Lumbopelvic Muscle Mobility and Resistance and their Association with Musculoskeletal Pain in Ballet Dancers

Mobilidade e resistência muscular lombopélvica e associação com dor musculoesquelética em bailarinas

Vitória Hamdan Padilha[1] Simone Lara[1] Susane Graup[1] Lilian Pinto Teixeira[1] Loreanne dos Santos Silva[1] Eduardo Timm Maciel[1]

[1] Universidade Federal do Pampa, Uruguaiana, RS, Brazil

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Address for correspondence Simone Lara, UNIPAMPA, Campus Uruguaiana, RS, BR 472, KM 592, 97508-000, Brasil (e-mail: slarafisio@yahoo.com.br).

Abstract

Objective The present study analyzes ankle mobility and lumbopelvic muscle mobility and resistance. In addition, it identifies factors associated with musculoskeletal pain in young ballet dancers.

Methods This is a quantitative, descriptive, cross-sectional study evaluating 14 ballet dancers aged 12 to 16 years old. We used the following instruments: a) Nordic Musculoskeletal Symptom Questionnaire (NSQ) for musculoskeletal pain assessment; b) leg lateral reach test, lumbar lock, and rotation test (for trunk mobility analysis) and lunge test (for ankle mobility evaluation); c) front bridge, lumbar extensor, and lumbar flexor muscles tests to assess lumbopelvic complex resistance.

Results The main complaints reported by ballet dancers were pain in the low back area and in the lower extremities, especially in the knee (57.1%). Those with low back pain had significantly lower lumbar mobility ($p = 0.05$) and lower ankle mobility on both sides ($p \leq 0.05$). Dancers with knee pain presented significantly lower muscular trunk extensor muscle resistance ($p = 0.05$).

Conclusions Our study revealed significant associations between the lumbopelvic complex function and musculoskeletal symptoms, supporting the implementation of preventive strategies.

Keywords
- dancing
- musculoskeletal pain
- low back pain

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Resumo

Objetivo Analisar a mobilidade e a resistência muscular lombopélvica e mobilidade de tornozelo, assim como identificar os fatores associados com dor musculoesquelética em bailarinas jovens.

Métodos Trata-se de um estudo quantitativo, descritivo e transversal que avaliou 14 bailarinas de 12 a 16 anos. Os seguintes instrumentos foram aplicados: a) Questionário Nórdico de Sintomas Osteomusculares (QNSO) para avaliação da dor musculoesquelética; b) *leg lateral reach test, lumbar lock* e *rotation test* (avaliação da mobilidade de tronco) e *lunge test* (avaliação da mobilidade de tornozelo); c) ponte frontal, extensores lombares e flexores lombares para avaliação da resistência do complexo lombopélvico.

Resultados A dor lombar e em membros inferiores, especialmente no joelho (57,1%), foram as principais queixas relatadas pelas bailarinas no presente estudo. As bailarinas avaliadas com dor lombar apresentavam significativamente menor mobilidade lombar ($p = 0,05$) e menor mobilidade de tornozelo em ambos os lados ($p \leq 0,05$). Entre as que apresentavam dores nos joelhos, a resistência muscular de extensores de tronco foi significativamente menor ($p = 0,05$).

Conclusões O presente estudo encontrou associações importantes entre a função do complexo lombopélvico e sintomas musculoesqueléticos e apoia a construção de estratégias preventivas neste contexto.

Palavras-chave
- dança
- dor musculoesquelética
- dor lombar

Introduction

Dance emerged due to the natural human need to express feelings; people danced even before speaking.[1] Although classical ballet originated in Renaissance Italy in the 1500s, it only gained strength in the following century, in France, under Louis XIV.[2] A dancer himself, Louis XIV founded the first ballet school in the world, beginning a technical improvement that led to the recognition of French as the official language of ballet.[3]

Ballet is different from other dance modalities, with specific physical fitness and skills requirements.[4] In addition, it uses "en dehors" (a 180° external rotation of the lower limbs), pointe shoe work, extreme joint ranges, prolonged isometrics, and high-impact repetitive movements, including jumping and twisting, resulting in biomechanics prone to injury.[5]

These features make classical ballet the dance with the highest technical requirements and the highest rate of injuries.[6] Ballet dancers can present several injuries throughout their careers due to biomechanical changes causing functional imbalance and directly affecting the proper maintenance of body structures.[7]

The high physical demand resulting from repetitive spinal flexion, hyperextension, and rotation was associated with high rates of lumbosacral discomfort.[8] This was shown by Smith et al.,[9] who found a 62% prevalence of lumbosacral pain, and by Henn et al.,[10] who reported a 57% rate of low back pain in nonprofessional dancers. Other authors also demonstrated high rates of muscle imbalance and spinal dysfunction in this population.[11] In addition, there is evidence of reduced physical conditioning concerning muscle strength in dancers compared with athletes from other modalities.[12]

These injuries seem conditioned to inefficient lumbopelvic movements, since ballet favors a force imbalance between the anterior and posterior trunk muscles due to an exacerbated agonist contraction of the lumbar region at a disadvantage to the abdominal antagonist group.[8,13] The core acts on the hip-pelvis-lumbar complex, providing strength control and static and dynamic stability; moreover, it is essential for proper trunk and lower limb movements. Therefore, changes in this region can cause long-term functional loss and disability, shortening the career of a ballet dancer.[14]

The present study assessed ankle mobility and lumbopelvic muscle mobility and resistance due to their strong influence on functional and sports demands. It also identified factors associated with musculoskeletal pain in young ballet dancers.

Materials and Methods

Study and sample

This is a quantitative descriptive cross-sectional study with a convenience sample of classical ballet dancers practicing in a studio in 2021. Previously-trained researchers performed the evaluations in June 2021, following all sanitary measures for COVID-19 prevention and control.

We invited 15 nonprofessional ballet dancers to participate in the study. Fourteen agreed to participate voluntarily and met the inclusion criteria. To participate in the study, the dancer had to meet the following criteria: a) female gender; b) age between 12 and 16 years old; and c) to practice ballet for at least 3 years with a minimum frequency of 2 classes per week. We chose this age group and attendance to obtain a minimum practice time. Exclusion criteria were the following: a) orthopedic injury in the previous 3 months; b) neurological or rheumatic lesions or both attested by a medical report; and c) inability to perform the proposed tests.

We complied with all ethical precepts set forth by Resolution 466/12 of the Brazilian Health Council and the Declaration of Helsinki (2008). The institutional Research Ethics Committee approved the present project under opinion number 4.587.592. The ballet dancers and their legal guardians signed an informed consent form agreeing to participate in the research.

Procedures

Initially, the subjects answered a questionnaire for sample characterization, including age, time of ballet dancing (in years), use of pointe shoes, practice of other physical activity, and history of previous injuries. Then, the Nordic Musculoskeletal Symptom Questionnaire (NSQ), validated for use in Brazil, assessed the incidence of musculoskeletal disorders among the subjects. The NSQ is composed of questions regarding symptoms from all anatomical areas in the previous 12 months and in the 7 days preceding the interview.[15] It is worth mentioning that we only assessed symptoms occurring within 12 months.

The ballet dancers underwent mobility tests (trunk and ankle) and lumbopelvic muscular resistance tests at the dance studio before the beginning of the class so responses would not be influenced. The protocol was as follows:

- Anthropometric assessment: Determination of body mass with an electronic digital scale (Supermedy, with 180-kg capacity, and results given in kilograms) and height (in centimeters) using a measuring tape.
- Trunk mobility assessment with the following tests:
  - Leg lateral reach test: In this test, subjects were in a supine position with their arms at their sides. Then, they performed hip flexion with knee extension on one of the lower limbs, on the side to be tested, and directed it to the contralateral side, rotating the trunk without losing shoulder contact with the ground. The goal was to reach a previously marked measuring tape perpendicular to the popliteal fossa on the contralateral side and keep it at maximum reach for at least 5 seconds. The subjects performed this movement three times on each side (right and left) to determine the average maximum reach distance.[16]
  - Lumbar locked rotation test: In this test, the subjects were in a four bases position with knees and hips in maximum flexion. The elbows were flexed at 90 degrees and then placed in contact with the knees on the ground. Then, one hand was placed on the neck and the thoracic spine was rotated to the same side. We determined maximum rotation with a magnetic-based angle meter (inclinometer, Western) used for precise measurements from 0° to 90° positioned in the thoracic region between T1 and T2 at the end of the left- and right-sided rotation.[17]
- Lunge test: This test assessed ankle dorsiflexion range of motion (ROM). The subjects stood in front of a wall with a measuring tape fixed to the floor. The hands and contralateral foot were in a comfortable position. The second metatarsal of the assessed foot was 10 cm away from the wall. Then, the subject flexed the ipsilateral knee, leaning against the wall and keeping the heel in contact with the floor. If the dancer could rest her knee easily on the wall, the second metatarsal was moved 1 cm backward, and so on, until the ankle was at its maximum dorsiflexion. On average, there were 3 attempts, with 1-minute intervals between them.[18]
- Evaluation of the muscular resistance of the lumbopelvic complex: a smartphone timed all tests, determining the maximum time sustained during exercises. We selected the following tests:
  - Front bridge: We chose this test because it requires both abdominal and lumbar extensor muscle work at the same time, allowing the assessment of muscle strength and synergy. In the prone position, with elbows flexed at 90 degrees, shoulder-width apart, hips elevated from the stretcher, and feet supported only with the fingers, we asked subjects to form a straight line with suspended shoulders, hips, and ankles.[19]
  - Lumbar flexor muscles: We asked the subjects to seat down with hips and knees flexed at 90° and the trunk forming a 60° angle with the stretcher.[19]
  - Lumbar extensor muscles: Subjects were in the prone position, with the lower extremity of the body remaining fixed on the stretcher using a Velcro strip placed under the greater trochanter. The trunk remained elevated with no support, and the arms remained crossed in front of the chest.[19]

Data analysis used descriptive statistical procedures with mean, standard deviation (SD), and absolute and relative frequencies determination. The Pearson test correlated numerical variables. Variables categorization used median values. The Fisher exact test analyzed the association between categorical variables. IBM SPSS Statistics for Windows, version 21.0, performed all tests considering a significance level of 5%.

Results

Fourteen ballet dancers (age: 13.5 ± 1.55 years old) participated in the study. ►**Table 1** summarizes their descriptive data.

In addition to ballet, 9 (64.3%) dancers reported practicing another type of physical activity. Four (28.6%) did weight training, whereas 2 did functional training (14.3%). Most dancers reported a previous injury (57.1%), with ankle sprains (14.3%) and low back pain (14.3%) as the most frequent. Five dancers (35.7%) underwent physical therapy due to these injuries. Four (28.6%) dancers reported using pointe shoes in the previous 12 months of classes.

►**Fig. 1** shows the frequency distribution of musculoskeletal disorders reported by the participants in the last 12 months. Most dancers complained of knee pain (57.1%).

Table 1 Sample characterization and descriptive variables

Variables	Mean value	Standard deviation
Age (years old)	13.5	1.55
Mass (kg)	47.7	6.25
Height (cm)	157.0	4.20
Ballet time (years)	6.7	1.89
Classes per week (days)	2.7	0.46
Lumbar spine mobility, right side (cm)	69.8	5.47
Lumbar spine mobility, left side (cm)	80.7	31.56
Thoracic spine mobility, right side (°)	74.5	4.02
Thoracic spine mobility, left side (°)	72.6	6.31
Ankle mobility, right side (cm)	11.7	1.63
Ankle mobility, left side (cm)	12.0	1.88
Lumbopelvic muscle resistance (seconds)	107.9	37.75
Trunk flexor muscle resistance (seconds)	233.7	217.15
Trunk extensor muscle resistance (seconds)	148.3	47.34

Moreover, 42.9% of the dancers reported pain in the lumbar spine, the hip, and the ankles within the previous year.

The correlation between mobility measures and muscular resistance revealed that lumbar mobility has a significant moderate correlation with lumbopelvic muscle resistance ($r = 0.682$; $p = 0.007$). However, there was an inversely proportional and significant correlation between thoracic mobility and trunk extensor muscle resistance ($r = -0.640$; $p = 0.014$). The analysis of the categorical variables of mobility and muscular resistance showed a single significant association between left ankle mobility and trunk extensor muscle resistance ($p = 0.05$), since 85.7% of the ballet dancers with higher muscle resistance had less mobility in this segment.

►**Table 2** shows the association between mobility and muscular resistance and musculoskeletal disorders at the lumbar spine and in the lower limbs (hip, knee, and ankle). Ballet dancers with low back pain had significantly lower left lumbar mobility ($p = 0.05$), lower right ankle mobility ($p = 0.05$), and lower left ankle mobility ($p < 0.01$). On the other hand, ballet dancers with hip pain presented higher right lumbar mobility ($p = 0.05$), and those with ankle pain had higher left thoracic mobility ($p = 0.05$). Dancers with knee pain presented significantly lower trunk extensor muscle resistance ($p = 0.05$).

Discussion

In the present study, an expressive percentage of ballet dancers reported pain in the lumbar spine and in the lower limbs in the previous year, especially in the knee (57.1%),

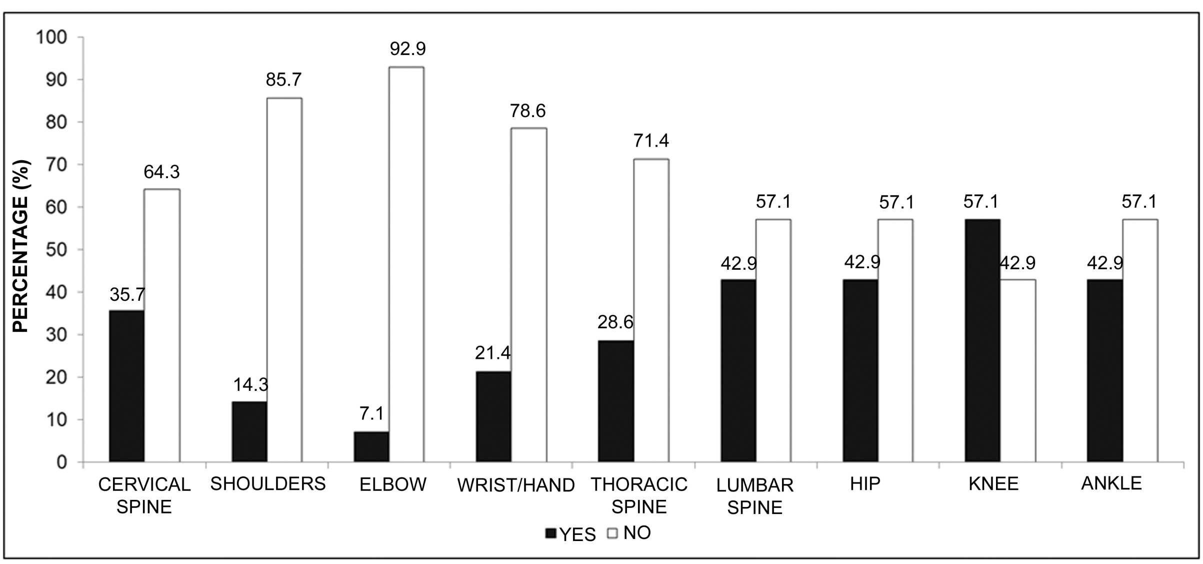

Fig. 1 Frequency distribution of musculoskeletal disorders presented by ballet dancers in the last 12 months.

Table 2 Association between mobility and lumbopelvic resistance variables with the most prevalent musculoskeletal symptoms

Variable	Lumbar spine $n=6$		Hip $n=6$		Knee $n=8$		Ankle $n=6$	
	Yes (%)	*p-value*	Yes (%)	*p-value*	Yes (%)	*p-value*	Yes (%)	*p-value*
Lumbar spine mobility, right side								
Lower mobility	50.0	0.70	16.7	0.05*	37.5	0.29	50.0	0.70
Higher mobility	50.0		83.3		62.5		50.0	
Lumbar spine mobility, left side								
Lower mobility	83.3	0.05*	66.7	0.29	50.0	0.70	33.3	0.29
Higher mobility	16.7		33.3		50.0		66.7	
Thoracic spine mobility, right side								
Lower mobility	33.3	0.59	33.3	0.59	37.5	0.40	0.0	0.07
Higher mobility	66.7		66.7		62.5		100.0	
Thoracic spine mobility, left side								
Lower mobility	50.0	0.70	50.0	0.70	50.0	0.70	16.7	0.05*
Higher mobility	50.0		50.0		50.0		83.3	
Ankle mobility, right side								
Lower mobility	83.3	0.05*	66.7	0.29	62.5	0.29	50.0	0.70
Higher mobility	16.7		33.3		37.5		50.0	
Ankle mobility, left side								
Lower mobility	100.0	< 0.01*	66.7	0.47	50.0	0.47	66.7	0.47
Higher mobility	0.0		33.3		50.0		33.3	
Lumbopelvic muscle resistance								
Lower force	50.0	0.70	66.7	0.29	50.0	0.70	66.7	0.29
Higher force	50.0		33.3		50.0		33.3	
Trunk flexor muscle resistance								
Lower force	50.0	0.70	66.7	0.29	50.0	0.70	50.0	0.70
Higher force	50.0		33.3		50.0		50.0	
Trunk extensor muscle resistance								
Lower force	33.3	0.29	50.0	0.70	75.0	0.05*	50.0	0.70
Higher force	66.7		50.0		25.0		50.0	

followed by the lumbar region, hip, and ankle (all with 42.9%). In addition, ankle sprain and low back pain were the most prevalent previous injuries in these subjects. Our findings corroborate those of Costa et al.,[6] who reported that ankle sprain was the most frequent injury among professional (69.8%) and nonprofessional ballet dancers (42.1%).

Other authors, such as Hendry et al.,[20] have demonstrated that lower limb injuries among adolescent dancers are significantly more frequent in comparison with athletes from different modalities, such as artistic gymnastics, within the same age group. Ratifying these findings, Lampe et al.[21] analyzed the most painful musculoskeletal regions in amateur dancers, reporting the knee, followed by the lumbar spine, as those with a higher incidence of pain. Moreover, Hendry et al.[20] proposed that this results from the excessive use of the lower limbs during classes, in repetitive jumping and landing movements, indicating a causal nexus between these factors, and explaining the high incidence of musculoskeletal symptoms in the lower extremities of dancers.

Another striking aspect is the use of pointe shoes due to their reduced impact absorption capacity.[22] In addition, Bickle et al.[23] suggested an accentuation of the ground reaction force when non-professional ballet dancers wear pointe shoes. Thus, because of the increased postural sway caused by pointe shoes, which is common in younger ballet dancers, their use can contribute to the onset of musculoskeletal pain in the lower limbs.[22] Hendry et al.[20] pointed out that the age group studied is within their peak growth and skeletal maturation, predisposing the development of biomechanical misalignments, in particular dynamic valgus. These misalignments generate predictive injury mechanisms during the execution of the movements required in dance.

Our findings are consistent with those of Swain et al.,[24] who found a high prevalence of low back pain in a sample of ballet dancers > 12 years old. These authors explain that low back pain may be associated with incorrect technique execution and muscle imbalances in the lumbopelvic region, leading to spinal instability during specific dance movements.

Regarding lumbar spine mobility, we noticed a moderately significant correlation with lumbopelvic resistance. In contrast, other authors demonstrated the importance of lumbopelvic stability for the correct execution of trunk and lower limb movements, especially in athletic activities.[25] Moreover, Bobály et al.[26] associated lumbopelvic strength with greater trunk mobility, improved flexibility, proper postural alignment, correct technique execution, and better performance in young ballet dancers.

Our study revealed that some factors relate to painful lumbar region events in ballet dancers, including lower left lumbar mobility and bilateral reduced ankle mobility. With similar outcomes, Mullerpatan et al.[27] associated low back pain with lower ankle mobility. The same study proposes that the hip, knee, and ankle are interconnected segments, components of a kinetic chain. Therefore, any change in this segment alters the kinematics of the lower limbs, directly influencing lumbopelvic performance.

Furthermore, ballet dancers with knee pain had significantly lower trunk extensor muscle resistance. Chaudhari et al.[28] also detected this association in a study identifying a reduced lumbopelvic stability in young athletes with increased patellofemoral contact pressure during running which could cause joint symptoms and, consequently, pain, such as the patellofemoral pain syndrome. Trompeter et al.[29] reiterate that the stability of the lumbopelvic complex refers to the ability of the body to transfer force control from the proximal segment to the distal components. However, ballet dancers have little central stability, and they may present biomechanical imbalances that indirectly affect the lower limbs. These imbalances impair functional demands and can culminate in musculoskeletal pain or injury.

Our study found some negative associations between trunk extensor muscular resistance and mobility, as the ballet dancers with less resistance in these muscles had greater thoracic and ankle mobility. These findings may be associated with compensatory factors involving extreme ranges of motion, as explained by Chan et al.[30] These authors stated that excessive joint mobility accompanies more fragile tendinous and ligament structures, contributing to a delay in soft tissue responses to the effects of training. This delay impairs the muscle strengthening process and makes the dancer more prone to injuries. Moreover, Steinberg et al.[31] reported that the prevalence of joint hypermobility was significantly higher in dancers compared with their control group, composed of nondancers.

On the other hand, our study found that dancers with hip pain had greater lumbar mobility, whereas those with ankle pain present higher thoracic mobility. Other investigations suggest that young ballet dancers seek to overcome individual limitations and mitigate technical deficiencies through compensations, including increased hip anteflexion angles and excessive lumbar and thoracic mobility.[32] Therefore, excess joint mobility has been associated with movement dysfunction throughout the kinetic chain and with an increased risk of musculoskeletal pain and injury.[33]

Although we obtained relevant findings, some limitations must be highlighted, such as the reduced number of ballet dancers evaluated and the lack of reference values for the tests applied. The latter makes it difficult to discuss the results and perform a more reliable sample comparison.

Conclusion

Based on the results, we can conclude that pain in the lower back and in the lower limbs, especially in the knee, were the main complaints reported by the ballet dancers in our study. Subjects with low back pain presented lower lumbar and ankle mobility, whereas those with knee pain had lower trunk extensor muscle resistance. These findings indicate critical associations between the lumbopelvic complex and lower limb biomechanics.

Therefore, our study draws attention to the implementation of preventive interventions aimed at the lumbopelvic complex to reduce the rate of musculoskeletal pain and injuries in dancers and improve their performance and quality.

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Conflict of Interests

The authors have no conflict of interests to declare.

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