UNIWERSYTET HUMANISTYCZNO-PRZYRODNICZY IM. JANA DŁUGOSZA W CZĘSTOCHOWIE
Sport i Turystyka. Środkowoeuropejskie Czasopismo Naukowe 2021, t. 4, nr 4

http://dx.doi.org/10.16926/sit.2021.04.30

Tomasz RUTKOWSKI*
https://orcid.org/0000-0001-9332-0537

Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers

Jak cytować [how to cite]: Rutkowski T. (2021): *Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers*. Sport i Turystyka. Środkowoeuropejskie Czasopismo Naukowe, vol. 4, no. 4, pp. 129–142.

Zakres ruchomości kręgosłupa i bioder oraz morfologia stóp u nastoletnich tancerek baletowych

Streszczenie

Celem niniejszego badania była ocena zakresu ruchomości kręgosłupa i bioder oraz kątów stopy u nastoletnich tancerek baletowych. Przebadano 20 tancerek baletowych (DANCE) oraz 20 nietrenujących kobiet w tym samym wieku stanowiącą grupę kontrolną (CON). Ocenę zakresu ruchomości kręgosłupa i bioder (ROM) przeprowadzono za pomocą goniometru i taśmy centymetrowej. Kąty stóp oceniano przy użyciu podoskopu. W badaniu ROM kręgosłupa istotne statystycznie różnice wykazano w teście Tomayera, ruchomości kręgosłupa piersiowego oraz zakresach rotacji odcinka lędźwiowego. Analizując ROM stawu biodrowego, zaobserwowano statystycznie istotne różnice we wszystkich badanych ruchach. U tancerek baletowych zaobserwowano zwiększony kąt koślawości palucha zarówno w kończynie dominującej, jak i niedominującej. Cechowały się także większym zakresem ruchu zgięcia i wyprostu w odcinku piersiowym kręgosłupa oraz większym wyprostem i rotacją kręgosłupa lędźwiowego. Uzyskane wyniki wskazują, że nastoletnie tancerki baletowe są predysponowane do zwiększonego ryzyka wystąpienia bólu związanego z urazem układu mięśniowo-szkieletowego.

Słowa kluczowe: tancerze baletowi, koślawość palucha, zakres ruchu, kąty stopy.

* PhD; Jan Długosz University in Częstochowa; e-mail: t.rutkowski@ujd.edu.pl

wpłynął do redakcji: 12.10.2021 r.; przyjęty do druku: 7.12.2021 r.

Abstract

The purpose of this study was to assess the spine and hip range of motion and foot angles in adolescent female dancers as compared to those of non-dancing females of the same age. Twenty adolescent female ballet dancers (DANCE) and a control group (CON) of 20 adolescent females were examined. The inclusion criterion for the study group was participation in dance training for over 10 years. Spine and hip range of motion (ROM) assessments were carried out using a goniometer and centimeter tape. Foot angles were assessed using a podoscope. In spinal ROM examination, statistically significant differences were demonstrated in the Tomayer's test, thoracic spine mobility, and lumbar rotation ranges. During foot angles evaluation, statistically significant differences were demonstrated in the Hallux Valgus angle of both feet. Ballet dancers developed greater hallux valgus in both the dominant and non-dominant limbs. They demonstrated higher flexion and extension range of motion in the thoracic spinal segment and the lumbar spine movement for the extension and rotation. The obtained results demonstrate that adolescent ballet dancers are predisposed to an increased risk of pain related to the trauma of the musculoskeletal system.
Keywords: ballet dancers, hallux valgus, range of motion, foot angles.

1. Introduction

Ballet is the type of physical activity that can be regarded both as sport and art. It is an artistic spectacle, expressed in choreographic dance accompanied by music and presented on stage. Dancers often begin their training at a very young age in order to achieve a high level of ballet skills [12, 10, 6, 17].

This type of physical activity requires a student's extensive preparation for many areas. Muscle strength, endurance, and flexibility are extremely important here. A broad range of motion in both the peripheral joints and the joints of the spine helps to facilitate the assumption of the proper stances as well as the correct performance of the required exercises. In addition to the physical aspect of the exercises, ballet dancers must have a sense of rhythm, balance, and body awareness [7, 9].

The characteristics of the training and the physical requirements that are placed on each dancer may cause overloads that could result in future injury. It is estimated that about 2/3 of all ballet injuries are caused by soft tissue trauma [10]. Research shows that the majority of injuries are related to the lower limbs. Due to constant jumps and landings, the tarsal and ankle joints are exposed to numerous and frequent overloads which the tissues may not be able to withstand. The most frequently cited injuries of the lower limb in ballet include hamstring strain, ankle instability, and ankle tendinopathy [5, 11, 18].

Another area of the body that is at risk of injury in ballet is the lumbar spine. Research on the causes of back pain in dancers is ambiguous. No statistically significant correlation was observed between the spine range of motion (ROM) of the dancers and the low back pain (LBP) [6]. Some studies indicate that the problem with the facet joint of the lumbar spine can be caused by overloads due to pointe's work and refined technique. The research shows that this problem is twice as frequent in women practising ballet as in men [4,20].

Therefore, the purpose of this study was to assess spine and hip range of motion, and foot angles in adolescent female ballet dancers and compare the results with those obtained from non-dancing, age, and sex-matched students.

2. Methods

A cross-sectional, observational design was used for this study. The study followed the ethical guidelines set out in the Declaration of Helsinki. Participation in the research was voluntary and was conducted with the written consent of each participant or their parent/guardian (for dancers under the age of 18).

2.1. Participants

The evaluation was performed on 40 adolescent females, 20 dancers (DANCE) from the Social Ballet Center and the Social Ballet School in Czestochowa (Poland), and 20 students (CON) from Primary, Secondary, and High Schools from the same city. Both groups included women in the age range of thirteen to nineteen. The mean age of the entire group was 15.52. An additional criterion for inclusion in the study group was dance experience of not less than ten years of systematic participation in dance classes (at least three times a week). In turn, the CON group comprised individuals that did not engage in regular physical activity other than physical education classes in school. At the start of the study, each group member was questioned to determine their age, body mass, body height, and dominant limb. The dancers in the study were also asked about the length of their dance experience.

2.2. Outcome assessment

2.2.1. Foot angles

A computer podoscope was used to assess the condition of the feet of the study's participants. As part of the podoscope examination, the subjects stood barefoot on the podoscope glass. This method was used to measure the foot pressure distribution. After a review of the foot image, the following parameters were calculated: Clarke's angle (CL, used to assess the longitudinal foot arch), Sztriter – Godunow's Index (KY, which provides information about the transverse foot arch), Wejsflog index (WF, which determines if transverse flat feet are present), heel angle (HA, which measures the transverse arch of the foot), hallux valgus angle (HVA), and small toe valgus angle (STVA, both angles represent deformation of the I and V toes in relation to the prevailing norms). Table 2 illustrates the results of the podoscopic examination.

2.2.2. Spine and hip range of motion

The second measurement was taken in order to gauge the mobility of selected sections of the spine: cervical, thoracic and lumbar, using a centimeter tape before and after performing specific movements in the sagittal, frontal, rotational, and transverse planes while standing or sitting. In some parts of the spine (i.e. cervical and lumbar spine), subjects were asked to perform orientation tests, such as touching the handle of the sternum with one's chin (measurement of the cervical spine), which was performed while sitting in a chair straight in the starting position with eyes directed straight ahead and hands placed freely on the thighs, and the fingertip-to-floor test (also called the Thomayer test, corresponding to the measurement for the lumbar spine), which consisted of making a forward bend, assuming that ballerinas would be more "flexible". This test was performed while standing on a landing, reaching as low as possible with the tips of your fingers towards the floor, paying particular attention to the positioning of the legs by placing them hip-width apart and keeping the knees straight while bending.

A subject's cervical mobility measurements were taken while they were seated, gripping the arms of the chair, and looking straight ahead. In the sagittal plane, the movements consisted of making a flexion, measuring the distance from the occipital tuberosity of the occipital bone to the spinous process of the C7 vertebra, and the extension movement, measuring the distance from the chin tubercle to the jugular notch of the sternum (in this plane, the previously described orientation test was performed, involving touching the sternum with the chin). In the frontal plane, movements of the head when tilted to the right and left were performed. Depending on the direction of the movement, the distance from the end of the right or left ear lobe to the right or left shoulder process of the scapula was measured. When rotating to the right, the distance from the top of the chin to the left shoulder process of the scapula was measured, and then the rotation to the left was measured analogously, measuring the distance from the top of the chin to the right shoulder process of the scapula.

In the thoracic segment, due to its low mobility, only flexion and extension movements in the sagittal plane were measured while standing barefoot with the feet positioned parallel to each other and hip-width apart. During the flexion and extension movement, the distance (if the distance in flexion increases and during extension decreases) was measured (after palpation and measuring and marking the appropriate places) from the Th1 spinous process to the Th12 spinous process (this place was roughly measured by measuring 30 cm from the spinous process of the 1st thoracic vertebra). In the lumbar region of the sagittal plane, the flexion and extension movements were measured while each subject stood barefoot with their feet positioned parallel to each other and hip-width apart. To measure the flexion movement the Schober test was used. This test consisted in initial palpation, measuring and marking a distance of 10 cm above and 5 cm below the L5 vertebrae, and finally measuring the distance between those two points. The extension movement was measured by performing a backward tilt and measuring the distance between the xiphoid process of the sternum to the pubic symphysis. In the frontal and transverse planes, measurements were made in a sitting position with the subject's arms folded behind their neck. During the measurement of the frontal plane of the lateral slopes to the right and left, the distance (depending on the measured right or left side) was measured from the hip crest to the xiphoid sternum projected onto the lateral side. In the transverse plane, turns were measured to the right and left from the L5 vertebrae (already turned and marked in earlier measurements during the Schober test) to the xiphoid process of the sternum (depending on which side of the measurement is made, on the opposite side, we run a centimeter tape, i.e. if we measure the twist to the left run the tape on the right from the L5 vertebra through the left side to the xiphoid process of the sternum and proceed in the same way when measuring the opposite side).

The examination of mobility in the hip joints was carried out using a goniometer in accordance with the principles of SFTR measurement of the sagittal, frontal and rotational planes while in the supine or forward lying position on a couch with the maximum active movement in a specific plane. In the sagittal plane, measurements of the flexion movement were taken in the supine position, whereas the forward lying position was used to measure the extension movement. The measurement for flexion and extension consisted in initial palpating and marking the greater trochanter of the femur and performing an independent lifting movement as high as possible on the examined limb while paying particular attention to keeping the knees straight and, additionally measuring the extension movement while not lifting the pelvis away from the couch. The phenomenon of compensation did not take place, as a result of which there would be a delusional increase in movement in the joint. In the frontal plane, the measurements of the abduction movement were carried out while lying on the side of the couch and consisted in lifting the examined limbs as high as possible, keeping one line with the body and straightening both knees. During the movement, the angle was measured with the goniometer with the axis of rotation applied to the anterior upper iliac spine. The measurement of the adduction movement was performed while lying backward on the couch by placing the axis of rotation of the goniometer in the same place like when measuring the abduction movement with one leg lowered loosely on the side of the couch and the other leg positioned along the body line. The measurement of the adduction movement consisted in "pulling" the straight leg to the other (still hanging loosely on the side of the couch), paying attention to the position of the pelvis, which should lie evenly on the couch during the movement. External and internal rotation were measured while lying on the back. It consisted in applying the goniometer to the heel tumor of the examined side and performing first the maximum external rotation, and then the internal one, making sure that the pelvis was evenly adjacent to the bed.

2.3. Data analysis

The obtained data were analyzed with IBM Statistical Package for the Social Sciences 26.0 software (IBM SPSS Statistics 26). The research material was analyzed using descriptive statistics, including mean, standard deviation (SD), and percentages. Prior to analysis, the data distribution was tested for normality using the Shapiro-Wilk test. The unpaired *t* test was used to compare results between groups. The differences in categorical variables were tested using the chi-square test. A significance level of $\alpha < 0.05$ was established.

3. Results

3.1. Participants characteristics

The mean age of the DANCE group was 15.75, the mean height was 166.10 cm, the mean body mass was 59.80 kg, and the mean ballet dancing experience was 11.58 years. The CON group comprised adolescent females with a mean age of 15.30. Their mean height was 164.85 cm, and their mean body mass was 61.17 kg. Table 1 illustrates the anthropometric characteristics of the examined participants.

3.2. Foot morphology

When analyzing the results of the morphological structure of the feet and the shape of the toes, a statistically significant difference was found in the parameter defining the valgus of the toe of the first foot. The study group was characterized by more than two times higher results of the HVA angle, both for the dominant ($P = 0.002$) and non-dominant ($P = 0.01$) limb (Table 2). The other parameters tested did not differ significantly between the groups. Table 2 shows the results of the parameters determining the morphological structure of the feet and the shape of the toes. Taking into account the frequency of the occurrence of individual types of foot arches (Table 3), no statistically significant differences were found, both between the studied groups and between the dominant and non-dominant limbs. Data from the American Medical Association was used to determine the reference values for the ranges of mobility of the spine and lower limbs [2].

3.3. Spine and hip range of motion

The study groups differed significantly in the results obtained in the Tomayer test ($P = 0.001$). The mean result of the DANCE group was 19.71 cm, and the mean of the CON group was 4.90 cm. The percentage difference between the groups was 75.17% (Table 4).

The statistical analysis of the measurements for the spinal movements showed a statistically significant greater ROM in DANCE group for the flexion movement (approx. 50%, *P*< 0.01) and for the extension movement (53%, *P*< 0.01) of the thoracic spine, right rotation (24%, *P* = 0.007) and left rotation (24%, *P* = 0.004) for the lumbar spine. In terms of mobility of the cervical spine, no statistically significant differences were found in the studied groups (Table 4).

Analysis of the ROM for the lower limbs showed statistically significant differences (*P* = 0.00) for all parameters, which demonstrated that all the data differed significantly between the groups (Table 5). The greatest percentage differences for statistical means in both the dominant and non-dominant limbs are shown in the means for external and internal rotation. The percentage of difference in the results in the dominant limb for external rotation was 43.00% and for internal rotation 49.3%. For the non-dominant limb, the percentage difference between the results for external rotation was 47.39% and for internal rotation 50.50%. In the dominant limb, the smallest percentage difference in the mean difference is observed in the sagittal plane for the flexion movement, which was 25.28%, and for the non-dominant limb in the sagittal plane, it was 26.60% for the extension movement (Table 5).

4. Discussion

The research was conducted in order to determine the difference in the range of mobility of the spine and the lower limbs, and the difference in the morphological structure of the feet of female adolescent ballet dancers as compared with a group of non-dancers.

4.1. Spine and hip range of motion

The results indicate that the greatest difference in the spine ROM can be observed in the thoracic segment. In the sagittal plane, both flexion and extension are more than twice as high in ballet trainees as in the control group. Statistically significant differences can be noticed in the mobility of the spine in rotation and extension in the lumbar section. The Thomayer test highlighted the greatest difference between the test and control groups. However, it should be noted that this test combines the assessment of the range of motion of both the mobility of the spine and the length of the muscles from the ischio-shin group.

Increasing the range of motion in joints can also increase the risk of injury. A study of 1359 female dancers specializing in various types of dance, such as ballet, jazz, and contemporary dance, indicated that increased mobility of rotation in the hip joint may contribute to an increased risk of injury. Increasing external rotation may disturb the line along which the patella should move, and this may result in patellofemoral pain and be the beginning of chondromalacia [19]. Another publication devoted to the increased range of spine mobility in young gymnasts suggested a different claim. Particular attention was paid to the extension of the spine in the lumbar region. The author of the publication suggested that there is insufficient evidence that increasing the mobility of the spine may be dangerous for the dancer, as long as it is performed professionally and under the supervision of an experienced instructor. However, the author himself noted that more research should be done in this area so that more certain conclusions can be drawn [16].

Research by Hawrylak et al. (2017) illustrated a reduced range of motion in some planes of the spine's movement in people involved in extreme climbing. Thirty athletes with an average age of 28.13 ± 3.61 and at least two years of training participated in the study. Compared to the control group, the study group showed less mobility in the thoracic section of the spine. Statistically significant results were related to extension, left and right rotation. The authors explain this fact by the specificity of the positions taken, where with bent hip joints and strong abdominal muscles the mobility of the spine in these sections could be limited in this group of climbers. It is worth mentioning that the study group had a significantly greater range of mobility in other parts of the spine, mainly in the flexion of the lumbar and thoracic spine [8].

A greater range of motion may also be observed in people participating in other sports activities. In the studies of Luca Molinaro et al., a difference was noticed in people practising karate, between the groups that specialize in "*kumite*" and those who practise "*kata*". The study involved twenty-four people (women and men) aged 24, who had fifteen years of training and compared them with a group of eighteen people who did not constantly engage in any additional physical activity. The hip mobility test was performed in three positions: in the supine position and hip flexion with the knee straightened, in the spreading position with the hips bent to an angle of 90°, and in the sit and reach test. Significant differences were observed in each of the groups between the karate fighters and the control group. Additionally, a significant difference in mobility was observed between the group training "*kumite*" and "*kata*" in the flexion test. The study did not separate the subjects according to their gender [15].

4.2. Foot morphology

This research compared the morphological structure of the feet between adolescent female ballet dancers and their peers. Out of the six different examined parameters, statistically significant changes were observed only in the HVA angle. The observed changes occurred in both the dominant ($P = 0.002$) and non-dominant ($P = 0.01$) foot. This angle is more than twice as large as compared to the control group. The studies of Ozdinc and Turan (2016) observed the lack of differences in the morphological parameters of the feet in ballet dancers ($N = 36$) and the control group ($N = 31$) [14]. The difference between the above-mentioned results may arise from the different dance experience inclusion criteria, which was two years in those study, and ten years in our research.

López-López et al. (2020) conducted a study on one hundred and fifty-six women aged 15 to 65. They were divided into a ballet training group and a control group. Both groups were asked to complete two questionnaires. One was related to the quality of life and the other to the health of the feet. The results showed significantly higher life satisfaction among women who train ballet despite worse foot health compared to the control group [12].They were divided into two equal groups. The subject group participated in the twelve-week rehabilitation program. Physiotherapeutic sessions were held three times a week for twelve weeks. Additionally, the study group wore the silicone toe separator for at least eight hours a day. Physiotherapy consisted of mobilization of metatarsophalangeal joints, glides, and traction. Achilles tendon stretching and isometric exercises for the toe muscles were also performed. An important element was to keep the toes in a neutral position. The outcomes of this study showed an improvement in radiographic measurements, toe muscle strength, foot ROM and reduction in pain. The results of the research may indicate the rightness in introducing additional therapeutic elements into ballet training. Introducing more stretching, strengthening, and mobilizing the big toe joints can effectively reduce the frequency of the appearance of a hallux valgus in women training ballet [1].

4.3. Clinical implication

Research suggests that insufficient mobility in the joints may affect the occurrence of pain and overload syndromes in the spine and peripheral joints. In recent times, many jobs require a sitting position and physical activity itself is relatively limited. Therefore, increasing the range of mobility of individual muscles through the use of stretching may positively affect the body's functioning and reduce the appearance of pain in various overload states. An example may be the work of Mohanty and Pattnaik devoted to the treatment of patients with coccydynia, which showed the effectiveness of stretching as a therapeutic method. The study was conducted on a group of forty-eight adults. For the therapy, the piriformis muscles and iliopsoas muscles were stretched for two minutes, five times a week for three weeks. A position was assumed in which the patient felt a slight discomfort associated with the stretching of the above-mentioned muscles [14]. Given the above results, physical activity and exercises to increase the range of motion in the joints are needed, thus, ballet may be one of them.

In order to assess the injuries that may accompany attending ballet classes, it is also worth paying attention to the accessories. The pointe shoe is worn by dancers. Made of layers of hessian fabric and glue, the shoe stiffens a dancer's forefoot while providing the greatest possible freedom in the joints of the foot and ankle. In research of 2018, it was noted that shoe wear may reduce the stabilization properties of the foot, which may result in overloading the ankle joint by increasing metatarsal flexion while maintaining the "toe position" [3]. One of the most common treatments for extreme valgus fingers is surgery. It is worth considering preventive methods that could reduce the occurrence of this foot defect. One of such activities could be the introduction of additional strength exercises and stretching the muscles of the big toe. The second activity could be cyclical visits to a physiotherapist in order to mobilize and traction the joints of the big toe and other toes [1].

5. Conclusions

Ballet dancers developed greater hallux valgus in both the dominant and non-dominant limbs. They demonstrated higher flexion and extension range of motion in the thoracic spinal segment and the lumbar spine movement for the extension and rotation, as well as in all hip joint movements of both lower limbs. The obtained results demonstrate that adolescent ballet dancers are predisposed to an increased risk of pain related to the trauma of the musculoskeletal system. It seems necessary to implement prevention against the above dysfunctions in the early stages of ballet training.

Table 1. Anthropometric characteristics of the surveyed people, mean (SD)

Variable	DANCE (*N = 20)*	CON (*N = 20)*	*P*-Values
Age [year]	15.75 (1.58)	15.30 (1.78)	0.40
Body height [cm]	166.10 (4.27)	164.85 (5.23)	0.41
Body mass [kg]	59.80 (4.49)	61.17 (2.72)	0.65
BMI [kg/m^2]	21.66 (1.16)	22.42 (4.11)	0.42

SD: Standard Deviation; BMI: Body Mass Index.

Table 2. Characteristics of the morphological structure of the feet, mean (SD)

Variable	CL [°]	KY[°]	WF[°]	HA [°]	HVA [°]	STVA[°]
Dominant limb						
DANCE (*N = 20*)	45.28 (10.33)	0.43 (0.15)	2.54 (0.12)	15.00 (2.05)	3.71 (4.98)	18.35 (4.60)
CON (*N = 20*)	43.90 (10.21)	0.44 (0.13)	2.38 (0.72)	14.95 (3.54)	8.90 (5.24)	15.65 (5.39)
Δ%	−3.04	2.33	−6.29	−0.33	139.9	−14.71
P-Values	0.67	0.86	0.34	0.95	0.002	0.09
Non-dominant limb						
DANCE (*N = 20*)	46.28 (8.39)	0.44 (0.09)	2.63 (0.11)	14.92 (1.57)	3.35 (3.95)	18.78 (a5.21)
CON (*N = 20*)	45.40 (12.95)	0.43 (0.13)	2.39 (0.73)	14.85 (3.03)	7.10 (5.28)	18.30 (7.18)
Δ%	−1.90	−2.27	−9.10	−0.67	111.94	−2.55
P-Values	0.79	0.70	0.15	0.92	0.01	0.80

SD: Standard Deviation; CL – Clarke's Angle; KY – Sztriter-Godunow's Index; WF – Weisflog Index; HA – heel angle; HVA – Valgus of the First Toe; STVA – Valgus Angle of the Fifth Toe.

Table 3. The frequency of the occurrence of particular types of longitudinal arches of the feet

	Dominant limb			Non-dominant limb		
	DANCE (*N* = *20*)	CON (*N* = *20*)	*P*-Values	DANCE (*N* = *20*)	CON (*N* = *20*)	*P*-Values
Flat %, (*N*)	5 (1)	5 (1)	1.00	5 (1)	10 (2)	1.00
Lowered %, (*N*)	5 (1)	25 (5)	1.00	5 (1)	5 (1)	1.00
Normal %, (*N*)	75 (15)	55 (11)	0.18	80 (16)	50 (10)	0.09
Rised %, (*N*)	15 (3)	15 (3)	1.00	10 (2)	3 (7)	0.12

Table 4. Spinal ROM differences, mean (SD)

Variable	DANCE (*N* = *20*)	CON (*N* = *20*)	Δ%	*P*-Values
Thomayer's Test [cm]	19.71 (5.14)	4.90 (12.44)	−75.17	<0.001
Cervical spine				
Flexion [cm]	3.95 (1.31)	4.40 (1.18)	11.39	0.26
Extension [cm]	7.75 (2.26)	6.85 (1.84)	−11.60	0.17
Right side bending [cm]	5.95 (1.27)	6.10 (1.37)	2.52	0.72
Left side bending [cm]	6.05 (1.35)	6.00 (1.55)	−0.83	0.91
Right rotation [cm]	8.00 (1.45)	7.20 (1.60)	−10.00	0.10
Left roration [cm]	7.60 (1.46)	7.45 (1.73)	−1.97	0.76
Thoracic spine				
Flexion [cm]	4.40 (1.56)	2.05 (1.10)	−53.40	<0.001
Extension [cm]	5.45 (1.76)	2.65 (1.98)	−51.40	<0.001
Lumbag spine				
Flexion [cm]	6.45 (1.27)	6.85 (2.00)	6.20	0.45
Extension [cm]	6.35 (2.56)	2.95 (1.31)	−53.54	<0.001
Right side bending [cm]	6.45 (2.13)	5.25 (1.61)	−18.60	0.05
Left side bending [cm]	6.20 (1.93)	5.75 (1.65)	−7.26	0.43
Right rotation [cm]	5.85 (1.59)	4.40 (1.63)	−24.78	0.007
Left rotation [cm]	6.20 (1.60)	4.70 (1.52)	24.19	0.004

ROM: Range of Motion; SD: Standard Deviation.

Table 5. Lower limb ROM differences, mean (SD)

	Sagittal plane		Frontal plane		Rotation	
Variable	Flexion [°]	Extension [°]	Abduction [°]	Adduction [°]	External Rotation [°]	Internal Rotation[°]
Dominant Limb						
DANCE (*N* = *20*)	118.45 (15.60)	58.55 (17.51)	106.60 (32.28)	52.50 (17.43)	81.25 (12.12)	74.90 (13.76)
CON (*N* = *20*)	88.50 (12.04)	42.75 (17.12)	69.75 (20.29)	31.75 (9.07)	46.25 (13.46)	38.00 (13.01)
Δ%	−25.28	−27.00	−34.60	−39.52	−43.00	−49.30
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Non-dominant limb						
DANCE (*N* = *20*)	115.55 (19.97)	57.90 (15.56)	109.25 (21.10)	55.85 (16.94)	76.50 (14.96)	71.75 (17.42)
CON (*N* = *20*)	84.75 (13.61)	42.50 (16.26)	69.50 (23.94)	30.25 (8.95)	40.25 (8.18)	35.50 (9.85)
Δ%	−26.65	−26.60	−36.40	−45.34	−47.39	−50.50
P-Values	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

ROM: Range of Motion; SD: Standard Deviation.

References

[1] Abdalbary S.A. (2018): *Foot Mobilization and Exercise Program Combined with Toe Separator Improves Outcomes in Women with Moderate Hallux Valgus at 1-Year Follow-up A Randomized Clinical Trial*. Journal of the American Podiatric Medical Association, 108(6), pp. 478–486. https://doi.org/10.7547/17-026.

[2] American Medical Association (1993): *Guides to the Evaluation of Permanent Impairments* (4th ed). Chicago, IL.

[3] Bickle C., Deighan M., Theis N. (2018): *The effect of pointe shoe deterioration on foot and ankle kinematics and kinetics in professional ballet dancers*. Human Movement Science, 60, pp. 72–77; https://doi.org/10.1016/j.humov.2018.05.011.

[4] Biernacki J.L., Stracciolini A., Fraser J., Micheli L.J., Sugimoto D. (2021): *Risk factors for lower-extremity injuries in female ballet dancers: a systematic review*. Clinical Journal of Sport Medicine, 31(2), pp. 64–79; https://doi.org/10.1097/JSM.0000000000000707.

[5] Giboin L.-S., Gruber M., Kramer A. (2015): *Task-specificity of balance training*, Human Movement Science, 44, pp. 22–31; https://doi.org/10.1016/j.humov.2015.08.012.

[6] Gorwa J., Michnik R., Nowakowska-Lipiec K. (2021): *In Pursuit of the Perfect Dancer's Ballet Foot. The Footprint, Stabilometric, Pedobarographic Parameters of Professional Ballet Dancers*. Biology, 10(5),435; https://doi.org/10.3390/biology10050435.
[7] Guss-West C., Wulf G. (2016): *Attentional focus in classical ballet: a survey of professional dancers*. Journal of Dance Medicine and Science, 20(1), pp. 23-29; https://doi.org/10.12678/1089-313X.20.1.23.
[8] Hawrylak A., Chromik K., Ratajczak, B., Barczyk-Pawelec K., Demczuk-Włodarczyk E. (2017): *Spinal range of motion and plantar pressure in sport climbers*. Acta of Bioengineering and Biomechanics, 19(2), pp. 169–173; https://doi.org/10.5277/ABB-00647-2016-01.
[9] Janura M., Procházková M., Svoboda Z., Bizovská L., Jandová S., & Konečný P. (2019): *Standing balance of professional ballet dancers and non-dancers under different conditions*. PloSONE, 14(10), e0224145; https://doi.org/10.1371/journal.pone.0224145.
[10] Kimmerle M. (2010): *Lateral bias, functional asymmetry, dance training and dance injuries.* Journal of Dance Medicine & Science, 14(2), pp. 58–66.
[11] Lambert B.S., Cain M.T., Heimdal T., Harris J.D., Jotwani V., Petak S., McCulloch P.C. (2020): *Physiological Parameters of Bone Health in Elite Ballet Dancers*. Medicine & Science in Sports & Exercise, 52(8), pp. 1668–1678; https://doi.org/10.1249/MSS.0000000000002296.
[12] López-López D., Fernández-Espiño C., Losa-Iglesias M.E., Calvo-Lobo C., Romero-Morales C., Rodríguez-Sanz D., Navarro-Flores E., Becerro-de-Bengoa-Vallejo R. (2020): *Women's Foot Health-Related Quality of Life in Ballet Dancers and Nondancers*. Sports health, 12(4), pp. 347–351; https://doi.org/10.1177/1941738120922962.
[13] Makuszewska A. (2019): *A student, a spectator, an artist – educational values of dance and dance theatre heritage in teaching children and young people*. Annales Universitatis Paedagogicae Cracoviensis. Studia de Cultura, 11(2), pp. 49–59; https://doi.org/10.24917/20837275.11.2.4. [Polish].
[14] Mohanty P.P., Pattnaik M. (2017): *Effect of stretching of piriformis and iliopsoas in coccydynia.* Journal of Bodywork and Movement Therapies, 21(3), pp. 743–746; https://doi.org/10.1016/j.jbmt.2017.03.024.
[15] Molinaro L., Taborri J., Montecchiani M., Rossi S. (2020): *Assessing the Effects of Kata and Kumite Techniques on Physical Performance in Elite Karatekas*. Sensors, 20(11), 3186; https://doi.org/10.3390/s20113186.
[16] Sands W.A., McNeal J.R., Penitente G., Murray S.R., Nassar L., Jemni M., Mizuguchi S., Stone M.H. (2016): *Stretching the Spines of Gymnasts: A Review*. Sports Medicine, 46(3), pp. 315–327; https://doi.org/10.1007/s40279-015-0424-6.
[17] Sheppard A., Broughton M.C. (2020): *Promoting wellbeing and health through active participation in music and dance: a systematic review*. Inter-

national Journal of Qualitative Studies on Health and Well-being, 15(1), 1732526; https://doi.org/10.1080/17482631.2020.1732526.

[18] Smith T.O., Davies L., de Medici A., Hakim A., Haddad F., Macgregor A. (2016): *Prevalence and profile of musculoskeletal injuries in ballet dancers: A systematic review and meta-analysis*. Physical Therapy in Sport, 19, pp. 50–56; https://doi.org/10.1016/j.ptsp.2015.12.007.

[19] Steinberg N., Siev-Ner I., Peleg S., Dar G., Masharawi Y., Zeev A., Hershkovitz I. (2012): *Joint range of motion and patellofemoral pain in dancers*. International Journal of Sports Medicine, 33(7), pp. 561–566; https://doi.org/10.1055/s-0031-1301330.

[20] Swain C., Whyte D.G., Ekegren C.L., Taylor P., McMaster K., Lee Dow C., Bradshaw E.J. (2019): *Multi-segment spine kinematics: Relationship with dance training and low back pain*., Gait &Posture, 68, pp. 274–279. https://doi.org/10.1016/j.gaitpost.2018.12.001.

Deklaracja braku konfliktu interesów

Autor deklaruje brak potencjalnych konfliktów interesów w odniesieniu do badań, autorstwa i/lub publikacji artykułu *Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers.*

Finansowanie

Autor nie otrzymał żadnego wsparcia finansowego w zakresie badań, autorstwa i/lub publikacji artykułu *Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers*.

Declaration of Conflicting Interests

The author declared no potential conflicts of interests with respect to the research, authorship, and/or publication of the article *Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers.*

Funding

The author received no financial support for the research, authorship, and/or publication of the article *Spine and Hip Range of Motion and Foot Morphology in Adolescent Female Ballet Dancers*.