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The impact of contemporary dance on foot alignment in dancers aged 18–25

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Abstract

Study aim: The aim of this study was to assess foot alignment in individuals aged 18–25 who practise contemporary dance, compared to a reference group of individuals of the same age who do not practise dance

Material and methods: The study included 25 dancers aged 18–25 and 25 non-dancing individuals aged 22–25. The dancers were members of the ”Strecz” Contemporary Dance Ensemble in Krosno and the ”Agitatus” Contemporary Dance Group in Cracow. The control group consisted of students from the Jagiellonian University Medical College. Foot alignment was assessed using the Foot Posture Index (FPI-6). The right and left feet were evaluated separately, and the foot with the greater deviation from the norm was selected for final analysis.

Results: A higher frequency of normal foot alignment was observed among the dancers (88% vs. 56%). While not all individual test elements reached statistical significance, the final analysis revealed a statistically significant difference between the groups ($p = 0.012$), indicating that contemporary dance training may contribute to healthier foot biomechanics.

Conclusions: Amateur contemporary dance training appears to have a positive effect on foot alignment in dancers. Therefore, it may be considered a preventive strategy to support foot health.

Keywords: Contemporary dance – Foot alignment – Foot biomechanics – Foot function – Postural control – Injury prevention

1. Introduction

The foot is a key part of the human body and, as the part of the body in contact with the ground, it provides stability and balance. The foot can be divided into four parts: forefoot, midfoot, rearfoot and phalanges. The rearfoot consists of the ankle bone and the heel bone; the midfoot is made up of the scaphoid bone, the cuboid bone and the three sphenoid bones; and the forefoot comprises the five metatarsal bones. The hallux is formed by two phalanges, proximal and distal, while the other four toes have three bones: the proximal, middle and distal phalanges (Abboud, 2002). The foot, as an integral part of the musculoskeletal system, plays an important role in stabilising the body and maintaining correct posture. In order to respond optimally to ground reactions while walking, it needs the active participation of a number of muscles located in its area and those in the proximal parts of the body. Such collaboration allows the body to achieve complex movement dynamics (Arnold et al., 2017). Therefore, even small disturbances and discomforts in the more proximal sections can affect foot alignment. Conversely, changes in the feet have a real impact on what happens to the rest of the body. A study (Gulrandhe et al., 2023) additionally found an association of excessive tension in the ischiofemoral muscles with impaired foot alignment and altered foot biomechanics during walking.

Locomotion is the primary function of the feet. When the heel makes contact with the ground, the body’s centre of gravity shifts upwards and forwards. Together with the rebound of the forefoot in the metatarsophalangeal joints area, this allows for reduced energy consumption, during both walking and running (Asghar et al., 2022). Bipedalism in itself is possible due to evolutionary processes that have occurred in human feet, including the development of the medial longitudinal arch of the foot and the permanent adduction of the toe (McKeon et al., 2015). All the bony and muscular structures in the foot develop and are already subjected to high loads or shearing and stretching forces from birth. This enables its correct development, which allows for upright posture, balance and gait (Bosch et al., 2010). The mechanism that enables humans to walk properly can

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be compared to the action of a spring. During locomotion, the feet, together with the entire ankle and shin complex, significantly influence the ergonomics of the movements that take place, and the energy that accompanies movement is dissipated due to the action of flexible structures (Riddick et al., 2019). These structures, combined with the stability of the foot and the ankle and shin joint, allow for the adaptation of gait to a variety of challenging environmental conditions, for example, the curvature of the terrain (Arnold et al., 2017). The strong and defined Achilles tendon and the strong plantar aponeurosis allowed the foot to adapt to this type of activity (McKeon et al., 2015).

Various foot misalignments can affect gait biomechanics. The function of the feet depends on their shape. A foot with a low arch (flat foot) is more mobile than one with a high arch (hollow foot). In this case, there is a greater risk of injury due to incorrect movement and rotation of the joints when walking or running. In a foot with a high arch, the mechanism will differ. Such feet are less mobile and injuries may result from poorer shock absorption by the lower limbs (Buldt et al., 2013; Razeghi & Batt, 2002). Reduced pressure on the fourth and fifth metatarsal bone heads was observed (Buldt et al., 2018) in the flat foot in comparison with the hollow foot, as well as the normal foot. Interestingly, there was no increased impact on this area of the hollow foot compared to the normal foot. In addition, in the case of the foot with a low arch, the load on the toe was intensified with the simultaneous reduction of the pressure on the head of the first metatarsal bone. In the foot with a high loading arch, the pressure forces were distributed inversely, with greater forces acting on the midfoot than on the toe. Another important factor that changes the gait pattern is pain within the foot itself. In an attempt to protect themselves from it, patients avoid certain directions, but such activities only exacerbate the progression of a disorder. Depending on which foot area is painful, the compensations occurring in the foot will differ. Pain in the rearfoot results in a significant weight transfer to the forefoot, whereas patients with forefoot pain put more weight on the midfoot and rearfoot (Riskowski et al., 2015; Kangas et al., 2011).

The foot not only functions during movement, but also provides support for the entire lower limb and pelvis. These structures, in turn, create support for the upper body. This combination of tissues will carry the various stresses and strains to which the human body is subjected. The key correlation occurs between the deep muscles responsible for central stabilisation and the feet. Dysfunction of these muscles will result in the appearance of compensation in the peripheral parts of the body, which may also lead to the development of disorders of the foot (Lewit & Lepšíková, 2012).

Foot muscle training and core muscle exercises are important to prevent improper foot alignment, especially excessive pronation and lowering of the longitudinal arches (Sánchez-Rodríguez et al., 2020; Lee et al., 2019). Short foot exercises involve the structures located in the sole of the foot, such as the toe abductor muscle, short toe flexor muscle and quadratus plantae muscle. Each is designed to keep the medial longitudinal arch stable and maintain its proper position when it comes under load during functional movements. The toe abductor muscle plays an important role in the foot pushing off during gait; strengthening this muscle can increase the angle of the longitudinal arch and counteract the lowering of the scaphoid bone. The above muscle structures are also responsible for maintaining static balance, such as in standing on one leg (Brijwasi & Borkar 2023).

Although based on ballet, contemporary dance is characterised by a looser form. Dancers are subjected to extreme exertion while performing complex combinations of movements and jumps. To perform well on stage, they need strong muscles and stable joints, as well as good fitness. People who practise this style of dance do so barefoot, so their feet are put under considerable strain during each training session and performance. The aim of this study was to assess foot alignment in individuals aged 18–25 who practise contemporary dance, compared to a reference group of individuals of the same age who do not practise dance The specific objectives included:

- Assessment of ankle bone and heel bone alignment in the study group.
- Assessment of foot supination and pronation in the study group.
- Assessment of the talonavicular joint area and the height of the foot arch in the study group.
- Final assessment of foot alignment in the study group.

2. Material and methods

2.1. Characteristics of the study group

The study included a test group and a control group. The test group comprised contemporary dancers from the Strecz Contemporary Dance Group in Krosno and the Agitatus Contemporary Dance Group in Cracow. The control group consisted of students from the Jagiellonian University Medical College who were not involved in dance. The participants in the study were amateur contemporary dancers. Training sessions, while regular, were held only twice a week, with each session lasting 1.5 to 2 hours. The dancers had a minimum training experience of one year, and none reported practising any other dance style besides contemporary dance.

The study involved 50 participants: 25 dancers and 25 non-dancers. The age of the study participants ranged from 18 to 25 years. The test group consisted of 25 women, while the reference group consisted of 21 women and 4 men. The reference group was composed of non-dancers matched for age with the dancer group, which highlights the strength of the study design. The dancer group had a mean age of 19.36 ± 1.93, while the non-dancer group had a mean age of 23.36 ± 0.79 years.

The members of the test group were enrolled in the study on the basis of meeting the relevant eligibility criteria: a contemporary dance artist, aged 18–25 and willing to participate in the study. The participants in the control group were recruited based on the following criteria: non-dancers, aged 18–25 and willing to participate in the study.

2.2. Study methods, techniques and tools

The study used qualitative methods such as observation and manual examination. The technique used during the study was a questionnaire survey. The tool indispensable for the performance of the study was the Foot Posture Index (FPI-6) (Physiopedia, 2024), which comprises an examination of six components: ankle bone alignment, foot pronation/supination, heel bone alignment, talonavicular joint area, foot arch performance and foot alignment (Figure 1).

For each component, no points were given for a normal state, 1 point for pronation, 2 points for excessive pronation, −1 point for supination and −2 points for excessive supination. Statistical and econometric methods, including the chi-square test, were used for the qualitative variables collected. Statistical analysis was performed using the chi-square test in SPSS. Statistical significance values were assessed at $p < 0.05$.

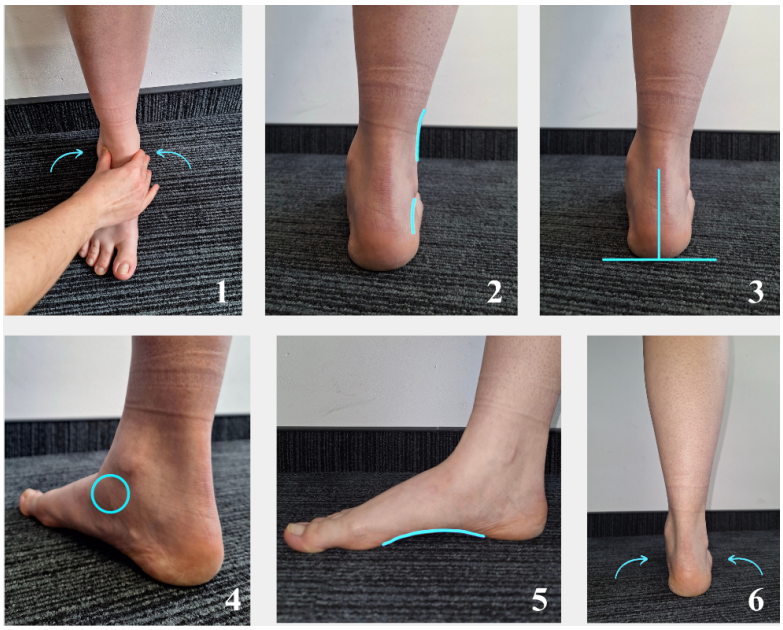

Figure 1. Assessment of foot alignment according to FPI-6

Source: own elaboration.

The research was approved by the Research Ethics Committee of the Jagiellonian University Medical College, No. 118.0043.1.386.2024, dated November 25, 2024. Consent was obtained from the organisations to which the dance groups belonged, as well as informed consent from all participants prior to their participation in the study. The study was conducted in accordance with the Declaration of Helsinki.

3. Results

The side that presented a greater deviation from the norm was selected to assess each study item. In the next step, a classification was established with two categories: normal (0 points) and abnormal (−2/−1/1/2 point/s).

3.1. Effect of practising contemporary dance on ankle bone and heel bone alignment

In the observation of ankle bone alignment, majority of dancers scored normal. In the ankle bone assessment, the mean score was 0.48 ± 0.50 in the dancer group and 0.80 ± 0.89 in the non-dancer group. Taking into account the division between normal and abnormal ankle bone alignment, the differences between the groups were not significant.

The chi-square test result for ankle bone alignment was found to be statistically non significant, indicating no statistically significant relationship between contemporary dance training and correct ankle bone alignment in dancers. The details are shown in Table 1.

In the observation of heel bone alignment, majority of dancers had normal results. In the heel bone assessment, the mean score was 0.40 ± 0.49 in the dancer group and 0.72 ± 0.72 in the non-dancer group. When divided into normal and abnormal results, the differences between the groups were not large.

The chi-square test result for heel bone alignment was found to be statistically non significant, indicating no statistically significant relationship between contemporary dance training and correct heel bone alignment in dancers. The details are shown in Table 1.

Table 1. Characteristics of ankle bone alignment and heel bone alignment in the study group divided into normal and abnormal

			Ankle bone alignment		*p* value	Heel bone alignment		*p* value
			Normal	Abnormal		Normal	Abnormal	
Study group	Dancer	Number	**13**	**12**	**0.395**	**15**	**10**	**0.258**
		% of group	52.0%	48.0%		60.0%	40.0%	
	Non-dancer	Number	**10**	**15**		**11**	**14**	
		% of group	40.0%	60.0%		44.0%	56.0%	

Source: own elaboration.

3.2. Effect of practising contemporary dance on supination and pronation of the feet

In the observation of foot pronation/supination, majority of dancers and subjects in the reference group had normal results. In the pronation/supination assessment, the mean score was 0.40 ± 0.49 in the dancer group and 0.68 ± 0.73 in the non-dancer group. When divided into normal and abnormal, there were few differences between the groups.

The chi-square test result for the final assessment of foot pronation/supination was found to be statistically non-significant, indicating no statistically significant relationship between modern dance training and correct foot alignment in the context of excessive foot pronation/supination in dancers. The details are shown in Table 2.

In the observation of foot alignment, majority of dancers had normal results. In the foot alignment assessment, the mean score was 0.28 ± 0.60 in the dancer group and 0.76 ± 0.90 in the non-dancer group. In the division between normal and abnormal foot alignment, differences between the test group and the reference group were not large.

The chi-square test result for foot alignment was found to be statistically non significant, indicating no statistically significant relationship between contemporary dance training and correct foot alignment in dancers. The details are shown in Table 2.

Table 2. Characteristics of foot pronation/supination and foot alignment in the study group divided into normal and abnormal

			Foot pronation/supination		*p* value	Foot alignment		*p* value
			Normal	Abnormal		Normal	Abnormal	
Study group	Dancer	Number	**15**	**10**	**0.569**	**14**	**11**	**0.396**
		% of group	60.0%	40.0%		56.0%	44.0%	
	Non-dancer	Number	**13**	**12**		**11**	**14**	
		% of group	52.0%	48.0%		44.0%	56.0%	

Source: own elaboration.

3.3. Effect of practising contemporary dance on the talonavicular joint area and foot arch performance

In the observation of the talonavicular joint area, majority of dancers and subjects in the reference group had normal results. In the talonavicular joint area assessment, the mean score was 0.28 ± 0.45 in the dancer group and 0.60 ± 0.69 in the non-dancer group. In the division between normal and abnormal alignment, abnormality occurred more frequently in the reference group.

The chi-square test result for talonavicular joint area alignment was found to be statistically non-significant, indicating no statistically significant relationship between contemporary dance training and correct talonavicular joint area alignment in dancers. The details are shown in Table 3.

In the observation of arch performance, a normal result was observed in minority of dancers and non-dancers. In the arch performance assessment, the mean score was 0.68 ± 0.68 in the dancer group and 0.80 ± 0.89 in the non-dancer group. In the division between normal and abnormal performance, abnormality occurred more frequently in the group of dancers.

The chi-square test result for the final assessment of foot arch performance was found to be statistically non-significant, indicating no statistically significant relationship between contemporary training and correct foot arch performance in dancers. The details are shown in Table 3.

Table 3. Characteristics of talonavicular joint area alignment and foot arch performance in the study group divided into normal and abnormal

			Talonavicular joint area alignment		*p* value	Foot arch performance		*p* value
			Normal	Abnormal		Normal	Abnormal	
Study group	Dancer	Number	**18**	**7**	**0.145**	**11**	**14**	**0.774**
		% of group	72.0%	28.0%		44.0%	56.0%	
	Non-dancer	Number	**13**	**12**		**10**	**15**	
		% of group	52.0%	48.0%		40.0%	60.0%	

Source: own elaboration.

3.4. Final assessment of foot alignment

The results obtained from the FPI-6 questionnaire were used to assess foot alignment. There were five categories: normal (0 to 5 points), pronation (6 to 9 points), excessive pronation (10 to 12 points), supination (−4 to −1 points) and excessive supination (−12 to −5 points). The results were calculated separately for the right and left foot. Normal results for the right foot were achieved by majority of dancers and subjects in the reference group. The mean score was 1.8 ± 1.94 in the dancer group and 3.6 ± 4.13 in the non-dancer group. For the left foot, it was majority of dancers and non-dancers, respectively. The mean score was 1.84 ± 2.03 in the dancer group and 4.04 ± 3.93 in the non-dancer group.

In the assessment of right foot alignment, pronation occurred with lower frequency in the group of dancers; excessive pronation occurred only in the reference group of the non-dancers. Supination was observed more frequently in the non-dancers group.

The chi-square test result for right foot alignment was found to be statistically significant, indicating a statistically significant relationship between contemporary dance training and correct right foot alignment in dancers. The details are shown in Table 4.

Table 4. Assessment of right foot alignment

			Right foot alignment				*p* value
			Normal	Pronation	Excessive pronation	Supination	
Study group	Dancer	Number	**23**	**1**	**0**	**1**	**0.029**
		% of group	92.0%	4.0%	0.0%	4.0%	
	Non-dancer	Number	**14**	**7**	**2**	**2**	
		% of group	56.0%	28.0%	8.0%	8.0%	

Source: own elaboration.

In the assessment of left foot alignment, pronation occurred with greater frequency in the non-dancers group; excessive pronation occurred only in the reference group. Supination was observed equally in both groups.

The chi-square test result for left foot alignment was found to be statistically non-significant, indicating no statistically significant relationship between contemporary dance training and correct left foot alignment in dancers. The details are shown in Table 5.

For the final assessment of foot alignment, each subject was assigned a score that was at a greater deviation from the norm. Two categories emerged: normal (0 to 5 points) and abnormal (-12 to -1 or 6 to 12). Normal results were obtained by majority of dancers and non-dancers. The mean score was 2.48 ±2.19 in the dancer group and 4.32 ± 4.10 in the non-dancer group.

More disorders were observed in the non-dancers than in dancers. Correct foot alignment was definitely predominant in the group of dancers.

The chi-square test result for final assessment of foot alignment was found to be statistically significant, indicating a statistically significant relationship between contemporary dance training and correct foot alignment in dancers. The details are shown in Table 6.

Table 5. Assessment of left foot alignment

			Left foot alignment				*p* value
			Normal	Pronation	Excessive pronation	Supination	
Study group	Dancer	Number	**23**	**1**	**0**	**1**	**0.074**
		% of group	92.0%	4.0%	0.0%	4.0%	
	Non-dancer	Number	**16**	**5**	**3**	**1**	
		% of group	64.0%	20.0%	12.0%	4.0%	

Source: own elaboration.

Table 6. Final assessment of foot alignment

			Foot alignment		*p* value
			Normal	Abnormal	
Study group	Dancer	Number	**22**	**3**	**0.012**
		% of group	88.0%	12.0%	
	Non-dancer	Number	**14**	**11**	
		% of group	56.0%	44.0%	

Source: own elaboration.

4. Discussion

The aim of the study was to investigate the effects of contemporary dance on the alignment and biomechanics of the feet in dancers and to increase knowledge of different types of dance.

The present study assessed foot alignment in people engaged in contemporary dance compared to a group of non-dancers. Although dancers with scores within the norm prevailed, the differences between the test group and the control group were not always significant. The effect of dance that proved to be statistically significant was observed when assessing the alignment of the right foot ($p = 0.029$), while the examination of left foot alignment did not produce statistically significant results. The final assessment of foot position also yielded results indicating a statistically significant relationship between dance and foot position ($p = 0.012$). The above results demonstrate the positive effect of contemporary dance on maintaining healthy and correctly aligned feet, which can be used as a preventive measure.

The results of the study showed that regular training in contemporary dance contributes to correct foot alignment, which may also be a result of improved postural control. In a study conducted by Sirois-Leclerc et al. (2017), dancers were observed with regard to the correlation between modern dance, foot alignment and postural control. The participants in that study were students and graduates of The School of Dance in Ottawa, Canada who completed a three-year programme on contemporary dance in the modern style. The reference group consisted of non-dancers. The researchers investigated how the centre of pressure changes when a subject performs different dynamic and cognitive tasks simultaneously. The dancers performed better with side-to-side body movements, and a smaller increase in their reaction time was observed. Although the differences between the two groups was not statistically significant, dance training was found to promote better postural control and faster reaction times to environmental factors.

Similar findings were reported by Kuliś et al. (2023) in a study on top-level competitors performing the Viennese waltz, where precise and coordinated movements of the pelvic girdle and thoracic spine, particularly during sway motions, were found to be essential for achieving high technical scores and maintaining balance. Arslan-Kabasakal et al. (2023) further demonstrated that forward head posture negatively impacts dynamic balance in wrestlers aged 10–12 years. On the other hand, Macan et al. (2024) detected asymmetries in postural stability and balance among sub-elite gymnasts, which were likely the result of favouring one side of the body. However, such asymmetries may contribute to tissue overload. These findings highlight that maintaining proper body posture not only supports stable balance, but may also play a critical role in reducing the risk of injuries during sports activities, emphasizing the importance of postural control for overall athletic performance.

Comparing how foot alignment is impacted by contemporary dance trained on either an amateur or professional basis may also provide interesting research findings. The results of this study show that amateur contemporary

dance training contributes to correct foot biomechanics. However, the situation of professional dancers practising this dance style is different. This aspect was investigated by Cimelli & Curran (2012), who concluded that forced turnout, i.e. resulting from rotation of the foot instead of the hip, increases foot pronation. This alignment puts more stress on the joints of the foot area. Similar conclusions were also reached by Carter et al. (2019), whose study focused on female ballet dancers. They were shown to pronate their feet to achieve the desired turnout, which, however, may increase the probability of future injuries.

The results of our study also prove that, despite the fact that the specific nature of contemporary dance has a positive effect in terms of maintaining strong muscles in and around the foot, like any professional sport, it can lead to numerous injuries. According to Werber (2011), in a variety of dance styles, the most common injuries are those affecting the ankle and shin joint, with the predominant number of injuries affecting the ligaments on the lateral side of this area.

One of the final conclusions from our study confirms the correct alignment of the feet of modern dance enthusiasts in their static posture. Rowley et al. (2015) extended the investigation of this aspect to the context of dynamic foot alignment, during a functional study of dancers' feet. They observed a greater range of extension in the first metatarsophalangeal joint in study subjects standing in the demi-point position. The dancers also had better results in maintaining balance while standing on one foot on tiptoe. Comparing the results of our study with those of other authors, we concluded that dance supports the maintenance of correct static as well as dynamic biomechanics.

The limitations of this study included the relatively small number of participants and the undetermined duration of their involvement in amateur dancing. Future research could broaden the scope by applying more specific inclusion and exclusion criteria. Additionally, the study could be extended to examine the distribution of loads acting on the feet using a strain gauge platform and to analyse gait by means of specialised tools such as a baropodometric treadmill.

Future research directions in the field of foot alignment in dancers should emphasize the importance of developing individualized interventions, particularly in relation to footwear adapted to specific dance styles and individual foot morphology. Such approaches may help to optimize biomechanical efficiency, enhance performance, and simultaneously reduce the risk of overuse injuries. In addition, educational interventions – such as professional footwear counselling and the dissemination of evidence-based educational materials – should be considered an essential element in promoting dancers' foot health.

5. Conclusions

The main objective of this study – The aim of this study was to assess foot alignment in individuals aged 18–25 who practise contemporary dance, compared to a reference group of individuals of the same age who do not practise dance – was successfully achieved, as were the specific objectives. Although no significant differences in foot alignment were observed between the test group and the reference group in the analysis of the individual components of the FPI-6 test, the final results were in favour of the group of dancers: a statistically significant difference was observed between the groups with regard to correct foot alignment. These results support the conclusion that contemporary dance training is beneficial for the correct alignment and biomechanics of dancers' feet. In addition, contemporary dance training can help maintain correct postural control and, even in its amateur form, serve as a preventive strategy to support healthy feet, improve body posture and gait patterns, and reduce the risk of future injuries and overloads. Furthermore, contemporary dance contributes to the maintenance of proper balance, which, in conjunction with correct foot alignment, reduces the risk of injuries and falls. This may also have long-term benefits, as regular practice of contemporary dance can potentially delay age-related declines in mobility. Additionally, the expressive and integrative nature of dance supports psychological well-being, as it enhances body awareness and helps to reduce stress, thereby promoting overall health.

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