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Evaluation of posture and flexibility in ballet dancers

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Abstract

Objectives: Ballet dancers require a high level of control on their muscles in order to perform various dance figures. Special ballet moves require adaptive changes in order to maintain posture while performing classical ballet dance. The aim of the present study was to evaluate the differences in body postures and range of motion in certain joints between female classical ballet students and female non-dancer students.

Methods: Fifty nine female university students participated in the study; 30 were studying classical ballet at Hacettepe University Ankara State Conservatory and 29 were studying at Başkent University with no professional dancing history. Students in both groups were compared by conducting a body posture analysis anteriorly, laterally and posteriorly with the symmetrigraf chart. Range of motion of the joints was measured using a goniometer and distances were measured using an anthropometer.

Results: Ballet education was a factor in the development of hallux valgus and genu varum deformities ($p<0.001$). Being a ballet dancer or not was determined to be a factor for the development of genu recurvatum ($p=0.004$), but not related to the flexion angle on knee ($p>0.05$). The median values of body flexion and hyperextension showed statistically significant differences between the two groups ($p<0.001$).

Conclusion: Postural defects caused by the adaptive changes that occur during ballet training can be assessed easily by using a symmetrigra. It is also possible to evaluate the degree of the deformities that can develop by time.

Keywords: ballet dancer; posture; range of motion; symmetrigraf

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Introduction

Dance is a performance that requires not only technical skills, but also adequate physical strength and flexibility. Classical ballet training is a long training process that begins at the ages of 10 or 11 and requires intensive practicing. Ballet dancers need to exert a high level of control on their muscles in order to perform various dance figures that are incompatible with human anatomy and to gain expertise in their postures.[1,2] When dancers in their developmental ages lack an adequate level of muscle strength, joint range of motion and flexibility, this intensive training process will engender rapid physical and biomechanical changes that might lead to various permanent changes in their anatomy. These changes are the intrinsic risk factors in terms of injuries.[3,4]

"Turnout" is a position in which ballet dancers force their hip joints and the other joints of their lower limbs to perform an outward rotation while standing in an upright position.[5] The "en pointé" is a position in which the body weight is carried by the joints and ligaments of the foot while standing on tiptoes with special shoes. To achieve the right posture in classical ballet, when these moves are performed repeatedly they lead to adaptations in the musculoskeletal system.[6]

Posture is defined as the combination of the positions that the joints assumed in any and every move performed by the body. To ensure stability with the support of ligaments or to make a move at the time of muscle activity, the body achieves a proper stance as a result of the coordina-

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tion between various muscles.[7] Postural stability is necessary when performing a ballet move. This postural activity may occur with the contraction of antagonist muscles, or with the participation of all muscles in the body. The muscle activities required to achieve a posture are not voluntary, as they are regulated automatically by the central nervous system.[8]

In physiological and biomechanical terms, a good posture provides the maximum competence control with minimum effort.[2,9] Posture is affected by genetics, race, gender, season, diet, socioeconomic status, contemporary fashion, profession, hobbies, psychological state, hygiene, sleep, exercising as much as possible in open and fresh spaces, emotional states (such as happiness, sadness, stress etc.), exhaustion, fractures, soft tissue defects, and defects occurring in the normal settlement angles of the joints.[7]

In addition, the postural habits gained by practicing the moves and positions of a branch of sports since childhood also have an impact on posture. When only one side of the body is subjected to effort during exercise, the symmetry of the physical structure may become affected.[2] Injuries that are caused by overuse, such as metatarsal stress fractures, patellofemoral syndrome and cervical disk injuries may occur frequently in ballet dancers depending on their age and experience level.[10]

The aim of the study was to analyse and evaluate the differences in terms of posture and range of motion of certain joints between female classical ballet students and a control group consisting of female non-dancer students.

Materials and Methods

A total of 59 university students between the ages of 18 to 25, including 30 female students studying classical ballet for at least 8–10 years at Hacettepe University State Conservatory and 29 female students studying at Başkent University with no professional dancing history, participated in the study. Participants in both groups had no clinically diagnosed musculoskeletal disorders or symptoms during the study.

Posture analysis of the students was performed using the transparent symmetrigraf of 2 m length and 1 m width (**Figure 1**). The symmetrigraf that was designed for the present study was divided into large squares of 3×3 cm^2 that also contained smaller squares of 1×1 cm^2. There was a thick line in the middle of the chart, overlapped with the midline. In an anatomic position, the participants were assessed anteriorly, posteriorly and laterally.

The anterior analysis evaluated the presence of hallux valgus, inversion and eversion in the feet; tibial torsion, genu varum and genu valgum in the legs; asymmetry between the anterior superior iliac spine (ASIS); and the asymmetry between the right and left shoulders. The lateral analysis evaluated pes planus and pes cavus in the feet; genu recurvatum and flexion in the knees; anterior and posterior tilt in the pelvis; lordosis and kyphosis in the spine; and anterior and posterior tilt in the head. The posterior analysis evaluated pronation and supination in the feet, and it was also assessed whether there was scoliosis in the spine by marking the spinous processes.

In the lateral view, the anterior and posterior tilt in head was assessed to determine whether the head was tilted forward or backward, based on the relation between the tip point of shoulder joint and the auricle.

Figure 1. Symmetrigraf chart. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

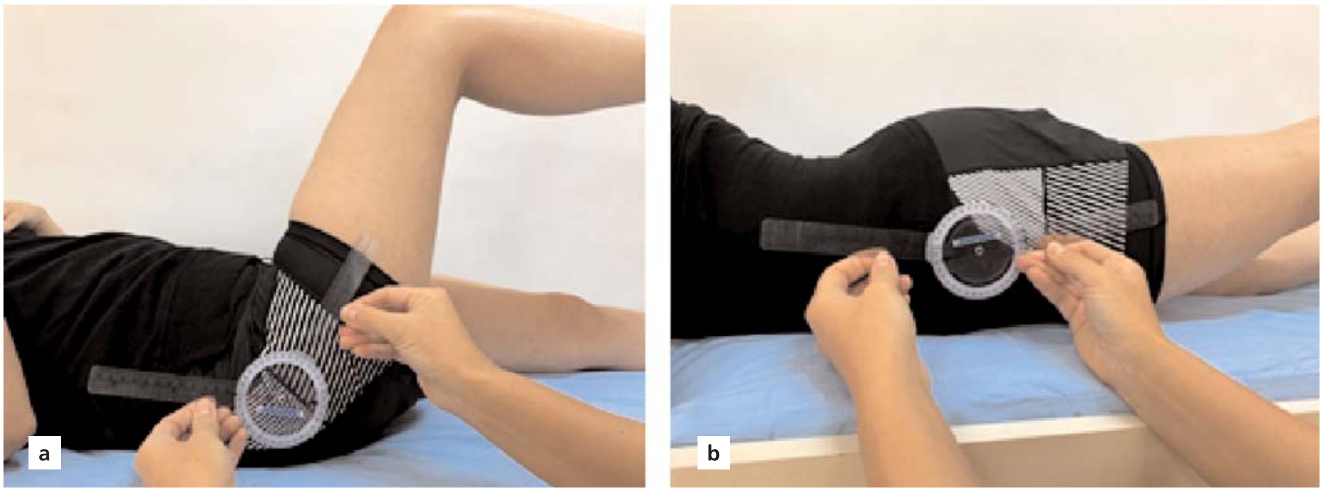

Figure 2. Measurement of the flexion (**a**) and extension (**b**) angles of the hip joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

Increased pelvic inclination was considered as an anterior pelvic tilt, while decreased pelvic inclination was considered as a posterior pelvic tilt.

The range of joint motion in flexion and extension of hip joint, knee joint, in dorsiflexion, in plantar flexion of the ankle, and in inversion and eversion motions were measured using goniometer as seen in **Figures 2a–b**, **3a–b**, **4**, and **5a–b**. Body flexion, hyperextension, rotation and lateral flexion, hip abduction angle and hamstring length were measured using anthropometer.

Body flexion and extension were assessed anthropometrically. To measure body flexion, the participants were made to stand on a 40 cm-high block and asked to reach the maximum level of forward flexion without bending their knee. Then, the distance between the distal of the third toe and the block was measured. The values below the block surface were assessed as positive, and the ones above as negative. To measure body extension, the participants were made to face a wall, and with their pelvis and body fully in contact with the wall, the participants were then asked to stand upright. First, the distance between the jugular incisure and the wall was measured. This value was subtracted from the value obtained by measuring the distance between the jugular incisure and the wall while the body was in maximum backward extension by supporting the pelvis.

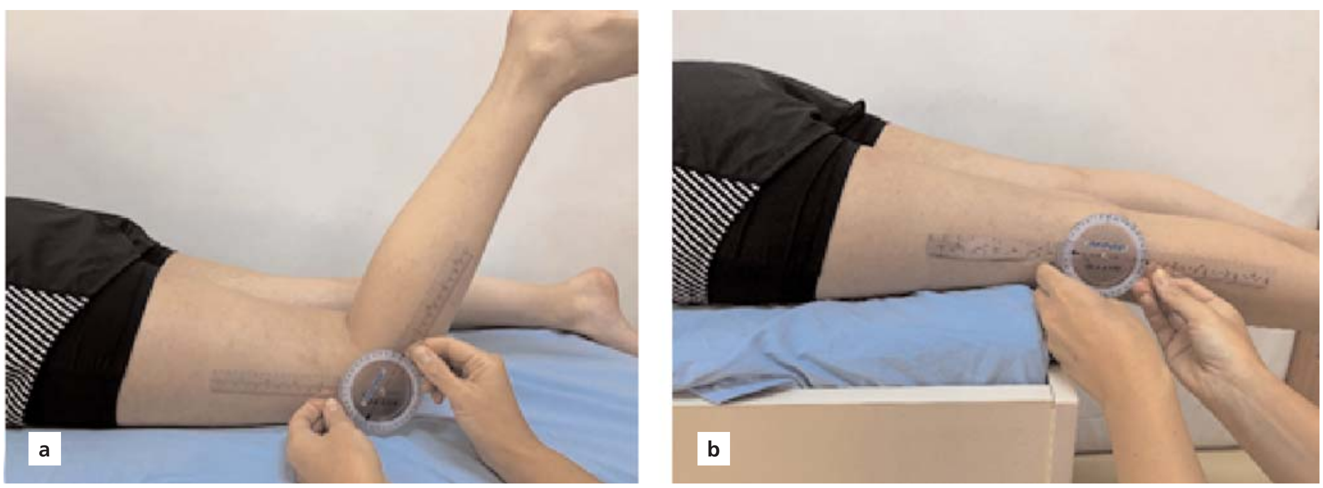

Figure 3. Measurement of the flexion (**a**) and hyperextension (**b**) of the knee joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

To measure the body rotation, the participants were first made to face the wall, and the distance between the acromion and the wall was measured while the pelvis was in full contact with the wall. Following, with one shoulder and the pelvis still in full contact with the wall, the other shoulder was moved away from the wall by rotating the body. Again in this position, the distance between acromion and the wall was measured, and the first value was subtracted from the second value and recorded as body rotation value.

The lateral flexion of the body was measured as follows: the participants were first brought to their anatomic position, and the point where the distal tip of the middle finger in hand coincides with thigh was marked. The participants were then asked to make a lateral flexion with their body by moving their hands downwards by sliding them on their thigh, without interrupting the contact between the hands and thigh. In this position, the distal tip of the 3rd middle finger was marked again, and the distance between the first mark and the second mark was measured and recorded as the body's lateral flexion value.

To measure hip abduction, the participants were first brought to a sitting position, and then asked to move their soles adjacent to each other, so as to ensure the maximum abduction in the hip joint. During this movement, the hips are moved into a position of external rotation and the knees to a position of flexion. The participants were then asked to hold their ankles and push their

Figure 4. Measurement of the dorsiflexion and plantar flexion angles of the ankle joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

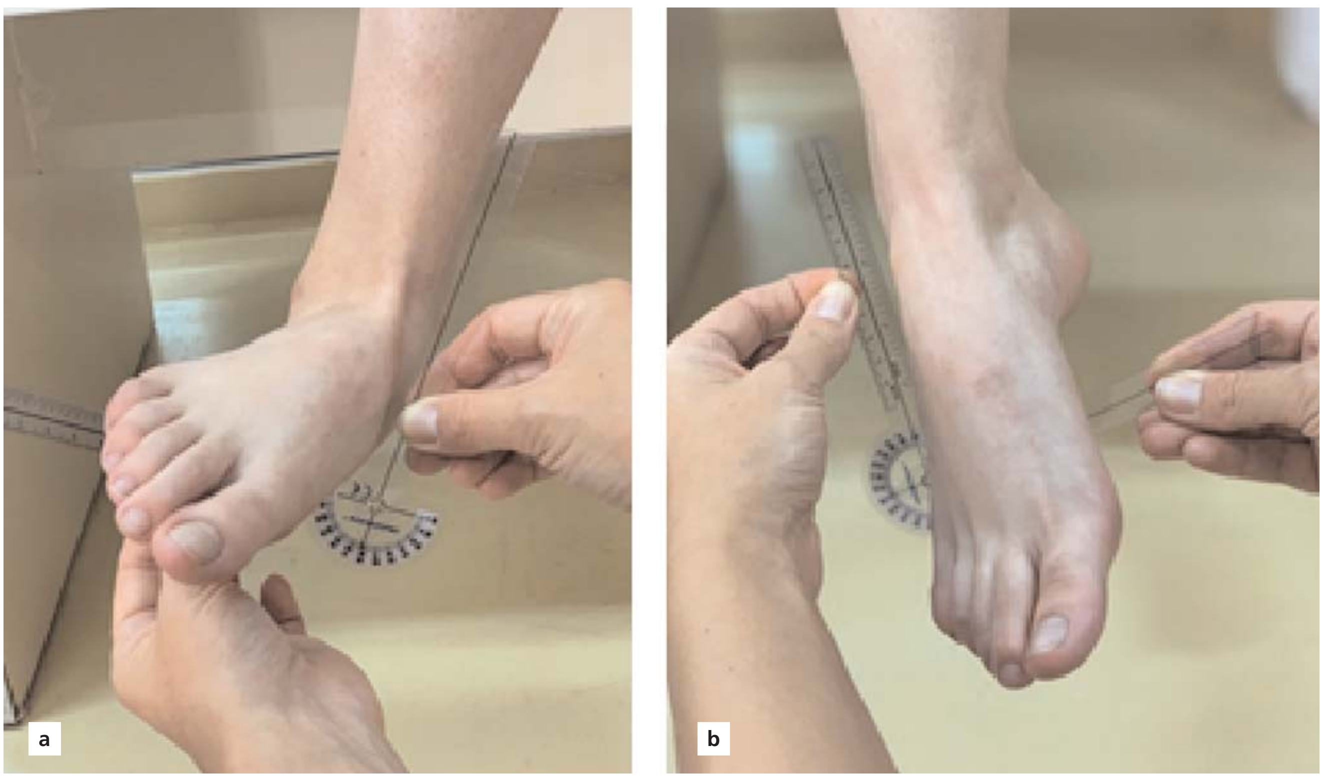

Figure 5. Measurement of the eversion (**a**) and inversion (**b**) angles in the ankle joint. [Color figure can be viewed in the online issue, which is available at www.anatomy.org.tr]

elbows and knees towards the ground as much as they could. The distance between the lateral condoyle and the ground was measured using a tape measure.

Hamstring length was measured as follows: the participants were first brought to a supine position, and asked to perform a hip extension as much as they could while keeping one knee in extension position. To assess hamstring length, the hip was kept in full flexion, and the distance between lateral condoyle and the ground was measured using a tape measure.[7]

Statistical analysis was performed using IBM SPSS Statistics for Windows (Version 25, Armonk, NY, USA). Descriptive statistics were expressed as mean ± standard deviation when the parametric assumptions were satisfied. If these assumptions were not satisfied, the descriptive statistics were expressed as median (minimum-maximum). The descriptive statistics for the categorical variables were given as frequency (n) and percentage (%).

For the continuous dependent variables Student's t test or Mann-Whitney U test was used for comparisons between two groups, depending on whether the dependent variable follows a normal distribution.

For the categorical dependent variables Pearson's chi-squared test or Fisher's exact test was used for testing the independence. The probability of a Type I error (alpha) was chosen as 5% in all tests.

This study was approved by the Başkent University Medical and Health Sciences Research Committee (Project number: KA18/214) and supported by the Başkent University Research Fund.

Table 1
Demographic characteristics of participants.

	Ballet students (min–max)	Non-dancer students (min–max)	p
Age	20 (17–25)	20 (19–26)	0.791*
Height (m)	163.25±5.69	162.57±5.31	0.639†
Weight (kg)	51.4 (43.1–67.3)	57.9 (45.3–91.7)	**0.002***
Body mass index (BMI)	19.1 (15.9–23.5)	21.4 (17.6–32)	**0.001***

*Mann-Whitney U test; †Student's t test.

Results

The demographic results concerning classical ballet students and nondancer students are shown in **Table 1** along with their p values.

While there was no statistically significant difference between the ballet students groups and non-dancer students in terms of mean height (p=0.639) and the median values for age, their medians for weight (p=0.002) exhibited statistically significant differences.The results from the anterior posture analysis concerning the classical ballet students and non-dancer students are shown in **Table 2**.

Being a person is a ballet dancer or not had a statistically significant effect on the presence of hallux valgus

Table 2
Anterior posture analysis of ballet and non-dancer students.

Anterior posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Hallux valgus	(+)	27 (90%)	9 (31%)	<0.001*
	(–)	3 (10%)	20 (69%)	
Eversion	(+)	2 (6.7%)	3 (10.3%)	0.671†
	(–)	28 (93.3%)	26 (89.7%)	
Inversion	(+)	2 (6.7%)	0 (0.0%)	0.492†
	(–)	28 (93.3%)	30 (100%)	
Tibial torsion	(+)	3 (10.7%)	1 (3.4%)	0.352†
	(–)	25 (89.3%)	28 (96. 6%)	
Genu varum	(+)	20 (66.7%)	3 (10.3%)	<0.001*
	(–)	10 (33.3%)	26 (89.7%)	
Genu valgum	(+)	0 (0.0%)	5 (17.2%)	0.052†
	(–)	29 (100%)	24 (82.8%)	
Symmetry of hip ASIS	(+)	12 (40.0%)	16 (55.2%)	0.243*
	(–)	18 (60.0%)	13 (44.8%)	
Asymmetry of shoulder	(+)	17 (58.6%)	17 (58.6%)	>0.999*
	(–)	12 (41.4%)	12 (41.4%)	

*Pearson's chi-square test; †Fisher's exact test.

($p<0.001$). As a condition where the metatarsophalangeal joint stays in dorsal flexion and the proximal interphalangeal joint remains in plantar flexion, the hallux valgus was not seen in either of the groups of ballet students and non-dancer participants. Whether a person is a ballet dancer or not did not have a statistical effect on keeping the foot in eversion ($p=0.671$) and inversion ($p=0.492$) in upright standing position (**Table 2**).

Tibial torsion was not affected statistically by being a ballet dancer or not ($p=0.352$). Being is a ballet dancer or not was a factor that had a statistically significant effect on the presence of genu varum in the legs ($p<0.001$) (**Table 2**).

Genu valgum deformity was not seen in the group of classical ballet students, but in five (17.1%) of the non-dancer students. Being a ballet dancer or not was not a statistically significant factor on the presence of the genu valgum deformity ($p=0.052$), SIAS symmetry ($p=0.243$) and shoulder asymmetry ($p>0.05$) (**Table 2**).

The results from the posterior posture analysis regarding classical ballet students and nondancer students are shown in **Table 3**.

A pronation position in the feet was seen in only three of the 30 ballet students, and in 11 of the 29 non-dancer students. Being a ballet dancer or not did not have statistically significant effect on the presence of foot pronation ($p=0.012$), foot supination ($p>0.999$), scoliosis ($p=0.632$) (**Table 3**).

The results from the lateral posture analysis concerning classical ballet students and nondancer students are shown in **Table 4**.

Whether a person is a ballet dancer or not was not a statistically effective factor on the presence of pes cavus in the foot ($p=0.483$). However pes planus was statistically affected by whether a person is a ballet dancer or not ($p=0.041$) (**Table 4**).

Genu recurvatum was seen in 53.3% of the ballet dancers and being a ballet dancer or not was statistically significant for the presence of genu recurvatum ($p=0.004$), but not on the presence of flexion in the knee ($p>0.999$).

The results from the body flexion and hyperextension analysis on classical ballet students and nondancer students are shown in **Table 5**.

The distrubution for body flexion, as well as the ditribution of body hyperextension showed statistically significant differences between the group of students studying ballet and the other group of students who did not studying ballet ($p<0.001$).

In terms of lateral flexion, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body ($p_{right}<0.001$; $p_{left}<0.001$). In terms of both hip flexion and extension, there was a significant difference between the ballet students and non-dancer students in the measurements taken on two sides of their body ($p_{right}<0.001$; $p_{left}<0.001$). In terms of hip abduction, there was a significant difference between the ballet students and non-dancer students in the measurements taken on both sides of their body ($p_{right}<0.001$; $p_{left}<0.001$). In abduction measurements, a lower value of measurement means a higher level of flexibility. It is for this reason that hip abduction flexibility was higher in the group of ballet dancers (**Tables 6** and **7**).

In terms of knee hyperextension, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body ($p_{right}=0.002$; $p_{left}=0.004$). In terms of plantar flexion, there was a significant difference between the ballet students and the non-dancer students in the measurements taken on both sides of their body ($p_{right}<0.001$; $p_{left}<0.001$). In terms of eversion, there was a significant difference between the ballet students and the non-dancer

Table 3

Posterior posture analysis of ballet and non-dancer students.

Posterior posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Pronation of foot	(+)	3 (10%)	11 (37.9%)	0.012*
	(–)	27 (90%)	18 (62.1%)	
Supination of foot	(+)	1 (3.3%)	0 (0%)	>0.999†
	(–)	29 (96.7%)	29 (100%)	
Scoliosis	(+)	10 (33.3%)	8 (27.6%)	0.632*
	(–)	20 (66.7%)	21 (72.4%)	

*Pearson's chi-square test; †Fisher's exact test.

Table 4
Lateral posture analysis of ballet and non-dancer students.

Lateral posture analysis		Ballet students (n=30)	Non-dancer students (n=29)	P
Pes planus	(+)	6 (20%)	13 (44.8%)	0.041*
	(–)	24 (80%)	16 (55.2%)	
Pes cavus	(+)	0 (0%)	1 (3.6%)	0.483†
	(–)	30 (100%)	27 (96.4%)	
Genu recurvatum	(+)	16 (53.3%)	5 (17.2%)	0.004*
	(–)	14 (46.7%)	24 (82.8%)	
Flexion of knee	(+)	0 (0%)	1 (3.4%)	>0.999†
	(–)	30 (100%)	28 (96.6%)	
Anterior pelvic tilt	(+)	24 (80%)	17 (58.6%)	0.075*
	(–)	6 (20%)	12 (41.4%)	
Posterior pelvic tilt	(+)	1 (3.3%)	1 (3.8%)	>0.999†
	(–)	29 (96.7%)	25 (96.2%)	
Increase of lumbar lordosis	(+)	22 (73.3%)	18 (62.1%)	0.355*
	(–)	8 (26.7%)	11 (37.9%)	
Decrease of lumbar lordosis	(+)	0 (0%)	2 (6.9%)	0.232†
	(–)	30 (100%)	27 (93.1%)	
Kyphosis	(+)	1 (3.3%)	2 (6.9%)	0.612†
	(–)	29 (96.7%)	27 (93.1%)	
Anterior tilt of head	(+)	12 (41.4%)	19 (65.5%)	0.065*
	(–)	17 (58.6%)	10 (34.5%)	
Posterior tilt of head	(+)	1 (3.3%)	3 (10.3%)	0.353†
	(–)	29 (96.7%)	26 (89.7%)	

*Pearson's chi-square test; †Fisher's exact test.

students in the measurements taken on both sides of their body ($p_{right}<0.015$; $p_{left}<0.007$) (**Tables 6** and **7**).

Discussion

The posture analyses conducted on a group of female conservatory students studying classical ballet and control group of students from Başkent University were compared using the symmetrigraf. Hallux valgus, genu varum, genu recurvatum deformities were more prevalent in ballet students compared to the non-dancer students. Pronation and pes planus in foot were seen in the group of non-dancer students more than ballet students.

In a study conducted by Iunes et al., there was a statistically significant difference between the group of ballet dancers and the control group in terms of anterior pelvic tilt and pes cavus.[6] In the current study, pes cavus was not seen in the group of ballet dancers. As for anterior pelvic tilt, it was seen in 80% of the group of ballet students and 58.6% of the group of non-dancer students. There was no statistically significant difference between the two groups. It could be the reason of the routine habitude and specific body type and posture of the Turkish woman.

In the study conducted by Sürenkök and Livanelioğlu, it was observed that the values of lumbar lordosis and pelvic tilt were lower in the control group. The reason for this was explained as follows: Among students studying classical ballet dance, it is necessary to reduce lumbar lordosis in order to achieve the ideal posture, which causes a posterior pelvic tilt to occur.[11] In

Table 5
Flexion and hyperextension of trunk of ballet and non-dancer students.

	Ballet students (min–max)	Non-dancer students (min–max)	p*
Flexion of trunk	21 (5–31)	0 (-28–9)	**<0.001**
Hyperextension of trunk	36 (25–45)	21 (5.5–35)	**<0.001**

*Mann-Whitney U test.

Table 6
Right side flexibility measurements of ballet and non-dancer students.

Flexibility measurements	Ballet students (min–max)	Non-dancer students (min–max)	p*
Rotation of trunk	16 (7–26)	15 (11–28)	0.772
Lateral flexion of trunk	28 (20–37)	23 (13–38)	**<0.001**
Length of hamstring	45 (25–57)	42.5 (35–50)	0.120
Abduction of hip	4 (0–18)	13 (5–22)	**<0.001**
Flexion of hip	166.5 (131–180)	130 (117–152)	**<0.001**
Extension of hip	37 (22–60)	23 (12–37)	**<0.001**
Flexion of knee	134 (121–147)	132 (118–152)	0.933
Hyperextension of knee	4 (-2–14)	0 (-2–8)	**0.002**
Dorsiflexion of ankle	16.5 (3–32)	17 (4–23)	0.316
Plantar flexion of ankle	89 (78–179)	52 (35–72)	**<0.001**
Inversion of ankle	40 (26–51)	37 (34–47)	0.680
Eversion of ankle	26.5 (17–37)	22 (0–32)	**0.015**

*Mann-Whitney U test.

Table 7
Left side flexibility measurements of ballet and non-dancer students.

Flexibility measurements	Ballet students (min–max)	Non-dancer students (min–max)	p
Rotation of trunk	15 (8–25)	16 (11–30)	0.885*
Lateral flexion of trunk	27.5 (19–39)	22 (15–39)	**<0.001***
Length of hamstring	45.5 (27–60)	44 (37–50)	0.428*
Abduction of hip	4 (0–15)	13 (4–20)	**<0.001***
Flexion of hip	159.73±12.086	128.24±11.618	**<0.001**†
Extension of hip	37 (22–58)	22 (11–40)	**<0.001***
Flexion of knee	135 (120–147)	132 (116–150)	0.539*
Hyperextension of knee	3 (0–12)	0 (-3–8)	**0.004***
Dorsiflexion of ankle	16 (12–35)	17 (3–26)	0.527*
Plantar flexion of ankle	90 (78–180)	55 (38–73)	**<0.001***
Inversion of ankle	39.5 (33–55)	37 (28–52)	0.921*
Eversion of ankle	24.5 (16–33)	20 (0–30)	**0.007***

*Mann-Whitney U test; †Student's t test.

the present study, however, lumbar lordosis and pelvic tilt values did not show any statistically significant difference between the two groups (p>0.05). Also in the study by Sürenkök and Livanelioğlu, genu recurvatum values were higher in the group of ballet dancers compared to the control group.[11] Similarly in the present study, genu recurvatum values were higher in the group of ballet dancers compared to the control group (p<0.05).

According to Klemp et al., hyperextension of the knee is a sign of hypermobility. In our study, there is a statistically significant difference between the group of students studying ballet and the other group of students who did not study ballet in terms of body flexion and hyperextension (p<0.001).[3]

The study of Kim et al. studied the impact of calcaneal posture on the thoraco-lumbar area in the upright standing position. In the said study in which three-dimensional motion analysis was used, it was demonstrated that one-sided and double-sided inversion causes medial and anterior tilt on the pelvis, along with posterior and lateral rotation on the body. It was highlighted that these changes might increase lumbar pain by increasing lumbar lordosis.[12] In the current study, no significant difference was found between the control group and the group of ballet dancers in terms of anterior and posterior pelvic tilt and lumbar lordosis (p>0.05).

It was found that forward flexion (i.e. the flexion of the body) increases through practice and exercising, while dancers with hypermobility are not necessarily more successful, and hypermobility is not necessarily important in their career.[3] In the present study, body flexion and hyperextension values were found to be significantly higher in the group of ballet dancers compared to the control group (p<0.05).

Other biomechanical studies conducted on dancers have concluded that long-term intensive dance training programmes bring about increased flexibility particularly in the lower extremities.[13] In the present study, body flexion; hyperextension and lateral flexion; hip flexion, extension and abduction; knee hyperextension; plantar flexion of ankle and its eversion angles were all found to be higher in the group of ballet dancer both on the right and left sides.

In their study, Wyon et al. divided a group of dancers into three separate groups based on six-week-long mild, medium and high intensity training programmes involving stretching, in order to assess their pre- and post-training lower extremity active and passive joint range of motion. Based on their results, they found an increase in all of the three groups in terms of both active and passive joint range of motion. On the other hand, our study compared the lower extremity active joint range of motion of a group of ballet dancers who danced ballet for a certain period of time (and exercised stretching at adequate levels during this process) with another group of non-ballet-dancing individuals. Based on our results, we concluded that the lower extremity joint range of motion was generally higher in the group of ballet dancers.[14]

The present study has demonstrated that ballet dance requires a certain level of flexibility that can be achieved through stretching exercises during the dance education process; however, inadequate levels of strength and flexibility were found to bring about postural changes.

Conclusion

In the present study that assesses postural differences in individuals studying classical ballet and those who do not, it was demonstrated that classical ballet dance training has an impact on posture. This finding was critical in terms of understanding the relation between posture and injuries in ballet dancers.

In conclusion, based on the information we have obtained, we are of the opinion that any potential injuries can be prevented if posture defects that occur due to ballet dancing are examined in time, and supportive exercises are planned to remedy them.

References

1. Rein S, Fabian T, Zwipp H, Rammelt S, Weindel S. Postural control and functional ankle stability in professional and amateur dancers. Clin Neurophysiol 2011;2:1602–10.
2. Lin CF, Lee IJ, Liao JH, Wu HW, Su FC. Comparison of postural stability between injured and uninjured ballet dancers. Am J Sports Med 2011;39:1324–31.
3. Klemp P, Chalton D. Articular mobility in ballet dancers. A follow-up study after four years. Am J Sports Med 1989;17:72–5.
4. Yin AX, Geminiani E, Quinn B, Owen M, Kinney S, McCrystal T, Stracciolini A. The evaluation of strength, flexibility, and functional performance in the adolescent ballet dancer during intensive dance training. PM R 2019;11:722–30.
5. Sammarco GJ. Diagnosis and treatment in dancers. Clin Orthop Relat Res 1984;(187):176–87.
6. Iunes DH, Elias IF, Carvalho LC, Dionísio VC. Postural adjustments in young ballet dancers compared to age matched controls. Phys Ther Sport 2016;17:51–7.
7. Otman S. Tedavi hareketlerinde temel değerlendirme prensipleri. 9. baskı. Ankara: Pelikan Yayınevi, 2016.
8. Gövsa FG. Sistematik anatomi. İzmir: İzmir Güven Kitabevi, 2008. p. 200–1.
9. Beyazova M, Gökçe KY (ed): Fiziksel tıp ve rehabilitasyon. Ankara: Güneş Kitabevi, 2000. p. 156, 177–182, 330, 459–477, 2493–4.
10. Sobrino FJ, Guillén P. Overuse injuries in professional ballet: influence of age and years of professional practice. Orthop J Sports Med 2017;5:2325967117712704.
11. Sürenkek Ö, Livanelioğlu A. Klasik bale eğitiminin lumbal bölge ve alt ekstremite postüral özellikleri üzerine etkileri. Spor Bilimleri Dergisi Hacettepe 2001;12:25–31.
12. Kim SC, Yi JH, Jung SW, Seo DK. The effects of calcaneal posture on thoracolumbar alignment in a standing position. J Phys Ther Sci 2017;29:1993–5.
13. Khan KM, Bennell K, Ng S, Matthews B, Roberts P, Nattrass C, Way S, Brown J. Can 16–18-year-old elite ballet dancers improve their hip and ankle range of motion over a 12-month period? Clin J Sport Med 2000;10:98–103.
14. Wyon MA, Smith A, Koutedakis Y. A comparison of strength and stretch interventions on active and passive ranges of movement in dancers: a randomized controlled trial. J Strength Cond Res 2013;27:3053–9.

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