Hip Range of Motion and Strength in Young pre-professionals Ballet Dancers versus Non-Dancers

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Abstract

Introduction: Lower-extremity external rotation, commonly known as turnout, is a fundamental skill in dance. Limited data exist regarding joint range of motion and strength in pre-professional young dancers and non-dancers. This study aimed to evaluate the differences in hip range of motion and hip strength between pre-professional ballet dancers and non-dancers. Additionally, the study assessed the variations between the left and right sides within each group.

Methods: This observational study assessed 60 pre-professional ballet dancers and 31 non-dancers with an average age of 11.91±1.49. Evaluation included passive hip rotation, tibial torsion, total passive turnout measured with digital goniometers, and total active turnout (both static and dynamic) through standing on paper and rotational discs. Hip rotation strength was measured using a force sensor device. Statistical analyses encompassed student t-tests, Pearson's correlations, and ANCOVA with age and body weight as covariates, applying the Bonferroni correction for multiple comparisons.

Results: Ballet dancers exhibited greater passive hip external rotation and lower passive hip internal rotation compared to non-dancers. They also demonstrated superior total active turnout (static and dynamic). After adjusting for age and weight, dancers demonstrated significantly higher hip external rotation strength than non-dancers. Hip internal rotation strength did not differ significantly between the groups. Ballet dancers displayed inherent asymmetry, with the left side showing greater tibial torsion and standing active turnout, while the right side exhibited greater hip external rotation during dynamic active turnout. Non-dancers did not show significant side differences.

Conclusions: Young pre-professional ballet dancers exhibited significant hip rotation differences compared to non-dancers, including notable right-left asymmetry. These findings should be considered when planning training, aiming to optimize musculoskeletal attributes and promote balanced hip rotation. Recognizing these asymmetries and addressing muscular imbalances is vital for injury prevention and performance enhancement.

Keywords: Anthropometrics, Ballet, Dance For Health, Dance Medicine, Dance Science, 2 Hip, Musculoskeletal, Turnout

Key Points

1. Young ballet dancers exhibit more passive external rotation but lower passive internal rotation than non-dancers.
2. Dancers display better active turnout, potentially due to their strength training, while passive turnout differences are minor.
3. Young dancers show more pronounced right-left differences in hip rotation and turnout than non-dancers.

Introduction

Turnout, or external rotation of the lower limbs, is an integral part of classical ballet technique.[1,2] Both passive range of motion (ROM) and strength are important components of turnout, making them vital elements in professional ballet training. In addition to enhancing flexibility, range of motion, and crucial aesthetic quality in classical ballet, turnout also contributes to improved strength, stability, and overall body alignment.[3]

Turnout refers to the general outward rotation of the hips and lower extremities, while hip external rotation specifically addresses the rotational movement occurring within the hip joint.[4] Both concepts are interconnected, with hip external rotation contributing to the overall turnout position in dance; according to the International Association of Dance Medicine and Science, on average, 60 percent of turnout comes from the hip.[5]

Understanding turnout involves considering passive ROM and strength of the muscles engaged in external rotation of the hip (six deep external rotators, along with some fibers of the gluteus and adductor magnus). Additionally, it requires evaluating contributions from lower limb structures categorized into hip external rotation (HER) and non-hip contributions to turnout (NHCTO).[2] While passive hip external rotation refers to the rotation of the hip joint achieved without active involvement or muscular contraction by the individual, total passive turnout (TPT) is the cumulative result of the individual contributions of passive ROM from the hip, knee, tibial torsion, ankle, and foot. On the other hand, total active turnout (TAT) represents the amount of turnout the dancer could ideally use by engaging all passive bone and joint contributions along with muscular contraction of the hip external rotators.[4] Notably, total passive turnout (TPT) is typically larger than total active turnout (TAT).[4]

Various studies advocate that the knee joint, tibial torsion, the foot, and the ankle may contribute to natural non-hip components of turnout.[4,6-8] However, when a dancer attempts to achieve a greater turnout than their natural range allows, compensatory movements occur at other anatomical sites, not just the hip joint. These compensations can potentially increase the risk of acute and chronic injuries, particularly affecting the tibiofemoral and patellofemoral joints.[9] It is important to consider these compensatory movements and their impact on the dancer's overall movement patterns and injury susceptibility. Compensatory strategies can often lead to imbalances and increased strain on specific muscle groups or joints. Over time, these imbalances may not only compromise the dancer's technical performance but also significantly raise the risk of acute injuries and contribute to the development of chronic musculoskeletal issues.[9]

Apart from the appropriate skeletal structure and flexible connective tissue, hip external rotation demands sufficient hip external rotator muscle strength.[10,11] Factors that restrict optimal turnout are not only skeletal, ligamentous, and muscular flexibility factors. Dance science literature commonly recognizes that proper neural activation patterns, muscular strength, and muscular endurance, will assist in reaching optimal individual turnout.[12-14]

Most of the studies conducted on ballet hip range of motion and strength have compared dancers to non-dancers and have primarily focused on late adolescents[9] aged 16-18 and adults[15,16] aged 17-24. However, there is a lack of data specifically regarding children in ballet. Some studies, including those by Steinberg et al.[17] and Kadel et al.[18], have explored hip range of motion in children but did not investigate the relationship between hip range of motion and strength. Additionally, participants in Steinberg's study practiced a minimum of 2 hours per week in classical ballet, indicating relatively limited training hours for children.[17] Similarly, participants in the Kadel et al. study practiced ballet at least 4.5 hours per week.[18] However, according to Warren et al.[19], training hours for pre-professional dancers aged 10 to 11 are reported to be 7.3 ± 2.2 hours per week.

In 1999, Bennell et al.[20] conducted a study comparing hip range of motion and strength in ballet students and control subjects with a mean age of 9.6±0.8 years. Surprisingly, the results showed that the dancers had a smaller range of motion in hip external rotation and less strength in hip rotators compared to the control group. One possible explanation could be that dancers practiced ballet only for an average of 2.7 hours per week. However, the study solely focused on active measurements and did not include passive hip external rotation measurements. In addition, it is worth noting that the study assessed turnout, which combines both hip external rotation and non-hip components. Yet, the study did not measure non-hip components like tibial torsion. The researchers calculated non-hip external rotation by subtracting the active external rotation of the right hip from the angle of the right leg's turnout during active standing. In our study, we also investigated tibial torsion and non-hip components of turnout in both ballet dancers and non-dancers. In addition, our study aimed to examine passive and active turnout and hip rotation strength in young girls aged nine to fourteen. We hypothesized that there would be differences in passive and active turnout and hip external rotation strength between ballet dancers and non-dancers. We also investigated tibial torsion and non-hip components of turnout in both ballet dancers and non-dancers.

Methods

Participants

Sixty female pre-professional ballet students, aged 9 to 14 years with a mean age of 11.91±1.49 years, and 31 age- and sex-matched non-dancers participated in the study. The dancers came from two pre-professional ballet schools, while the control group consisted of students from a music school. Pre-professional ballet dancers spent an average of 9.57 ± 2.35 hours per week in ballet training. Additionally, they dedicated an average of 2.08 ± 0.18 hours per week to body conditioning. Table 1 presents the participants' characteristics, and Table 2 outlines the inclusion criteria.

Procedure

School directors were contacted to discuss the purpose of the study and request their collaboration. Once they agreed to participate, we obtained permission for student involvement, ensuring compliance with institutional policies. Subsequent meetings with potential participants were arranged to thoroughly explain the study's details and implications. Parental and participant consent was secured through detailed consent forms. The collaborating entities provided all researchers and instructors with mandatory training prior to their contact with the participants. This training, which is routinely conducted each season, ensured that all personnel were fully equipped with the necessary skills and knowledge regarding ethical research practices and child safety. All researchers successfully completed this training before conducting any measurements or interacting with the students. Testing occurred at the school, conducted by the principal investigator. Ethical approval was received from the Research Ethics Committee of XXX School of Education and Sport Sciences (No. 1819009D). Following the measurement of height and weight, each participant completed a standardized 5-minute warm-up focused on the hip area, prior to their screening. This warm-up was meticulously designed and supervised by the researchers to ensure that both dancers and controls consistently performed identical exercises. The principal investigator conducted the measurements of both limbs, starting with the right limb for passive range of motion, with the right leg for hip internal rotation strength, and with the left leg for hip external rotation strength, due to apparatus positioning.

Measurement protocol

Passive Hip External Rotation (PHER) - Passive Hip Internal Rotation (PHIR)

PHER and PHIR were measured in a prone position with the hip extended and the knee flexed at 90°. The non-measurement leg remained extended and relaxed, hip-width apart. A belt was positioned on the posterior aspect of the pelvis, placed two centimeters below the line that crosses the anterior superior iliac spine (ASIS) to maintain neutral pelvis position. The EasyAngle Digital Goniometer (Meloq AB, Stockholm, Sweden) was used, with ±1° sensor accuracy within 180°. Excellent validity and inter-rater reliability of the EasyAngle have been confirmed.[21] The EasyAngle was aligned along the tibial tubercle and midpoint between the medial and lateral malleoli. External and internal rotations were performed until the end range of the hip joint capsule. Measurements were conducted on the right leg first, followed by the left leg. Three measurements were taken for each leg, and the average score was calculated for analysis.

Tibial torsion (TT)

Tibial torsion of the right (TTr) and left (TTl) lower limbs were assessed using the "thigh-foot angle" method[22] with the same digital goniometer. Participants assumed a prone position with knees flexed at a 90° angle off the table (Figure 1). The digital goniometer measured the angle between the bisector of the heel and the femur axis. One goniometer arm aligned with the second metatarsal shaft, while the other aligned with the long axis of the femur toward the ischial tuberosity. Measurements were conducted on the right leg first, with each measurement repeated three times to calculate the leg's average value. In this study, tibial torsion measurement underwent inter-rater reliability testing, where two different evaluators assessed the TTr and TTl of the lower limbs. The evaluators' sequence was randomized to ensure impartiality, with each evaluator testing 50% of the participants first. Once the first examiner had evaluated the TTr and TTl of the participant, the subject had a 5-minute rest period. Following this, the second examiner evaluated the same participant. The inter-rater reliability analysis revealed a high level of agreement (TTr ICC = .991; 95% CI = .975 - .997; TTl ICC = .931; 95% CI = .795 - .977) between the evaluators. The coefficient of variation for these measurements was 17% for TTr and 15% for TTl. These tests were necessary due to the absence of prior reliability measures for this specific measurement.

Total passive turnout (TPT)

The TPT (total passive turnout) value was calculated by summing the values obtained from passive hip external rotation (PHER) and tibial torsion turnout (TT) measurements.[8] During TPT testing, it was important to maintain the foot in subtalar neutral to prevent any extra degrees of turnout caused by forefoot abduction.[6] Subtalar neutral refers to a specific foot position where there is no pronation or supination, ensuring alignment of the metatarsal heads and calcaneus in the same plane.[23] This precaution was taken because there is no established gold standard for measuring out-toeing with dorsiflexion in dancers. Therefore, foot joint angles were not considered in the calculation of the TPT.[8]

Total active turnout (TAT)

Two measures were used to evaluate total active turnout (TAT). Static active turnout (SAT) was measured using a floor paper measure and dynamic active turnout (DAT) using Functional Footprints®.

Static Active Turnout (SAT)

To measure SAT (static active turnout) participants were instructed to stand in their best first position on a large sheet of paper to measure turnout (Figure 2 left). The midpoint of the posterior calcaneus and the second metatarsal were marked on the paper, and the angle was measured using the digital goniometer. Turnout measurements were taken three times for each leg, and the average for each leg (both right and left) was calculated. For the overall Static Active Turnout (SAT), the averages of both legs were then summed to determine the final overall value.

Dynamic Active Turnout (DAT)

To measure DAT (dynamic active turnout) participants were instructed to stand on Functional Footprints© (Balanced Body, Sacramento, CA) rotational discs and perform turnout. Participants were instructed to stand barefoot, aligning the second metatarsal of each foot with the center line on the discs and ensuring the center of the heel was appropriately placed. Starting in a parallel position, participants smoothly and slowly moved into their maximum turnout from the hip, holding the position for five seconds. Initially, they could use a barre for balance, but as they gained stability, they performed the movement without holding the barre (Figure 2 right). The Functional Footprints® discs had marked rays from 0° to 90° in 10° intervals. Turnout measurements for both legs were taken simultaneously as the participants stood in first position, with each leg turned out. This procedure was repeated three times, and the average turnout for each leg was subsequently calculated based on these measurements. For the overall static active turnout (SAT), the averages of both legs were then summed to determine the final overall value. Participants were instructed to follow qualitative criteria for proper turnout, focusing on knee alignment, weight distribution, and lower limb rotation, according to Gilbert et al.[24] The tester observed these criteria during the measurements. Cuing was standardized across all participants, though the potential unfamiliarity of non-dancer controls with ballet-specific positions is recognized as a study limitation.

Hip external rotator strength (HERS) - Hip internal rotator strength (HIRS)

Isometric HERS and HIRS were assessed using a strain gauge (Chronojump Boscosystem, Barcelona, Spain) and its software (Chronojump v. 2.2.1, Barcelona, Spain). The reliability of the device was tested in a previous study;[25] Courel-Ibánez et al.[25] found that the device's intra-session reliability for assessing maximal voluntary contraction force (MVC) was very high (ICC= 0.89-0.97), and the test-retest reliability was also very high (ICC: 0.94-0.95). Participants lay prone on a table with the tested hip extended and the knee flexed at a 90° angle. A belt was used to maintain a neutral pelvis, and a strap connected to a chain on the wall barre was placed on the mid-calf muscle (Figure 3). The strap length was adjusted for each participant's comfort and consistency. To familiarize themselves with the movement, participants performed a trial with minimal force. They were then instructed to exert maximum effort, receiving strong verbal encouragement. Visual feedback of the strength curve was provided only during the first attempt to help participants understand the apparatus and their actual strength output. Participants exerted their maximum force until the force started to decline (approximately 4-5 seconds), followed by a rest period of 30 seconds to allow for muscle recovery. Three trials were performed, and the highest value was recorded in the Chronojump software and used for the analysis. This process was repeated with the opposite leg, with a rest period of one minute between legs. After testing, participants performed a cool-down using the same protocol as the warm-up.

Statistical analyses

Descriptive statistics were obtained for all variables. The variables of interest including PHER, PHIR, TT, TPT, SAT, DAT HERS and HIRS for both the right and left legs, were analyzed and compared between the two study groups. Additionally, potential differences between each leg were examined for all variables within each group. The Kolmogorov-Smirnov and Shapiro-Wilk normality tests were used to check the normality of the data. As the data were normally distributed, we based our analysis on parametric tests. The mean and standard deviation were used for quantitative variables. For qualitative variables, frequency and % were used. Student t-tests were conducted to compare group characteristics. Pearson's correlation analyzed the relationship between quantitative variables. To assess group differences in the variables of interest, we employed an analysis of covariance (ANCOVA), with age and body weight as covariates, and applied the Bonferroni correction for multiple comparisons. The critical values for statistical significance were assumed at an alpha level <0.05. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) v25.0 (IBM SPSS Statistics, Chicago, IL, USA).

Results

Ballet dancers had higher PHER values compared to non-dancers, but lower PHIR values (Table 3). There were no significant differences in TT between dancers and non-dancers (Table 2). TPT was higher but not significant in ballet dancers (Table 3) and they also achieved higher scores in both SAT and DAT (Table 4). Initially, there were no significant differences in HERS and HIRS (Table 5) between ballet dancers and non-dancers. However, after adjusting for age and weight, significant differences were found in HERS for both legs, as reflected in the p-values presented in Table 5. Ballet dancers showed more pronounced differences between the right and left sides in TT, TPT, and SAT compared to the control group (Table 6).

Discussion

The current study highlights notable differences in hip mobility and muscle strength between young ballet dancers and non-dancers, accompanied by evident asymmetries between limbs.

Passive Hip External Rotation (PHER) - Passive Hip Internal Rotation (PHIR)

The findings demonstrate significant differences in hip rotation between ballet dancers and non-dancers, with dancers exhibiting greater PHER and lower PHIR compared to non-dancers. These results align with previous studies that have investigated hip rotation in dancers. Gupta et al.[15] found that dancers had significantly greater hip external rotation range of motion (ROM) but reduced hip internal rotation ROM. However, the age of the participants was 17-24. Similarly, Sutton et al.[16] observed greater supine turnout in dancers compared to non-dancers, indicating increased external rotation. The emphasis on external rotation in ballet training, coupled with the lack of emphasis on internal rotation, likely contributes to the observed differences. Ballet technique and choreography require extensive external rotation, which promotes flexibility and range of motion in that direction.

Additionally, Kadel et al.[18] found that dancers exhibited significantly greater PHER compared to non-dancers, but there was no significant difference in PHIR. In a study by Khan et al.,[11] dancers demonstrated increased passive hip external rotation compared to non-dancers, but less internal hip rotation. However, it is important to note that Khan et al.[11] measured PHER in the supine position and included both females and males within a different age range (16-18 years) compared to our investigation. Another study conducted by Sutton et al.[16] explored hip passive range of motion in a mixed-age group of dancers and non-dancers, focusing on supine turnout. Their findings demonstrated greater supine turnout in dancers compared to non-dancers, which is consistent with our results. However, it should be noted that our study focused exclusively on female participants aged 9-14 and assessed hip rotation in the prone position. According to Steinberg et al.,[17] the range of motion (ROM) measurements for external rotation in dancers and non-dancers were generally similar across most age groups, with only a few exceptions. The similarity in ROM measurements between dancers and non-dancers observed by Steinberg et al. may be attributed to their study's inclusion of non-pre-professional participants. In contrast, our study involved pre-professional dancers who are exposed to a higher level of training intensity and frequency. This difference in training background may account for any variations in ROM capabilities observed between our studies.

Tibial torsion (TT)

In our study, TT differences between ballet dancers and non-dancers were not statistically significant (Table 3). The reason may be that the ballet dancers were too young to show an adaptation in tibial torsion, and therefore, there was no significant difference between them. To our knowledge, there is no study comparing TT in dancers and non-dancers. However, normative data for TT in the general population, ranging from 10° to 42°, is available in the existing literature.[6] Studies[4,8,26,27] focusing specifically on dancers have reported average values between 10° and 36°. Grossman et al.[8] measured tibial torsion in dancers and found significant variation both between subjects and between legs within the same subject. The range of tibial torsion measurements in the right leg ranged from 16° to 60°, while in the left leg, it ranged from 16° to 52°. These measurements were obtained using Magnetic Resonance Imaging (MRI) and may, for this reason, have had different and greater values than in this study.

In comparison to the study by Sherman et al.,[28] which primarily focused on measuring TT in dancers, the present study found higher TT values in both ballet dancers and non-dancers, using the same thigh-foot angle method as employed by Sherman et al.[28] Variations in sample characteristics, such as age, could potentially contribute to these differences. To ensure measurement reliability, inter-reliability tests were conducted, acknowledging the inherent difficulty of this measurement technique. As opposed to the Sherman et al.[28] study, our research included a control group, allowing for a valuable comparison of our findings. However, the standard deviation in our study was 6.3, whereas in their study,[28] it was 3.84, indicating a difference in the variability of the data between the two studies. In addition, TT is a complex parameter influenced by various factors such as skeletal anatomy and genetic predisposition. While our findings did not reveal significant differences, it is possible that variables not assessed in this study, such as training load and techniques, could contribute to individual variations in TT within the dancer population. However, accurately capturing the complete range of training loads and specific instructional methods is challenging due to the inevitable discrete differences in training approaches and techniques among teachers.

Total passive turnout (TPT)

The observed differences in TPT values between the dance and control groups were not statistically significant (Table 3). This can be attributed to the combination of the dancers' higher PHER and the subtle but not significant differences in TT. These findings emphasize the importance of considering multiple anatomical factors when assessing turnout capabilities in dancers and non-dancers alike. In addition, Grossman et al.[8] reported a mean TPT of 83.50° (SD = 1.63) for the right leg and 81.92 (SD

= 8.64) for the left leg which is higher than our values (see Table 3). The significant differences may be attributed to the inclusion of college-aged students in their study, and the fact that TT was assessed using MRI in their research.

Total active turnout (TAT)

Ballet dancers demonstrated superior performance in both the SAT and DAT categories, with SAT scores being slightly higher than DAT scores (Table 4). This suggests that ballet dancers were particularly skilled in maintaining their turnout in a stationary position. The greater emphasis on SAT performance can be attributed to the fundamental importance of turnout in ballet technique. Ballet dancers are expected to showcase a strong and controlled turnout while standing still, as it forms the foundation for various movements and positions in classical ballet, and this specific measurement closely aligns with their daily in-class turnout practice.[28]

While ballet dancers also performed well in the DAT category, the slight difference in scores indicates that they may have faced additional challenges in maintaining turnout during dynamic movements. DAT requires the dancers to execute complex balletic sequences, involving jumps, turns, and rapid changes in direction, all while maintaining a consistent and controlled turnout.[15] These movements demand not only strong muscular engagement but also the ability to adapt and adjust turnout dynamically in response to the demands of the choreography. In addition, SAT performance may show higher values than DAT due to non-hip components of turnout in static positions and the influence of friction.[9]

Comparing our findings to another study,[11] which included participants aged 16-18 years of both sexes, we observed a similar trend of dancers demonstrating higher levels of DAT compared to non-dancers. However, these variations in age and sexes highlight the importance of considering different demographics when interpreting the results. Nonetheless, both studies support the notion that dancers tend to exhibit higher levels of DAT than non-dancers. The ability to maintain turnout during dynamic movements may be due to training and experience. Additionally, Sutton et al.[16] showed that dancers achieved greater DAT compared to non-dancers, although the difference was not statistically significant. These results imply that while SAT may be a prominent feature of dancers, DAT requires additional skills and adaptability. In Sutton et al.[16] study, dancers achieved an average of 107° of dynamic active turnout, while non-dancers achieved 92°. Dancers exhibited a standard deviation of 18°, while non-dancers had a standard deviation of 28°, indicating individual variations within each group. However, in our study, both ballet dancers and non-dancers groups achieved higher scores than the Sutton et al.[16] study with less standard deviation (see Table 4).

Dancers' superior performance in turnout can be attributed not only to their technical training but also to their refined proprioceptive abilities. The combination of technical skill, physical strength, and heightened proprioception allows dancers to achieve and sustain a greater degree of turnout, both in static and dynamic contexts.[29] The control group in our study had no prior experience with the first position of ballet, which may have affected their ability to perform the turnout movement accurately. Additionally, it is important to note that executing turnout in static and dynamic conditions may involve different neuromotor patterns, including variations in muscle synergies and the recruitment of different muscle groups.[8,12]

Hip external rotator strength (HERS) - Hip internal rotator strength (HIRS)

HERS initially showed higher values in non-dancers for both legs (Table 5). Nevertheless, subsequent adjustments for age and weight revealed significantly higher values in ballet dancers for both legs, as reflected in the p-values presented in Table 5. This suggests that the specific demands of ballet training, particularly the focus on external rotation, may contribute to enhanced hip external rotation strength in ballet dancers. Our results align with Sutton et al.[16] and Gupta et al.,[15] who also reported greater HERS in dancers compared to non-dancers. However, there are differences with the study conducted by Bennell et al.,[20] which reported weaker HERS in novice ballet dancers compared to non-dancers. These differences may be attributed to variations in training duration and experience, as this study included participants with an average of only 2.7 hours of ballet training.[20] The contrasting results suggest that the development of HERS may differ depending on the level of dance experience. However, there is currently no published literature available on the relationship between the level of dance experience and hip rotator muscle strength.

Moreover, the study by Bennell et al.[20] found that non-dancers exhibited stronger HIRS compared to ballet dancers. In our study, HIRS also displayed higher values in non-dancers. However, after adjusting for age and weight, higher values were observed in ballet dancers, although the difference was not statistically significant. This suggests that the specific demands of ballet training, especially the focus on external rotation, may not necessarily result in proportional gains in hip internal rotation strength. The lack of statistical significance in the difference between dancers and non-dancers could be attributed to the utilization of different muscle groups and movement patterns.

Discrepancies Between Right and Left Sides

According to Gorwa et al.[30] and Kimmerle,[31] classical ballet expects dancers to perform techniques symmetrically, but achieving perfect symmetry is more complex than anticipated. Gorwa et al.'s study reveals significant differences in hip external rotation between the left and right lower extremities, challenging the ideal of perfect symmetry in ballet. Moreover, asymmetry in strength is common in ballet despite the assumption of symmetrical strength, as noted by Kimmerle.[31] Trained dancers often display asymmetrical body structures and techniques, indicating preferences for certain skills on one side.[30-32] However, according to Kimmerle, determining the 'dominant' side can be complex, as preferences can vary based on the specific action undertaken, necessitating an evaluation of the action type. An important observation in dance is that a preference for using one side does not automatically imply greater skill on that side.

Similarly, our study also revealed that dancers exhibited significant differences between the right and left sides compared to the control group (Table 6). These findings highlight the asymmetrical characteristics observed in recent studies by Gorwa et al. (2023) and McMahon et al. (2021) in ballet dancers. One possible explanation for this asymmetry is that while dancers may possess greater turnout strength in the right hip during static positions, they tend to compensate and rely on non-hip components of turnout below the hip, leading to increased demands on the left side. In contrast, although the control group also showed differences between the right and left sides in some measurements, these differences were not as substantial. This emphasizes the unique challenges faced by dancers in developing and managing asymmetrical capabilities for optimal performance.

Gupta et al.[15] also found that dancers and non-dancers have significantly greater right HERS compared to the left, and this asymmetry is more pronounced in dancers. This asymmetry may be attributed to dancers favoring one side during training or performance due to limb preference.[32] Nevertheless, Kimmerlee[31] challenges the notion of a single 'preferred' leg, raising important questions about which skills are prioritized: Should it be the support leg, emphasizing strength and balance, or the gesture leg, which focuses on range of motion? This emphasizes the necessity of integrating both legs' functions rather than isolating one, emphasizing a holistic approach to understanding bodily asymmetries in dance.[31] Such preferential side-dominance in dance-specific poses and postures can lead to individual side-to-side differences, altering biomechanics, force transfer in the kinetic chain, muscle imbalances, and potentially increasing the risk of injury.[31] These findings highlight the importance of addressing and managing these asymmetries to minimize the risk of injuries in dancers.

Limitations

Variability in teaching methods and techniques among ballet schools and the timing of assessments could influence observed turnout differences in dancers. Hip rotator strength was measured in a prone position, which may differ from dance positions involving knee extension and flexion. Furthermore, limitations such as potential inconsistencies in language cues, the influence of puberty on the data, and the unfamiliarity of non-dancers with the position tested in two measurements should be acknowledged.

Practical and Clinical Applications and Implications

1. Evaluating and Enhancing Progress: Developing turnout measurement norms for both ballet dancers and non-dancers provides crucial reference points for evaluating dancers' abilities. Normative data are also particularly valuable for monitoring progress among young dancers. Given the potential negative effects on this impressionable group, it is crucial to apply these norms carefully. These measures should be integrated into a broader developmental

framework that supports individual growth and psychological well-being, ensuring they enhance training effectiveness without promoting negative behaviors or competition.

2. Training Planning: In optimizing training, the incorporation of age-specific turnout standards based on normative data is crucial. Dance educators could utilize regular assessments, integrating hip range of motion (ROM) and strength measurements, to tailor individualized training plans. Emphasizing periodic reassessments ensures ongoing customization of routines, accommodating evolving musculoskeletal needs over time.
3. Injury Prevention: For effective injury prevention, comprehensive screening protocols during early ballet training stages are recommended, including hip ROM and strength assessments. Dance educators should prioritize implementing strengthening and stretching conditioning exercises to address the balance between the hip external and internal rotators in both limbs. This approach aims to prevent significant imbalances not only between the limbs but also between external and internal rotation. Additionally, teachers should consider starting ballet class exercises not always with the right limb, but alternating between both the right and left legs. This approach can also promote balance and symmetry in the development of overall movement proficiency. Consistent monitoring of right-left side differences throughout training allows for ongoing adaptation of injury prevention strategies, ensuring the sustained well-being of dancers. This approach could generate a field of collaboration and dialogue between the dance teacher and the physical therapist.

Conclusions

Pre-professional ballet dancers exhibit distinct hip mobility and strength characteristics compared to non-dancers of the same age. They possess a higher degree of passive external rotation and a lower degree of passive internal rotation. Additionally, ballet dancers demonstrate increased active hip rotation, greater strength in external rotator muscles, and reduced strength in internal rotator muscles. Notably, there is a greater asymmetry between limbs in terms of both strength levels and dynamic rotation, with a clear dominance of the right limb.

Understanding and managing these parameters is crucial for optimal physical development, considering the significant functional relationship of the hip joint in turnout and its influence on other lower limb joints. Proactively addressing imbalances and preventing substantial asymmetries in mobility and strength between limbs serves as a proactive measure against potential musculoskeletal problems in the future. Dance instructors can assess young dancers from their initial stages of training and maintain consistent assessment practices throughout their training. This would serve as a comprehensive tool for evaluation, control, and prevention, actively contributing to the promotion of balanced musculoskeletal development and overall well-being among pre-professional ballet dancers. These systematic assessments are crucial as they help detect early signs of potential overuse injuries or incorrect techniques that could lead to long-term issues, ensuring that interventions can be timely and appropriate to support a dancer's career longevity and health.

Future research should involve a longitudinal study to monitor ballet dancers throughout their pre-professional years, aiming to comprehend the progression of musculoskeletal changes, particularly in hip mobility and strength. Additionally, studying the correlations identified during this pre-professional stage could offer findings that inform injury prevention strategies, providing valuable guidance for optimizing training methods and ensuring the well-being of ballet dancers.

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Tables

Table 1. Participants' Characteristics

	Group			
	Non-dancers (n=31)		Dancers (n=60)	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (years)	13.19	1.10	11.70	1.56
Weight (kg)	46.2	8.5	38.8	9.0
Height (cm)	1.58	.09	1.50	.10
Ballet h/week	.	.	9.57	2.35
Body conditioning h/week	.	.	2.08	.18

Table 2. Participants' Inclusion Criteria

	Inclusion criteria	Exclusion criteria
Experimental group	• female • 9-14 age • minimum of 6h/w ballet class	• current lower extremity injury • limit participation in ballet class 4 week prior to testing
Control group	• female • 9-14 age • less than 2 h/w of sporting activities • less than 3 months of balletic or gymnastic training	• current lower extremity injury

Table 3. Passive Measurements (in degrees)

	Dancers (N=60)		Non-dancers (N=31)		*p*-value
	Mean	SD	Mean	SD	

PHER R	50.32	7.21	46.06	6.82	.008*
PHER L	49.23	6.77	45.75	7.66	.028*
PHIR R	43.61	10.16	48.03	10.62	.056*
PHER L	42.53	10.37	47.63	9.06	.023*
TT R	17.32	6.3	16.18	6.37	.416
TT L	20.3	6.08	20.31	6.29	.993
TPT R	65.48	11.07	62.31	10.28	.188
TPT L	68.19	10.00	66.06	10.79	.351

PHER, passive hip external rotation; PHIR, passive hip internal rotation; TT, Tibial torsion; TPT, total passive turnout; R, right; L, left

Table 4. Total active turnout (in degrees)

	Dancers (N=60)		Non-dancers (N=31)		*p*-value
	Mean	SD	Mean	SD	
SAT overall	117.04	16.66	107.53	14.21	.022*
DAT overall	116.94	15.18	105.91	14.67	.002*

*Significant difference from controls is indicated: *p<0.05

SA, static active turnout; DAT, dynamic active turnout

Table 5. Hip rotator strength (in newtons) adjusted for weight and age

	Dancers (n=60)		Non-dancers (n=31)		*p*-value
	Mean	SD	Mean	SD	
HERS R	91.37	25.70	95.92	28.14	.003*
HERS L	85.99	27.73	90	26.33	.000*
HIRS R	76.66	22.58	83.57	23,01	.057
HIRS L	77,15	24.74	87,60	24.07	.203

*Significant difference from controls is indicated: *p<0.05

HERS, hip external rotation strength, in Newtons; HIRS, hip internal rotation strength, in Newtons; R, right; L, left

Table 6. Difference between right and left Leg (in degrees)

	Dancers (N=60)	*p-value*	Non-dancers (N=31)	*p*-value

	Mean	SD		Mean	SD	
PHER r-l	0.77	6.19	.338	0.37	3.93	.598
PHIR r-l	0.90	5.98	.249	0.39	5.49	.690
TT r-l	-3.48	5.28	.000*	-4.12	4.99	.000*
SAT r-l	-3.37	6.08	.000*	-4.41	9.58	.015*
DAT r-l	2.61	7.13	.006*	0.98	6.54	.407
HERS r-l	5.38	17.85	.023*	5.92	18.11	.079
HIRS r-l	-0.49	15.28	.803*	-4.02	20.44	.281
TPT r-l	-2.71	7.44	.007*	-3.75	5.73	0.001*

The difference between the means (right-left) is shown; Negative values indicate that left is greater than the right; *Right significantly greater than left (p(0.05)

PHER¸ passive hip external rotation; PHIR, passive hip internal rotation; TT, tibial torsion; SAT, static active turnout; DAT, dynamic active turnout; HERS, hip external rotator strength; HIRS, hip internal rotator strength; TPT, total passive turnout; r, right; l, left

Figure Legends

Figure 1. Tibial torsion measurement.

Figure 2. SAT and DAT measurements. SAT, static active turnout; DAT, dynamic active turnout

Figure 3. PHER measurements. PHER¸ passive hip external rotation

Note. Copyright 2023

Figure 1. Tibial torsion measurement.

90x62mm (600 x 600 DPI)

Note. Copyright 2023

Figure 2. SAT and DAT measurements. SAT, static active turnout; DAT, dynamic active turnout

90x62mm (600 x 600 DPI)

Figure 3. HERS measurements. HERS, hip external rotation strength

90x123mm (600 x 600 DPI)