateral expansion of the shoulders, chest, and hip joints is emphasized, which not only enhances stability but also showcases the elegance of the dance. These characteristics play a crucial role in improving body balance and enabling precise control of movement direction [12]. Multiple previous studies have consistently demonstrated that dancers possess superior balance control abilities compared to non-dancers [13–15].

Modern dance, in contrast, is characterized by intense movement through strong muscle contractions [16]. It often challenges traditional notions of symmetry, striving for an aesthetic of asymmetry. This is manifested through contrasts between the two sides of the body, such as one side being heavy while the other is light, or one side moving while the other remains stationary, thereby achieving a dynamic equilibrium. Moreover, modern dance frequently incorporates a combination of fundamental movements like jumping, spinning, inverting, and stretching, which further enhance its complexity and physical demands.

Korean dance predominantly involves heel-stepping and considerable knee flexion [17], with many movements characterized by circular motion. This circularity is evident in the arms, body, and dance trajectories, emphasizing symmetrical beauty. For instance, the "circle-drawing hand" movement transitions fluidly from the forearm to the wrist and finally to the fingertips, creating circular patterns that not only enhance the aesthetic appeal but also contribute to improved dynamic balance [18–20]. The long hours of training and repeated practice required for a good performance in Korean dance, similar to other dance forms, can lead to muscle asymmetry and changes in movement patterns [10].

Gait symmetry, defined as the similarity in movement between the left and right sides of the body during walking or running, is a crucial aspect of balance and falls prevention. It is evaluated through the gait ratio index, which allows for the observation of bilateral coordination and balance during gait [21]. An increase in gait asymmetry typically indicates poor coordination, which can disrupt gait stability and elevate the risk of falls [21,22]. Research has also shown that gait asymmetry may have detrimental effects on bone health, potentially leading to reduced bone density and osteoporosis in the affected limb [23]. It can also increase the dynamic loading on the contralateral limb and joints, raising the risk of osteoarthritis and musculoskeletal injuries [24]. Therefore, understanding the degree of asymmetry in various gait parameters is of utmost importance.

The Minimum Foot Clearance (MFC) point is another critical factor in fall risk. It occurs at the mid-swing phase when the distance between the lowest point on the swing foot and the ground reaches a local minimum, and the base of support is relatively small. MFC is directly linked to the tripping mechanism, as foot-ground contact (i.e., tripping) occurs when MFC reaches zero. Surveys have consistently shown that tripping during walking is a leading cause of falls, especially among older adults [25,26]. The likelihood of tripping-related falls is highest when MFC reaches its lowest point [27]. Thus, a trip occurring at or near the MFC point is more likely to result in a loss of balance and a fall compared to other points in the gait cycle [27,28]. Individuals with smaller MFC values, who do not lift their feet adequately while walking, are at a higher risk of trip-related falls [29].

In addition to MFC, factors such as faster heel contact velocity, slower transitional walking velocity, and longer step length may increase the Risk of Contact with an Obstacle Force (RCOF), thereby increasing the susceptibility to slip-induced falls [30,31]. The relationship between the friction demand of the foot on the floor during walking and the ground reaction force is also a crucial consideration in falls prevention [32]. These assessment metrics offer a novel approach to examining the resistance to potential fall risks among dancers after prolonged dance training [33].

Dancers develop heightened strength in their forefeet, facilitating enhanced ground contact and heightened grip, alongside improvements in flexibility and equilibrium. This compensatory adaptation, intertwined with protracted and intensive dance training, has the potential to modulate dancers' gait paradigms. Different types of dance, with prolonged and intensive training, impact the lower limb muscle groups of dancers in varying ways depending on the specific demands of the movements [9]. This can lead to changes in movement patterns, which can lead to differences such as gait symmetry [10]. Consequently, dancers may have varying risks of slips and trips. It remains unclear whether dance-based training can reduce slips and trips risk [34].

The purpose of this study is to delve into this uncertainty and investigate whether different types of dance training lead to varying risks of slips and trips.

2. Methods

2.1. Subjects

Recruited 32 participants (8 non-dancers, 8 ballet dancers, 8 korean dancers, and 8 modern dancers) from within the university to participate in the study (**Table 1**). All dancers had a minimum of ten years of dance experience and trained for a minimum of 4 h per session, five times per week. We screened the participants to exclude any potential orthopaedic problems that might limit their ability to perform walking tasks or affect gait variability and balance. Written informed consent was obtained from each participant prior to the experiment. Prior to participation in the study, all participants completed a short questionnaire containing personal information such as height, weight and age.

Table 1. Subject characteristics.

	Age (year)	Height (cm)	Body Mass (kg)	BMI(kg/m^2)
Non-dancer	19.50 ± 1.08	162.00 ± 3.40	55.90 ± 5.99	21.32 ± 2.43
Ballaet dancer	19.88 ± 1.13	162.50 ± 1.20	53.63 ± 1.77	20.31 ± 0.84
Korea dancer	20.21 ± 1.37	162.86 ± 2.98	54.64 ± 1.50	20.63 ± 1.03
Modern dancer	20.75 ± 1.04	162.75 ± 1.67	54.75 ± 4.43	20.69 ± 1.98

2.2. Preparation for testing

Trial data collection Thirteen infrared cameras (Prime 17W, OptiTrack, Natural Point,Inc., Corvallis, OR, USA) were used to capture the kinematic data of each participant at a sampling rate of 120 Hz (**Figure 1**). In the experiment, the matching marker was a 14 mm reflective marker, and each subject was marked with 57 reflective skin markers [35]. Ground reaction force data was collected at 1200 Hz using an OR6-6-2000 force platform (AMTI Inc.) from Newton, MD, MA, USA, with a maximum delay time of 6 ms.

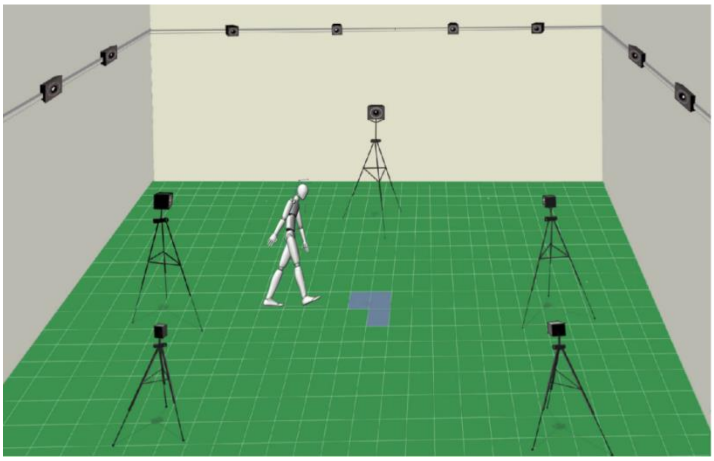

Figure 1. Field layout of the experiment.

2.3. Test procedure

Before the formal testing phase, participants were instructed to change into tight-fitting clothing and shoes provided by the laboratory, followed by morphological data measurements. After the preparatory procedures were completed, participants engaged in approximately 5 min of warm-up exercises and familiarized themselves with the experimental environment. Testing personnel explain the experimental procedures and requirements during the warm-up. At the commencement of the test, participants assumed a suitable starting stance, and upon receiving the cue “start”, proceeded to walk at their preferred pace along a predetermined pathway, ensuring that their left foot initiated contact with the force platform during each trial, and maintaining forward gaze until the conclusion of the test.

In this study, we utilized the classical 8-point method to divide the gait cycle into phases. As depicted in **Figure 2**, these eight phases include the Initial Contact phase (0% of the gait cycle), Loading Response phase (0%–10% of the gait cycle), Midstance phase (10%–30% of the gait cycle), Terminal Stance phase (30%–50% of the gait cycle), Pre-Swing phase (50%–60% of the gait cycle), Initial Swing phase

(60%–73% of the gait cycle), Mid-Swing phase (73%–87% of the gait cycle), and Terminal Swing phase (87%–100% of the gait cycle).

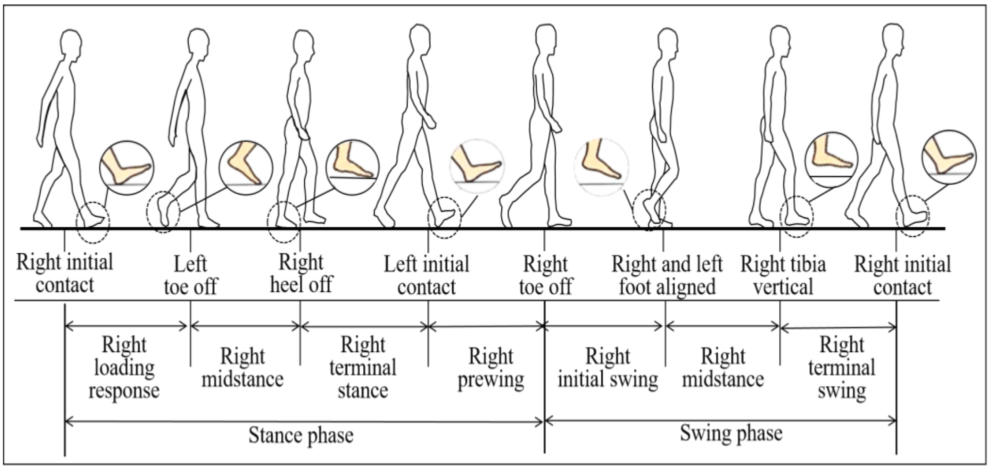

Figure 2. Gait cycle.

2.4. Data processing and analysis

Employed sophisticated motion analysis software to meticulously process and analyze the data from participants in the experiment. The data from the sensors were segmented into gait phases using Visual3D (Professional 6.0, C-Motion, Inc., Germantown, MD, USA). With this software, we could accurately extract kinematic data for each gait phase of the participants, ensuring precise analysis of their gait patterns.

Step Length (cm): The straight-line distance from the heel (or toe) of one side to the heel (or toe) of the opposite side in the direction of travel. Stride length (cm): it is the length between the first time the right foot hits the ground and the left foot hits the ground, and then the second time the right foot hits the ground. Step Width (cm): The shortest horizontal distance between the inner edges of the two feet is defined as the step width. Gait speed (m/s): The speed of the whole-body center of mass (CoM) velocity at walking. Stance time (s): It is calculated as the time from that foot’s heel strike event to its toe off event. Swing time (s): It is calculated as the time from that foot’s toe off event to its heel strike event. Step time (s): The step time for a given side of the body is the portion of the gait cycle between the opposite side’s heel strike event and the given side’s heel strike event. Cycle time (s): Actual uses the actual stride length/stride time.

Ratio index (RI)：It evaluates the symmetry of gait by comparing the differences in gait parameters between the left and right lower limbs [22], with the formula defined as:

$$\mathrm{RI} = \frac{X_1}{X_2}$$

here, X_1 = The gait parameter values of the right lower limb； X_2 = The gait parameter values of the left lower limb. If RI = 1, it indicates complete symmetry in the gait of the left and right lower limbs.

Minimum foot clearance (MFC): The minimum distance between the toes and the ground during the swing. Vertical displacement of a point on the swing foot near the great toe over one stride.

Heel Contact Velocity (HCV): The instantaneous horizontal heel velocity (HCV) at heel contact was calculated utilizing heel velocities in the horizontal direction at the foot displacement of 1/60 s (Δt) before and after the heel contact phase of the gait cycle using the formula:

$$\text{HCV} = \frac{\left[X_{(i+1)} - X_{(i-1)}\right]}{2\Delta t}$$

Required coefficient of friction (RCOF): The required coefficient of friction is obtained by dividing the horizontal ground reaction force by the vertical ground reaction force (Fx/Fz).

2.5. Statistical analysis

Analyzed the data using SPSS 23.0 and a normality analysis was conducted on the participants' data. The analysis showed that the data followed a normal distribution. One-way ANOVA was used to analyze the significance of differences between different groups. To achieve a normal distribution and reduce the impact of outliers, the data for cup inclination deviation were log-transformed. The significance level was set at $p < 0.05$.

3. Results

Table 2. Gait parameters during walking in each group of subjects.

		Non-dancers	**Ballaet dancers**	**Korea dancers**	**Modern dancers**
Stride Length (cm)		120.96 ± 1.28	125.19 ± 2.72 *	122.07 ± 5.78+	123.27 ± 1.56*+#
Stride Width (cm)		11.73 ± 1.33	8.17 ± 1.18 *	9.86 ± 0.97*+	9.86 ± 1.07+*
Stance Time (s)	Left	0.68 ± 0.03	0.68 ± 0.05	0.74 ± 0.07	0.66 ± 0.02#
	Right	0.67 ± 0.03	0.67 ± 0.04	0.73 ± 0.05* +	0.67 ± 0.01#
Step Time (s)	Left	0.55 ± 0.03	0.55 ± 0.04	0.58 ± 0.03	0.54 ± 0.04
	Right	0.54 ± 0.02	0.55 ± 0.05	0.57 ± 0.05	0.53 ± 0.02
Swing Time (s)	Left	0.41 ± 0.01	0.42 ± 0.02	0.42 ± 0.01	0.42 ± 0.03#
	Right	0.44 ± 0.01	0.44 ± 0.04	0.46 ± 0.04	0.44 ± 0.03#
Cycle Time (s)		1.09 ± 0.03	1.09 ± 0.06	1.16 ± 0.07	1.08 ± 0.05
Cadence (step/min)		109.38 ± 4.91	108.77 ± 6.27	104.44 ± 2.49	109.38 ± 4.91
Cait Speed (m/s)		1.18 ± 0.07	1.14 ± 0.07	1.08 ± 0.06 *	1.19 ± 0.05#

All values are expressed in degrees as mean ± standard deviation. * indicating a difference from the no-dancers group. + indicating a difference from the ballaet dancers group. # indicating a difference from the korea dancers group.

Table 2 is evident from the data that dancers exhibit significantly greater stride lengths compared to non-dancers. Ballet and modern dancers exhibited significantly longer stride lengths compared to non-dancers ($p < 0.001$). Additionally, regarding stride length, Korean dancers display shorter left strides. Moreover, the right step is diminished ($p < 0.001$) for Korean dancers, whereas modern dancers demonstrate a slightly larger right step ($p < 0.001$). Regarding temporal parameters, Korean dancers manifest prolonged right stance time ($p = 0.021$). Furthermore, Korean dancers exhibit lower cadence and slower gait Speed compared to non-dancers ($p < 0.001$).

Integrating **Figure 3** it becomes evident that during the process of walking, individuals who do not engage in dance activities exhibit a significantly reduced MFC during the swing phase of their gait when compared to those who are dancers. Among the three distinct dance genres, modern dancers demonstrate the highest level of MFC. And statistically significant differences in MFC between modern dancers and non-dancers ($p = 0.021$).

When examining the symmetry of step length between dancers and non-dancers, a striking disparity emerges, particularly when comparing ballet dancers and modern dance dancers with those who do not engage in dance (**Table 3**). This difference is statistically significant ($p < 0.001$). Furthermore, ballet dancers exhibit a notable variation in step width ($p = 0.004$), which suggests that this parameter is also significantly different for them compared to the other groups. However, apart from these measures, no other significant statistical differences were observed among the various groups being studied.

Table 3. Ratio index of gait parameters and joints ROM.

	Non-dancers	**Ballaet**	**Korea Dance**	**Modern Dance**
Step length ratio	1.01 ± 0.09	0.83 ± 0.10*	0.94 ± 0.05	0.81 ± 0.07*
Step width ratio	0.56 ± 0.45	1.67 ± 0.72*	0.79 ± 0.67	1.18 ± 0.56
Stance time ratio	0.99 ± 0.02	0.99 ± 0.07	0.99 ± 0.04	1.01 ± 0.03
Swing time ratio	1.08 ± 0.05	1.05 ± 0.07	1.11 ± 0.10	1.07 ± 0.04
Step time ratio	0.99 ± 0.05	0.99 ± 0.09	1.00 ± 0.03	1.02 ± 0.09
Cycle time ratio	1.02 ± 0.01	1.03 ± 0.03	1.02 ± 0.03	0.90 ± 0.36
Ankle ROM ratio	1.07 ± 0.19	0.98 ± 0.23	0.97 ± 0.16	1.20 ± 0.37
Knee ROM ratio	1.00 ± 0.04	1.02 ± 0.04	1.02 ± 0.05	1.02 ± 0.05
Hip ROM ratio	0.98 ± 0.05	0.94 ± 0.02	0.99 ± 0.12	0.97 ± 0.14

All values are expressed in degrees as mean ± standard deviation. * indicating a difference from the no-dance group.

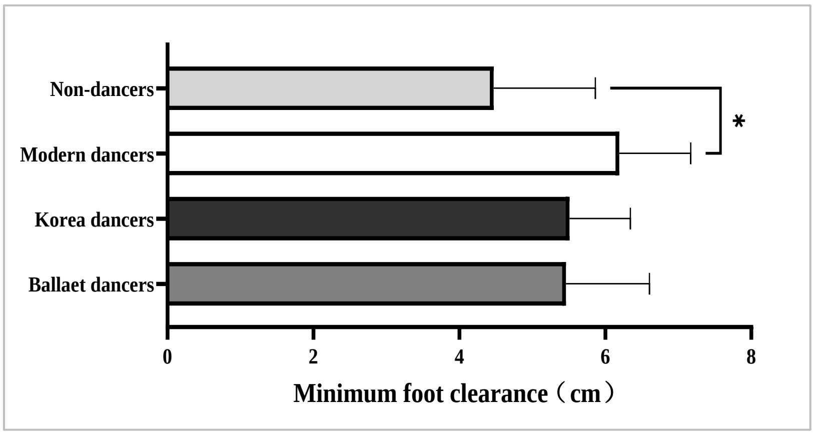

Figure 3. MFC in the swing phase.

All values are expressed in degrees as mean ± standard deviation. * indicating a difference from the no-dancers group.

Despite the fact that no significant statistical differences were observed among the various groups compared in the study, it was noted that the group consisting of Korean dance dancers exhibited a lower RCOF (p = 0.032), indicating a statistically significant difference (**Table 4**).

Table 4. Parameters at the heel contact.

	HCV (cm/s)	Horizontal GRF	Vertical GRF	RCOF
Non-dancers	96.55 ± 10.93	0.01 ± 0.01	0.10 ± 0.03	0.16 ± 0.13
Ballaet	90.11 ± 14.39	0.02 ± 0.01	0.16 ± 0.06	0.16 ± 0.08
Korea Dance	80.65 ± 12.96*	0.01 ± 0.01	0.11 ± 0.04	0.15 ± 0.11
Modern Dance	96.62 ± 16.39	0.01 ± 0.01	0.13 ± 0.06	0.16 ± 0.19

All values are expressed in degrees as mean ± standard deviation. * indicating a difference from the no-dance group. Horizontal GRF is horizontal force, Vertical GRF is vertical force, and RCOF is friction demand,the ration of horizontal GRF to vertical GRF.

4. Discussion

Analysis of the study shows that ballet dancers have the longest and narrowest gait; modern dancers exhibit the fastest walking speed and the highest MFC during the swing phase; Korean dance dancers have the longest stance time, the lowest HCV and RCOF, and the best symmetry in gait parameters. These results indicate that dancers, through years of rigorous training, develop unique gait patterns that distinguish them from individuals without dance training experience. Dancers exhibit superior proficiency in adjusting walking speed and stride length, as well as in accelerating and decelerating lower limb movements. Consequently, the gait patterns of dancers demonstrate greater symmetry and exceptional balance capabilities.

Step length is a crucial parameter in gait analysis as it reflects the spatial displacement of the body during walking [36,37]. In our study, no significant differences in left and right step lengths were observed among the modern dance, ballet, korean dance, and control groups. Although these findings suggest that dance training may not have a significant impact on step length, it is important to consider the complexity of dance movements. Dance styles often require intricate footwork and precise spatial positioning, which may lead dancers to adjust their steps to meet specific choreographic demands [38,39]. Future research involving more complex dance tasks and larger sample sizes may further elucidate the potential impact of dance training on step length. The temporal aspects of gait, including step time and swing time, provide valuable insights into the dynamic characteristics of dancers locomotion [21,40].

The minimum foot clearance (MFC) is a critical parameter for comprehending gait dynamics and mitigating the risk of trips and falls, particularly in the elderly population. MFC denotes the minimal vertical distance between the foot and the walking surface during the swing phase of gait. The research primarily focuses on how aging, fall history, and visual cues influence MFC across diverse walking tasks. Strategies to minimize tripping encompass enhancing MFC height, diminishing MFC variability, and augmenting the positive skewness of MFC distribution [41], where greater toe clearance correlates with a reduced risk of tripping. The height of the MFC is a critical factor in preventing tripping or falling. However, it often decreases with age, thereby increasing the risk of tripping [41,42]. Analysis of the variations in lower limb joint angles during locomotion reveals that the increased MFC observed in dancers stems from enhanced knee flexion during the swing phase. Dancers exhibit greater MFC compared to non-dancers, significantly diminishing the likelihood of tripping incidents.

The symmetry of gait, referring to the similarity in movement between the left and right sides of the body during walking or running. In healthy individuals, the two legs are generally symmetrical. Therefore, gait performance can be assessed through the symmetry of leg movements. Reports of gait asymmetry have been documented in healthy adults [43,44]. Clinically, gait asymmetry may be associated with several adverse outcomes, including reduced walking efficiency, compromised balance control, and increased risk of musculoskeletal injury to the dominant lower limb [45,46]. Asymmetrical behaviors of the lower limbs are observed in spatiotemporal and kinematic parameters, including speed distribution, step count and length, foot placement angle, maximum knee flexion, and joint range of motion. An increase in gait asymmetry typically reflects poor coordination, which can disrupt gait stability and increase the risk of falls [21,47]. Symmetry ratios constitutes a crucial aspect of human locomotion and is frequently employed to assess normal and pathological gait patterns [48,49]. In our study, both ballet dancers and modern dance groups exhibited a significantly lower step length symmetry index compared to korean dance dancers, while dancers, in general, showed lower step length symmetry compared to non-dancers. Understanding gait symmetry can offer insights into various conditions and assist in the development of rehabilitation strategies.

It is important to note that a ratio employs a value of 1.0 to signify “perfect” symmetry. For clinical purposes, comparing the ratios of gait parameters between dancers and non-dancers is valuable, as the direction of asymmetry is inherently indicated by the values. Studies have shown that with increased knee strength, the heel contact velocity of the non-dominant leg decreases more significantly compared to the dominant leg. Furthermore, after training, factors contributing to slipping risks, such as peak vertical ground reaction force (PFz) and required coefficient of friction (RCOF), are improved in the non-dominant leg. training can alleviate asymmetric gait or limb patterns, which may subsequently reduce the likelihood of slipping [50–52]. Several studies have demonstrated that asymmetry and variability diminish with increased physical exercise, attributing this phenomenon to the utilization of compensatory walking mechanisms aimed at restoring postural balance [53].

It is noteworthy that step length asymmetry is linked to various factors, such as muscle imbalances, joint limitations, and deficits in motor control [54]. Additional research is necessary to delve into the underlying biomechanical mechanisms that contribute to step length asymmetry in modern dancers and its potential implications for movement efficiency and injury risk. Regarding step width, dancers exhibit significantly greater symmetry compared to non-dancers. Among them, korean dance dancers demonstrate superior performance. Conversely, ballet and modern dance dancers display asymmetry in the symmetry index of step width, with gender differences being more apparent. These findings imply that ballet and korean dance styles might prioritize less on step length asymmetry, possibly owing to the technical demands and aesthetic principles inherent to these styles. Limb dominance can impact the symmetric or asymmetric behavior of the lower limbs, with functional disparities potentially linked to propulsion and control tasks during walking.

Kim et al. suggested in their study that identifying strategies to reduce HCV could serve as a preventive measure to mitigate the risk of slips and falls in frail older adults [55]. It is believed that faster heel contact velocity, slower transitional walking velocity, and longer step length may augment the RCOF, thereby heightening the susceptibility to slip-induced falls [30,31]. Studies indicate that dancers demonstrate faster heel contact velocities than non-dancers, potentially heightening their risk of slipping on horizontal surfaces [56]. Nevertheless, dancers also display higher activation rates in lower limb muscles compared to non-dancers, which could mitigate heel contact velocity and the probability of slipping-induced falls [57]. Nevertheless, most studies have failed to demonstrate a clear relationship between strength gains and alterations in gait characteristics.

Decreasing anterior leg momentum and accelerating the entire body are crucial components in avoiding hazardous slip incidents caused by high RCOF during the heel contact phase of the gait cycle [57]. Dance training can improvement in the hamstring muscles (knee flexors) contributes to reducing anterior leg momentum before heel contact, while enhancement in ankle plantar flexor strength plays a role in propelling the body's center of mass forward after heel contact. Walking speed and stride length are suggested to influence the likelihood of slipping [57] as they impact the horizontal shear force component during the heel contact phase of the gait cycle. Dancers exhibit slower gaits and shorter strides, as they aim to maintain safer gait characteristics. These findings may suggest that slower gaits and shorter strides should not necessarily be labeled as safer gaits. Dancers with prolonged dance training can potentially reduce the likelihood of slipping by solely modifying HCV and COM.

Due to resource limitations, the overall sample size in this study was relatively small. Additionally, the participants had varying dance training backgrounds, which might influence their responses to training effects differently. As a result, potential confounding variables cannot be entirely ruled out, which may have introduced biases into the statistical results. Future research should implement stricter controls over participants' training backgrounds or conduct subgroup analyses based on different backgrounds. Additionally, increasing the sample size would help validate the stability and reliability of the current findings.

5. Conclusions

Prolonged dance training induces significant alterations in the gait patterns of practitioners, consequently affecting their propensity to trip and fall during ambulation. Rigorous professional dance training endows dancers with a distinctive, stable gait, exceptional joint control, and unwavering balance, all contributing to a diminished risk of trips and slips. Notably, korean dancers exhibit the lowest risk of slips, whereas modern dancers demonstrate a reduced risk of trips. Nonetheless, the diversity inherent in modern dance styles results in variability in the reduction of slips and trips risks.

Dance training could be considered as an intervention strategy when designing fall prevention programs, particularly for older adults or individuals with reduced mobility. According to the findings, long-term dance training can significantly alter gait patterns, thereby reducing the risks of falls and trips. Among the three types of dance studied, Korean dance appears to be more suitable for older adults. The results indicate that Korean dancers exhibit greater gait symmetry, shorter stride lengths, and slower walking speeds. These characteristics contribute to a more stable gait and balance, thereby reducing the risk of falls. Additionally, Korean dancers demonstrate a greater Minimum Foot Clearance (MFC) while walking, which helps reduce the likelihood of tripping. However, it is important to note that these conclusions are based on studies involving young dancers, and their direct application to older adults may require further investigation and adaptation.

Author contributions: Conceptualization, QQ, XT and SK; methodology, QQ, XT and SK; software, QQ and JZ; validation, XQ, JZ and SK; formal analysis, QQ, XT and YK; investigation, QQ, XT and YK; resources, XQ and SK; data curation, XT and SK; writing—original draft preparation, QQ and XT; writing—review and editing, JZ and SK; visualization, XQ; supervision, SK; project administration, JZ. All authors have read and agreed to the published version of the manuscript.

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Jeonbuk National University (protocol code: JBNU2022-04-008-002; approval date: 26 May 2022). Informed consent was obtained from all subjects involved in the study.

Conflict of interest: The authors declare no conflict of interest.

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