Performance of young female ballet dancers' dominant and non-dominant lower limbs during hop and Y-balance testing

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Summary

Introduction: Ballet requires coordination and integration of movement, proper body alignment, cardiovascular and muscular endurance, muscular strength, flexibility, static and dynamic balance. Epidemiological studies indicate that most injuries that affect ballet dancers are related to the lower limb, especially the ankle, foot, knee, and hip due to the implications of these joints in specific movements. These injuries can result in significant lost time in rehearsals, high costs, and may cause long-term dysfunction. In this context, preventive strategies should be considered to decrease the risk of injury, and to provide insight to help to create prevention programs or rehab plans. For this are widely used the functional tests.
Objective: This study investigated the functional performance of lower limbs in young ballet dancers.
Material and method: Thirteen healthy female ballet dancers between 14 and 17 years who participated in dance Regional Festivals performed the Y-balance test (YBT) and four hop tests (single, triple, crossover, and timed hop tests). For both hop tests and YBT, ballet dancers completed three trials in each lower limb and the average of the three values was used to calculate the symmetry index between the limbs.
Results: There were no differences between the limbs in hop tests or YBT. However, it was observed the composite score of the YBT was below 94%, an average value lower than suggested by the literature.
Conclusions: Thus, the results demonstrated that young female ballet dancers have symmetry between the limbs in both functional tests, suggesting that dance training leads to greater skill in controlling the neuromusculoskeletal coordination between the limbs. However, they have a poor dynamic balance suggesting an increased risk of lower limb injuries. This research can contribute to the development of preventive programs and improve ballet dancers' performance and productivity.

Key words:
Ballet. Young female dancers. *Hop tests. Y-balance test.*

Rendimiento de las extremidades inferiores dominantes y no dominantes de jóvenes bailarinas de ballet durante *hop test* y *Y-balance testing*

Resumen

Introducción: El ballet requiere coordinación e integración del movimiento, alineamiento corporal adecuado, resistencia cardiovascular y muscular, fuerza muscular, flexibilidad, equilibrio estático y dinámico. Los estudios epidemiológicos indican que la mayoría de las lesiones que afectan a los bailarines están relacionadas con el miembro inferior, especialmente el tobillo, el pie, la rodilla y la cadera, debido a las implicaciones de estas articulaciones en movimientos específicos. Estas lesiones pueden resultar en una pérdida significativa de tiempo en los ensayos, altos costos y pueden causar disfunción a largo plazo. En este contexto, se deben considerar estrategias preventivas para disminuir el riesgo de lesiones y para proporcionar información que ayude a un proveedor a crear programas de prevención o planes de rehabilitación. Para eso las pruebas funcionales son muy utilizadas.
Objetivo: Este estudio investigó el rendimiento funcional de las extremidades inferiores en jóvenes bailarines de ballet.
Material y método: Trece bailarinas sanas de ballet entre 14 y 17 años que participaron en presentaciones regionales realizaron lo *Y-balance test* (YBT) y cuatro *hop tests* (single, triple, *crossover,* y *timed hop tests*). Tanto para las pruebas de salto como para YBT, las bailarinas completaron tres pruebas en cada miembro inferior y se utilizó el promedio de los tres valores para calcular el índice de simetría entre los miembros.
Resultados: No hubo diferencias entre las extremidades en los *hop tests* y YBT. Sin embargo, se observó un puntaje compuesto del YBT por debajo del 94%, valor promedio inferior al sugerido por la literatura.
Conclusiones: Así, los resultados demostraron que las jóvenes bailarinas de *ballet* tienen simetría entre las extremidades en ambas pruebas funcionales, lo que sugiere que el entrenamiento en danza conduce a una mayor habilidad en el control de la coordinación neuromusculoesquelética entre las extremidades. Sin embargo, tienen un equilibrio dinámico deficiente, lo que sugiere un mayor riesgo de lesiones en las extremidades inferiores. Esta investigación puede contribuir al desarrollo de programas preventivos y mejorar el rendimiento y la productividad de los bailarines de ballet.

Palabras clave:
Ballet. Jóvenes bailarinas. *Hop tests. Y-balance test.*

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Introduction

Ballet dance requires coordination and integration of movement, proper body alignment, cardiovascular and muscular endurance, muscular strength, flexibility, static and dynamic balance. These neuromuscular skills are essential for dancers to obtain a perfect and technically precise performance of functional movements important in ballet that requires grace and delicacy[1]. The ballet has been characterized as an intermittent type of exercise, in which lower limb explosive bursts such as jumps, and turns are followed by movements requiring precision and skill with adequate interaction of upper and lower limb movements[2]. Ballet dancers usually have complex and physically demanding routines with long training periods that may lead to physical exhaustion[3].

Epidemiological studies indicate that most injuries that affect ballet dancers are related to the lower limb[4,5]. The most injured areas are the ankle, foot, knee, and hip due to the implications of these joints in specific movements[3]. The main triggering factors of injuries usually are micro-trauma repetition and muscle fatigue caused by overtraining[6]. Also, ballet dancers present incidence values around 1.09 injuries/1000 hours of exposure. Furthermore, there is a positive correlation between injury risk and age, and it was shown that ballet dancers at ten years have an injury incidence of 0.3 injuries/1000 hours; dancers 11 to 14 years have 0.7 injuries/1000 hours, while ages 15 to 21 years have 0.9 injuries/1000 hours[7]. Musculoskeletal injuries can result in significant lost time in rehearsals, high costs, and may cause long-term dysfunction[6]. In this context, preventive strategies should be considered to decrease the risk of injury, and to provide insight to help a provider create preventable programs or rehabilitation plans the functional tests are widely used[8].

Functional tests are used to assess joint stability, balance, kinesthesia, agility, muscular control, and muscular strength[9,10]. Two types of functional tests, including the Y-balance test (YBT) and hop tests, are the most often used to assess the lower limbs function[10]. Hop tests are used to evaluate dynamic stability, lower limb strength, and neuromuscular control in preseason or pre-competition and during a rehabilitation session to track progress with an intervention[11]. The YBT is used to verify the lower limb dynamic balance, identify the risk of injury, evaluate muscle imbalance, and assess rehabilitation progress[12]. Hop tests and YBT have as main advantages: low cost, easy application, not time-consuming, not require a great deal of expertise, not require expensive equipment, and they are considered open field tests that can be performed in several locations[13]. In different sports, the hop tests and the YBT are used as screening tools to identify inter-limb asymmetries that have been associated with an increase in injury risk by several authors[14-17]. Considering that the functional tests are excellent tools to detect the risk of injury and they can help to create programs to improve performance[2], that few studies explore the YBT and the hop tests in ballet dancers; the main purpose of this study was to investigate the lower limbs functional performance of young female ballet dancers.

Material and method

Experimental approach to the problem

This study used a cross-sectional design to assess functional performance in dominant limb (DL) and non-dominant limb (NDL) lower extremities. This study was carried out in three different ballet schools in Garibaldi, Rio Grande do Sul, Brazil. The study was approved (protocol number 3.361.817) by the Ethical Committee at the University of Caxias do Sul. The study was in accordance with the Helsinki Declaration and 2012 Law N° 466 of the National Health Council, which approves the guidelines and rules for research involving humans.

Participants

Thirteen pre-professional young female ballet dancers (mean age 15.0 ± 0.91) who participated in dance Regional Festivals were recruited to participate in this research. The inclusion criteria to be eligible were: if they trained at least two days per week for at least two years and if they signed the Written Informed Consent by themselves and by their parents or legal keepers. The exclusions criteria were: acute illness on the day selected for evaluation, acute musculoskeletal injury, lower limb acute injury in the previous 30 days of assessment, use of medications such as analgesic, anti-inflammatory, and/or antihistaminic 48 hours before testing, and cognitive deficits that could interfere with the Written Informed Consent or study instructions. The anthropometric characteristics of the ballet dancers are summarized in Table 1.

Sample size

The sample size was determined by convenience conforming to the number of ballet dancers and their availability for participation in the research. Therefore, the sample was determined intentionally and not probabilistically[18].

Procedures

Prior to the tests assessments, aiming to assess the general health and wellness variables (e.g., the previous history of musculoskeletal injury, amount of training per week, number of rehearsals per week, number of performances per week/year, years of experience in the dance, leg dominance, and warm-up practices) each participant completed a health history questionnaire.

To define which test (YBT or hop tests) the ballet dancers would execute first, we performed a randomly draw (e.g., if first the ballet dancer

Table 1. Means ± standard deviations of anthropometric characteristics of young female ballet dancers.

Variable	M ± SD
Age (years)	15.0 ± 0.91
Body weight (kg)	52.59 ± 6.80
Height (m)	1.63 ± 0.05
Body mass index (kg/m²)	19.69 ± 2.41

M: Mean; m: meters; kgmm²: kilograms per square meter.

was drawn to execute the hop tests, after the hop test the ballet dancer executed the YBT, or vice-versa). The tests were performed in a specific room of assessment on a single day. The assessments were executed before the regional presentations and the tests were conducted from 2:00 to 5:00 p.m.

Prior to the tests, the ballet dancers received some recommendations such as do not consume stimulant substances (e.g., caffeine) 24 hours before testing, sleep at their usual time the day before testing, do not have any analgesic and/or anti-inflammatory medicine within 48 hours before testing, and do not perform high-intensity physical activities in the 48 hours prior to the tests.

Musculoskeletal injury questionnaire

Intending to verify if the ballet dancers could have some injury that could interfere with the YBT and hop tests performance, the ballet dancers answered a questionnaire containing the following questions: (1) personal data such as name, age, weight, height, and BMI; (2) if the ballet dancers have been submitted to some surgery on lower limbs; (3) if the ballet dancers suffered some injury; (4) type of injury and anatomic region; (5) if the injury was contact injury or noncontact injury; (6) pain intensity after injury; (7) if the ballet dancers did physiotherapy for the injury.

Functional performance tests

To investigate if the ballet dancers could have inter-limb asymmetries, the ballet dancers performed the hop tests that show inter-limb asymmetries relating to muscle power, and the YBT that indicates inter-limb asymmetries corresponding to dynamic balance.

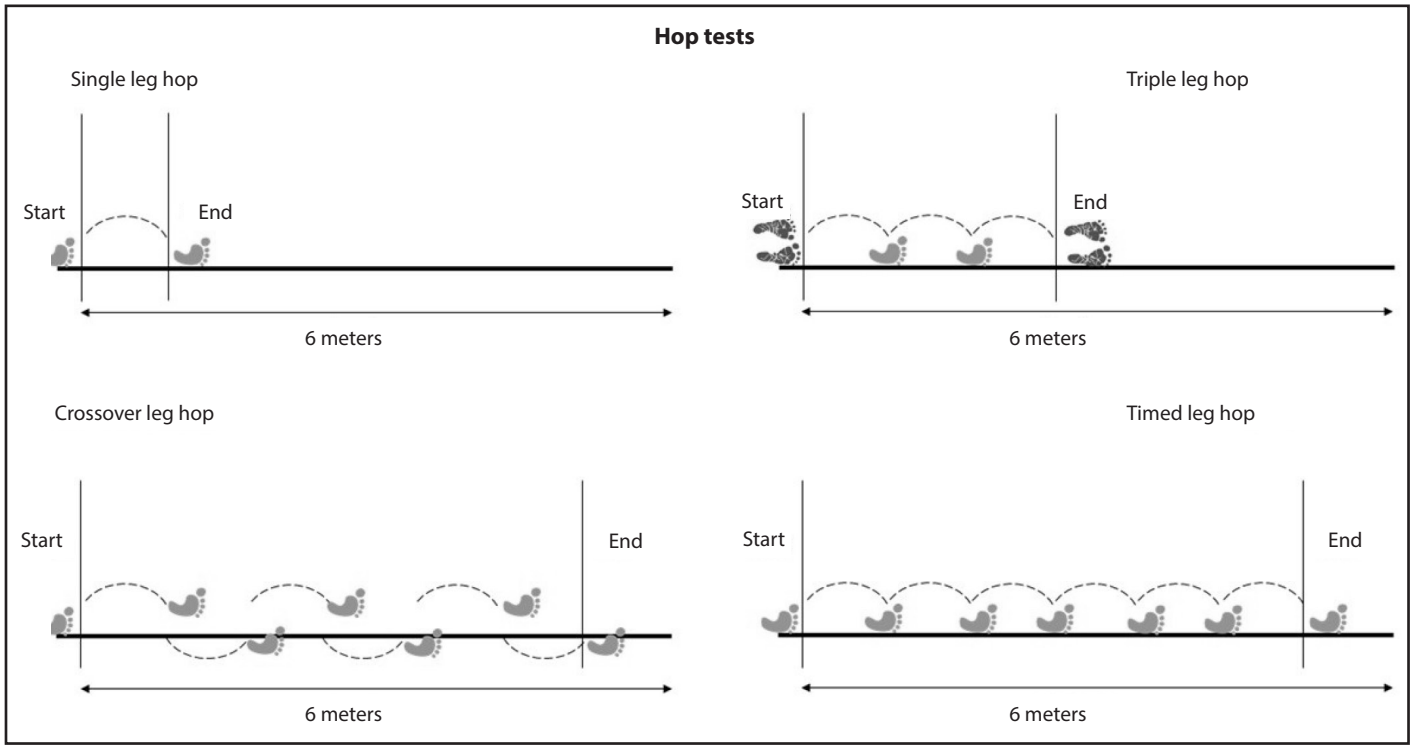
Hop tests. Hop tests are unilateral functional performance tests used to evaluate lower limb power and neuromuscular control in preseason or pre-participation in competition, to monitor progress in rehabilitation, and identify dynamic knee stability[11,19]. Hop tests provide an index of the ratio of limb symmetry known as LSI that expresses the distance or time recorded from the test as a percentage[11,20]. Four hop tests were selected to assess the dancers: single hop for distance, triple hop for distance, crossover hop, and timed hop[21,22].

The tests were executed as described previously by Wiprich *et al.* (2022)[23]. Firstly, the ballet dancers received the instructions about the test and then they performed three practice trials for each hop test in each lower limb. The trials were executed with 30 seconds of resting period between each test to reduce the errors associated with learning and fatigue such as landing with the assistance of the opposite lower extremity, lost imbalance, or took an extra step after landing. If some ballet dancer made an error the hop test was repeated. In all hop tests the dancers performed the tests with the NDL and next with the DL, and the upper limbs were free[23].

Distance (single hop, triple hop, and crossover hop) and time (timed hop) were measured in each one of the three trials. The distance was measured from the toe in the starting position to the heel where the subject landed (Figure 1).

The average of the three values was used to the comparison between NDL and DL and to calculate the hop symmetry index given by the formulas:

Figure 1. The course for the four hop tests.



For the single hop, triple hop, and crossover hop: Hop symmetry index = (NDL hop mean distance / DL hop mean distance) X 100[21,22].

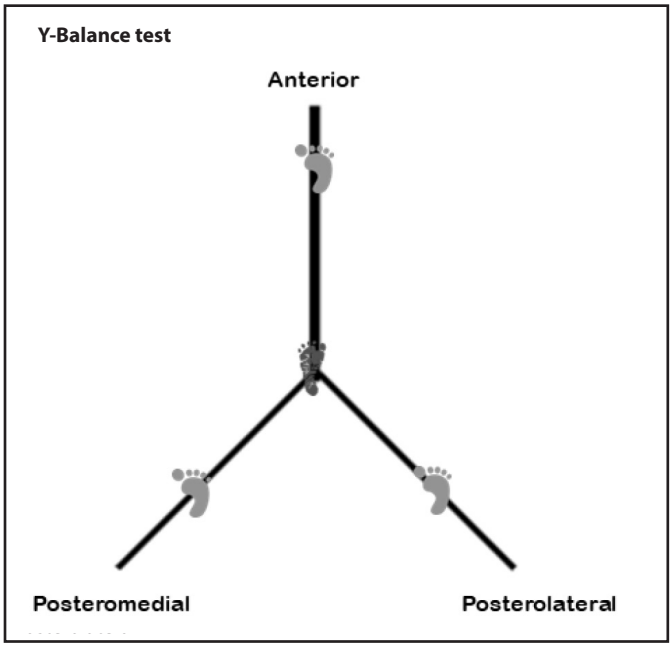
For the timed hop: Hop symmetry index (NDL hop mean time / DL hop mean time) X 100[21,22].

YBT. The test was executed based on Wiprich *et al.* (2022)[23] and Plisky *et al.* (2009)[24]. The ballet dancers received the instructions about the test and subsequently, they performed three warm-ups in each lower limb. Then, they executed the trials. In both warm-ups and trials, three metric tapes were placed on the floor and separated by an angle of 135°. One metric tape was placed in the anterior (ANT) direction, and the two other metric tapes, one in the posterolateral (PL) direction and the other in the posteromedial (PM) direction divided by an angle at 90°[24]. The ballet dancers were positioned centrally to three metric tapes with single-leg support in the lower limb to be tested with the hands-on waist. The dancers stood on one leg on the center foot tape with the most distal aspect of the foot at the starting line. While maintaining a single leg stance, the dancer was asked to reach with the free limb in the ANT, PM, and PL directions in relation to the stance foot[23,24].

Three practice trials were performed in each reach direction before the formal testing. From the fourth to the sixth trial, the examiner recorded the maximal reach distance (centimeters). In both warm-ups and trials, the ballet dancers first executed on the NDL, and next, on the DL, and the hands remained on the waist[23,24]. The maximal reach distance was measured by a tape measure, at the point where the most distal part of the foot reached (Figure 2)[24].

The trial was discarded and repeated if the subject: failed to maintain a unilateral stance, failed to maintain reach foot contact with the reach indicator on the target area while it was in motion, and failed to return the reaching foot to the starting position under control[24].

Figure 2. The directions of Y-Balance test*.



*The figure illustrates that the left foot is being tested in all directions of the YBT.

Three measures were calculated to quantify the dynamic balance: normal reach distance, total performance given by composite score, and limb symmetry index. For each limb, the reach distance was normalized by NDL and expressed as percent (%) (e.g., Normalized distance = distance reached (centimeters) X 100/ lower limb length). The total performance was determined by calculating the composite score, given by the formula:

Composite score = sum of three (ANT, PL, and PM) directions/ 3 X lower limb length) X 100.

For the lower limb length, the dancers were placed lying on a table in the supine position with the lower limbs extended, then the lower limb length was measured from the anterior superior iliac spine to the most distal portion of the medial malleolus with a tape measure[24]. The values used in the formulas were the means of each limb in each of the three directions[24].

To calculate the symmetry index for each direction and the composite score were used the formula:

Symmetry index = (NDL mean distance / DL mean distance) X 100[21,22].

Statistical analysis

Initially, the Shapiro-Wilk test determined whether data were normally distributed. Data from DL and NDL were analyzed by a two-tailed Student's t-test, while data from YBT composite score was evaluated by a one-tailed Student's t-test. All data were recorded as mean ± standard deviation (M ± SD). For all comparisons, the significance level was set at $P<0.05$. Data were analyzed by GraphPad Prism 8.0 (GraphPad, Inc., San Diego, California).

Results

Hop tests. There were no statistically significant differences between the limbs in all hop tests (Table 2). Moreover, the LSI presented a value above 90% in all hop tests (Table 2).

YBT. In YBT, the bilateral comparison did not show statistically significant differences between DL and NDL in all directions (Table 3). Nevertheless, the composite score in both DL and NDL limbs showed values significantly below 94% ($P<0.001$).

Musculoskeletal injury questionnaire. Two (15.3%) of the 13 ballet dancers reported injury (one in the lower limb and the other in the lumbar) the last three months before the tests, while eleven (84.7%) ballet dancers reported no injury (Table 4).

Further, Table 5 shows the overall activity level (amount of training per week, number of rehearsals per week, number of performances per week/year, years of experience in the dance, leg dominance, and warm-up practices) of ballet dancers.

Discussion

The purpose of this study was to investigate if young female ballet dancers could have inter-limbs asymmetries. For this reason, we used the hop tests and YBT which are tests that evaluate the lower limbs functional performance. No significant differences were seen between the DL and NDL in either hop tests (single, triple, crossover, and timed hop tests) or YBT three distances reached (ANT, PL, and PM). Also, the

Table 2. Means ± standard deviations of hop-tests scores in dominant limb and non-dominant limb of young female ballet dancers.

Variable	DL (M ± SD)	NDL (M ± SD)	*P*-value	Bilateral asymmetry (%)/ Symmetry Index ≥ 90%
Single Hop (m)	1.13 ± 0.25	1.09 ± 0.23	0.15	96.41 ± 5.38
Triple Hop (m)	3.08 ± 0.74	3.01 ± 0.72	0.15	97.72 ± 5.89
Crossover Hop (m)	2.58 ± 0.41	2.55 ± 0.49	0.33	98.84 ± 4.04
Timed Hop (s)	3.93 ± 1.01	4.18 ± 1.15	0.21	106.31 ± 14.25

M: Mean; m: meters; DL: Dominant limb; NDL: Non-dominant limb; S: Seconds; SD: Standard deviations.

Table 3. Means ± standard deviations of Y-balance test scores in dominant limb and non-dominant limb of young female ballet dancers.

Variable	DL (M ± SD)	NDL (M ± SD)	*P*-value	Bilateral asymmetry (%)/ Symmetry Index ≥ 90%
Composite score (%)	72.47 ± 9.13	71.74 ± 7.68	0.54	90.99 ± 5.21
Ant (m)	0.64 ± 0.05	0.66 ± 0.09	0.49	103.12 ± 3.44
PM (m)	0.86 ± 0.10	0.83 ± 0.11	0.41	92.52 ± 5.32
PL (m)	0.88 ± 0.14	0.86 ± 0.11	0.57	97.73 ± 5.67

Ant: Anterior; M: Mean; m: meters; DL: Dominant limb; NDL: Non-dominant limb; PL: Posterolateral; PM: Posteromedial; SD: Standard deviations.

Table 4. Musculoskeletal injury of young female ballet dancers.

Variable	%
Previous Injury Lower limb (n=1) Lumbar (n=1)	15.3%
No Previous Injury	87.7%

n: number of dancers.

Table 5. Means ± standard deviations of activity level and injury of young female ballet dancers.

Variable	M ± SD
Years of experience in the dance	10.12 ± 3.94
Leg dominance Right Left	 12 1

M: Mean; SD: standard deviations.

results did not present significant differences between the DL and NDL in the composite score. However, it was seen in the composite score in YBT in both DL and the NDL a mean score lower than the normal score (94%) suggested in the literature[24].

In ballet, the dancers use one leg as the gesture leg, while the other leg as the supporting leg. Besides, they perform tasks more complex requiring solicitation of the two sides of the body alternately on jump behaviors which is the major contributing factor to develop inter-limbs asymmetries[25,26]. Therefore, the understanding of lower limb asymmetries in artistic modalities that demands a high performance is essential to identifying the functional and muscular imbalance, and consequently is a tool that can help to create strategies to prevent injuries, since larger asymmetry scores inter-limbs could induce decreased in physical performance compromising the task technical efficiency, and thus can increase the risk of musculoskeletal injuries[27,28].

Asymmetries are defined as unevenness or mechanical imbalance in corresponding body parts (e.g., contralateral upper or lower limbs)[29]. Studies have demonstrated that both athletes and non-athletes who exhibit inter-limb asymmetries between >10%[30] and >15% are more susceptible to injury[31,32]; while asymmetries <10% have been proposed when athletes are returning to sport after an injury[33]. In this sense, the hop tests are included as tests that prove valid and reliable in quantifying inter-limbs asymmetries because it provides a quantifiable number that helps identify if they are more susceptible to injury[34].

We showed that no significant differences were found in the comparison between the limbs (DL and NDL) in hop tests. Another research studied ten professional female ballet dancers in a unilateral experimental task, and there were no differences between the impulsion (for the jump task) and gesture leg[25]. Moreover, the single leg hop performance in female collegiate dancers, around 18 years also did not show significant differences between left and right lower limbs[35]. In addition, an interesting study measured the effect of core stabilization training on lower limb performance in ballet and modern dancers[36]. The results showed that for the vertical jump performance before the training program, the dancers did not have significant differences between the DL and NDL, while after the training program, the dancers had a significant increase in the DL and NDL[36]. On the other hand, another study investigated the influence of structural muscle factors on vertical jump in female ballet dancers (around 17 years)[37]. It demonstrated significant differences between the DL and NDL during the first trial on a vertical jump that was not linked to muscle mass[37]. However, for the last trial, no differences were observed between the two limb sides, although the DL height of the jump was linked to its muscle mass[37]. Thus, the findings in the present study agree with the literature, suggesting that female ballet dancers do not have inter-limbs asymmetries in tasks requiring muscle power such as jumps.

The findings of YBT also showed no significant differences between the limbs in any of the three directions reached (ANT, PL, and PM) and the composite score. In addition, previous studies demonstrated that the differences between the limbs in the three directions range between two and three centimeters, and differences bigger than 4 cm in the anterior[38,39] and posterior directions[9] are associated with an increased risk of injury. In contrast, the dancers of the present study had a composite score of 72.47% in DL and 71.74% in NDL; statistically, less than 94% suggested by the literature, indicating more chance to have a lower limb extremity injury[38].

The YBT is an excellent, quick, and inexpensive method to measure dynamic balance and requires neuromuscular characteristics, such as coordination, flexibility, strength range of movement, proprioception, and balance, activating different muscle groups in each reach direction[39]. A recent study used the YBT and athletic single leg stability to assess ballet dancers between 10 to 17 years, and the results did not identify significant differences between the limbs in the reached directions[40]. Similar results were found in female ballet dancers between 19 to 22 years old[2,40]. Furthermore, studies reported that female dancers from 18 to 24 years also did not demonstrate a significant difference between the limbs in all three (ANT, PL, and PM) reached directions in the modified star excursion balance test, also known as YBT[35,36]. Likewise, another study evaluated the YBT performance in female ballet dancers compared with female non-dancing athletes, aged from 22 to 23 years[41]. The authors observed that the ballet dancers had a value of 71.5% in the ANT direction, 113.5% in the PM direction, and 112.8% in the PL direction, whereas the non-dancer athletes had in all direction values lower (61.3% in the ANT direction, 97% in PM direction and 94.1% in PL direction) than ballet dancers[41]. On the contrary, another study analyzing the YBT in female dancers around 17 years old, showed that the dancers presented asymmetry between the limbs in all directions[42].

Related to the composite score, previous reports showed that female ballet dancers at a mean age of 20 years have composite score values of around 90.8%[43,44]. Also, full-time preprofessional ballet dancers at a median age of 15 years obtained a composite score of 85.3% in the right and 85.4% in the left limbs[45]. The same study group also demonstrated that male and female ballet dancers at a mean age of 17.9 years had a similar composite score to the previous study (right limb 85.4%, and left limb 87.5%)[8]. Another research group found similar results in dancers aged 19 years old[1]. However, studies showed a composite score higher than 94% in ballet dancers from 18 to 22 years[41]. Therefore, our results are consistent with the literature, suggesting that in all reached directions (ANT, PM, and PL) the female ballet dancers do not present inter-limbs asymmetry, although presenting a composite score lower than the literature indicating a deficit in dynamic balance. Specifically, regarding the composite score found in our study that is lower than the previous studies mentioned above, we hypothesized that could be due to the age of ballet dancers once the neuromusculoskeletal system is not fully maturated.

The major strengths of this study are (1) the use of two screening tools that are easy to administer and could easily be incorporated at any activity level and sport; (2) the target population chosen for the study, once there are few studies with young female ballet dancers with the age selected in the present study using the YBT and mainly four horizontal hop tests to evaluate the muscle power and dynamic balance, thus the study becoming very relevant by the sport specificity and age of the sample. Furthermore, another important point was the analysis of four hop tests providing new very interesting information about the use of these tests in ballet dancers. Limitations of this study must also be noted.

Study limitations

Regarding the study limitation, although the sample size of the current investigation agrees with similar studies[1,36], the sample size based on convenience represents a limitation; so, future studies investigating muscle power and dynamic balance in ballet should use a large sample size to increase the external validity of research with ballet dancers.

Conclusion

In summary, these findings provide important take-home messages. Young female ballet dancers do not have asymmetry inter-limbs in both functional tests used and this may be due that the specific training of dance that stimulates the functional symmetric in jump tasks. However, they have a deficit in dynamic balance demonstrated by the YBT composite score, which might increase the risk of lower limb musculoskeletal injury. Considering that dynamic balance is affected by maturation and growth, this result can be explained by the dancers' age. However, further studies are needed to better understand the ballet dancers' functional performance of lower limbs. These results will also encourage and help multidisciplinary dance teams monitor injuries and can be used as a tool to implement strategies or rehab protocols that aid in the prevention of injuries in ballet dancers.

Ethical approval

The work included in this manuscript was approved by the Ethical Committee at the University of Caxias do Sul.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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