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Original research papers

DIFFERENCES IN BALANCE ABILITY BETWEEN FEMALE DANCERS AND ACTIVE NON-DANCERS

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Abstract

Introduction. Balance is used in almost every movement task; it is a complex process that requires control and is based on the interaction of the musculoskeletal and nervous systems. It depends on many external and internal factors, which include genetics, age, center of gravity, support area, emotional state, concentration, strength, coordination skills, flexibility, and visual control, as well as the frequency of participation in motor activities and training status. The study aimed to compare the balance of female dancers and non-dancers using the MyoPressure-T Noraxon FDM-T AC 5000m baroresistive treadmill. ***Material and Methods.*** The study involved a total of 128 women aged 20-26 in two groups: dancing and non-dancing. Based on the tests performed, the center of gravity deflection, the length of the COP (center of pressure) path, and the reaction of ground forces in both groups were analyzed. Additionally, an analysis of lower limb loads during walking and running was performed using the parameter Force max. [N] – maximum pressure force. The hypotheses of normal distribution were rejected using the Shapiro-Wilk test for all variables. The hypotheses of equal variance for all variables were rejected using the F test. The nonparametric Kruskal-Wallis test was used to assess the significance of differences and the effect size between the study groups. ***Results.*** The results of the dancers (95% confidence ellipse area) were better than those of the control group. This is visible in both the Romberg test with open and closed eyes. In the case of COP average velocity, there are no differences with open eyes, but statistically significant differences appeared in the test with closed eyes. The analysis of Maximum Force, N, during walking did not show statistically significant differences between the groups. They appeared only while running in favor of the dancers. ***Conclusions.*** The study results confirm the hypothesis that women who dance have better static balance than women who do not participate in dance classes. The study provides new evidence regarding balance in dancers and non-dancers.

Key words: balance, dance, postural stability, biomechanics, contemporary dance

Introduction

Balance is one of the most important human motor skills, and at the same time, it is a complex process that requires control and is based on the interaction of the musculoskeletal and nervous systems. It is used in almost every motor task [1]. This ability involves controlling the position of the body in space and maintaining its vertical orientation, which is established using many sensory references, including gravity (vestibular system), support surface (somatosensory system), proprioception, and the body's relationship to objects in the environment (visual system) [2].

The correct orientation of the body in space and maintaining balance in physiological conditions are ensured by information from the vestibular system, deep sensation receptors located in muscles, joints, and skin, and the organ of vision [3]. All data from the visual, somatosensory, and vestibular systems must be integrated and then processed in the central nervous system into efferent (motor) commands to activate the appropriate motor reactions necessary to maintain balance [3, 4, 5].

Body balance depends on many external and internal factors, including genetics, age, center of gravity, support area, emotional state, concentration, strength, coordination skills, flexibility, visual control, and the frequency of participation in motor activities and training status [6].

Balance ability is divided into two components: static and dynamic balance. Static balance is defined as the ability to maintain the body on a stable surface at rest, with minimal deviation from the established position. Dynamic balance is defined as the ability to maintain the body position in motion or on an unstable surface. It is the ability to maintain stability while shifting weight, often while changing the base of support [2]

Dance places high demands on the musculoskeletal system and influences motor behavior. It is based on coordination skills and complex body movements to the rhythm of music. Dancers usually participate in training and perform dance routines that require extensive control of body posture. On this basis, it can be argued that training and dance practice can improve balance over time. Studies appearing in the literature suggest a positive relationship between postural balance and dance experience. Stage performance, a dance based on various choreographic structures and dance techniques, is a complex act that includes almost all components of coordination and motor skills [7]. Dancers are expected to have a highly advanced sense of awareness in relation to body position and movement [8].

In the art of dance, the basic sensory modalities are proprioception and vision. However, it is difficult to precisely determine, based on previous research, which of the modalities are dominant. Dancers who rely more on proprioception than visual stimuli are characterized by better balance skills [9]. However, the importance of visual stimuli should not be underestimated. In the case of classical dancers, based on the research of Hugle et al., they play a dominant role in maintaining balance [10]. However, the visual conditions of the dancer vary significantly depending on the nature and environment of dance performances. This situation can also have a negative impact on the performance of dynamic balance. Individual dance techniques, types and forms of dance, and stage presentations determine behaviors and the way of approaching this issue. An important issue in the field of balance research in relation to dance art also seems to be the appropriate selection of tools and tests in the context of functionality and validity for assessing this ability [11]. The problems in question, their scope, and their complexity make any type of research and exploration into the balancing abilities of dancers critical.

Knowledge of balance issues can significantly affect the training process and dance preparation. First, understanding specific aspects of balance in the context of dancers can provide important information about its general condition. Second, the dancer's ability to maintain balance during dance movements allows a better understanding of his control over postural stability and its impact on dance technique.

The study aimed to compare the balance of female dancers and non-dancers using the MyoPressure – T Noraxon FDM-T AC 5000m baroresistive treadmill.

Based on the tests performed, the deflection of the center of gravity, the length of the COP (center of pressure) path, and the reaction of ground forces in both study groups were analyzed. Additionally, an analysis of lower limb loads during walking and running was performed using the parameter Force max. (N) – maximum pressure force.

Material and methods

The study involved a total of 128 women aged 20-26 in two groups: dancing and non-dancing. In the group of dancers, 65 students of the Institute of Choreography and Dance Techniques of G. and K. Bacewicz Academy of Music in Łódź, representatives of contemporary dance with at least 5 years of dance experience, were examined. The control group consisted of non-dancers, 63 students (women) of physiotherapy at Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health in Biała Podlaska. All examinations were conducted at the Regional Research and Development Center in Biała Podlaska, in the Biomechanics and Kinesiology Laboratory.

Participants were informed about the purpose of the study and signed written consent. The study was approved by the Ethics Committee of Józef Piłsudski University of Physical Education in Warsaw (SKE 01-05/2021), and the procedures presented were in accordance with the ethical standards regarding experiments specified in the Declaration of Helsinki.

During the static postural stability test, participants were instructed to stand barefoot on a level, stationary, baroresistive treadmill, with their feet parallel and hip-width apart. The project participants maintained an upright posture with their arms stretched out in front of them, their heads facing forward – depending on the test, with their eyes open or closed. The knees were fully straightened throughout the measurement in an active, non-relaxed state. The test lasted 30 seconds. The project used the possibilities of the baroresistive treadmill to record lower limb pressures during walking and running. This enabled a comparison of the study groups in terms of load amortization during these motor activities. In the case of these tests, the treadmill was elevated at an angle of 10 degrees.

The MyoPressure – T Noraxon FDM-T AC 5000m baroresistive treadmill was used for the measurements. Four measurements were performed at a sampling frequency of 100 Hz:

- Romberg test with eyes open (30 s),
- Romberg test with eyes closed (30 s),
- Walking analysis at 4 km/h (20 s),
- Running analysis at 10 km/h (20 s).

Static balance analysis was performed using the following parameters:

- 95% confidence ellipse area (mm^2) – 95% of the area over which the projection of the center of gravity moves on the support plane. This area is treated as the primary indicator of overall postural efficiency, and it is generally believed that the smaller the area, the better the postural balance.
- COP average velocity (mm/s) – the center of pressure average velocity. COP velocity is an indicator of the efficiency of the postural control system, and the smaller it is, the better.

The analysis of lower limb loads during walking and running was performed for both limbs using the parameter Force max. (N) – maximum pressure force.

Statistical analysis

The hypotheses of normal distribution were rejected using the Shapiro-Wilk test for all variables. The hypotheses of equal variances for all variables were rejected using the F test. The nonparametric Kruskal-Wallis test was used to assess the significance of differences and the effect size between the study groups. Calculations were performed using the R software [12] and the rstatix library [13].

Results

Based on the obtained data, it should be stated that the results of the dancers are better than those of the non-dancing control group. This is visible in both the Romberg test with eyes open and closed (95% confidence ellipse area). A higher value in this parameter: with eyes open in the non-dancers group, the average value of 187.033 ± 143.5989, in the test with eyes closed, 307.639 ± 224.308 indicates a greater deviation in COP and worse postural balance. In the case of COP average velocity, the results of both groups are similar during the test performed with eyes open. However, the advantage in favor of the dancers is visible in the test when the eyes are closed. The average value of the velocity of the center of gravity during the test with eyes closed in the control group was 13.656 ± 6.534, while in the dance group, it was 10.905 ± 3.481 (Tab. 1).

A significant effect of group membership was confirmed for variables such as 95% confidence ellipse area with eyes open at the level of $p < 0.05$ and eyes closed at the level of $p < 0.01$. There are no differences with eyes open, but statistically significant differences with eyes closed at the level of $p < 0.01$ may indicate significantly better proprioception in dancers.

During walking, there are no statistically significant differences; they appear only during running, both in the case of the right and left leg at the level of $p < 0.01$ in favor of dancers (Maximum Force, N) (Fig. 1-8). The descriptive characteristics of the Kruskal-Wallis test, the significance of differences, and effect size are presented in Table 2.

For the purpose of a complete illustration of the research results for both groups, the Z-score normalization formula was used for each variable. The results of the dance group were presented against the background of the control group of non-dancers (Fig. 9).

Table 1. Selected parameters of static balance tests in the control and dance groups

	Control group			Dance group		
	x	Me	± SD	x	Me	± SD
95% confidence ellipse area	187.033	153.000	143.598	139.048	99.000	130.299
95% confidence ellipse area – eyes closed	307.639	249.000	224.308	221.889	205.000	165.746
COP average velocity, mm/sec	7.967	7.000	4.095	7.016	6.000	3.215
COP average velocity, mm/sec – eyes closed	13.656	12.000	6.534	10.905	10.000	3.481
Maximum, N, walking/left leg	681.885	696.000	84.886	606.873	600.000	88.262
Maximum, N, walking/right leg	681.049	695.000	84.728	607.032	605.000	83.492
Maximum, N, running/left leg	1282.164	1293.000	205.103	1191.889	1165.000	194.383
Maximum, N, running/right leg	1290.410	1289.000	213.228	1187.524	1193.000	182.218

Table 2. Differences and effect size of selected parameters in balance tests between the control and dance groups

	Kruskal test	p	esize	95% ci
95% confidence ellipse area	6.22	0.012*	0.043	-0.005 - 0.14
95% confidence ellipse area – eyes closed	7.80	0.005**	0.056	-0.002 - 0.16
COP average velocity, mm/sec	1.52	0.217	0.004	-0.008 - 0.06
COP average velocity, mm/sec – eyes closed	6.70	0.009**	0.047	-0.004 - 0.16
Maximum, N, walking/left leg	22.70	1.904	0.178	0.07 - 0.32
Maximum, N, walking/right leg	20.32	6.533	0.158	0.05 - 0.3
Maximum, N, running/left leg	7.50	0.006**	0.053	-0.004 - 0.16
Maximum, N, running/right leg	8.94	0.002**	0.065	-0.0002 - 0.18

*** – p < 0.001, ** – p < 0.01, * – p < .05.

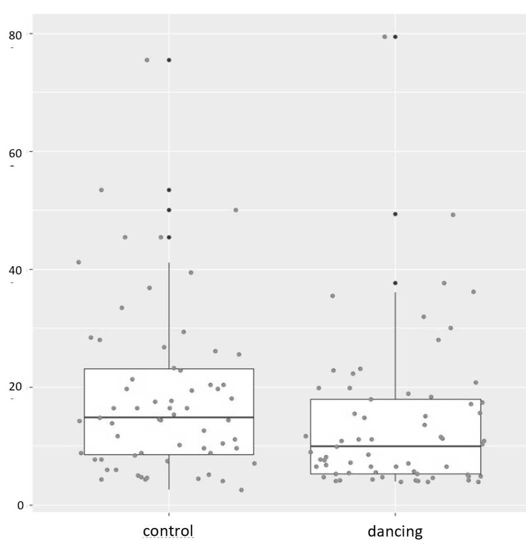

Figure 1. 95% confidence ellipse area

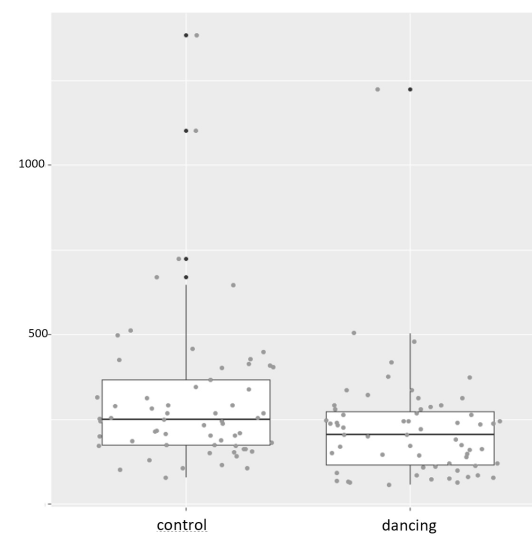

Figure 2. 95% confidence ellipse area – eyes closed

Discussion

The conducted research aimed to compare the balance of female dancers representing contemporary dance with at least 5 years of experience studying this discipline and non-dancers using the MyoPressure – T Noraxon baroresistive treadmill. Based on the tests performed, it can be concluded that the dance group had an advantage over the control group. However, this did not apply to all variables considered in this case.

There are many studies in the available literature on comparisons of dancers and non-dancers using various tests and tools. The results presented here correspond with the results of other authors [14].

In the study of Jatin et al., dancers had better balance than non-dancers only in some of the proposed tests. Dancing can improve balance, but there are no clear indications that it is better than other forms of physical activity [14]. Similarly, in their study, Kuczyński et al. claim that postural control in dancers

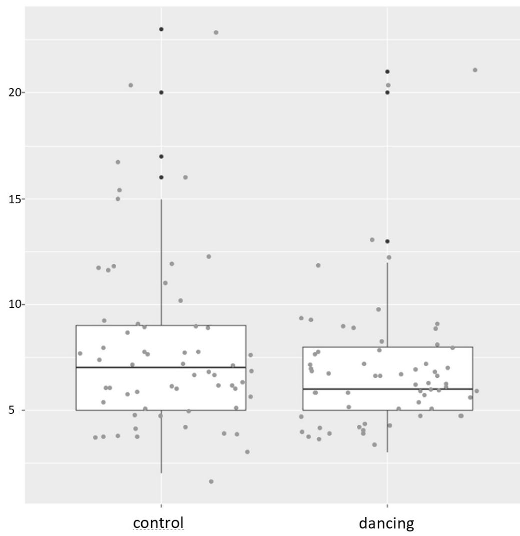

Figure 3. COP average velocity, mm/sec

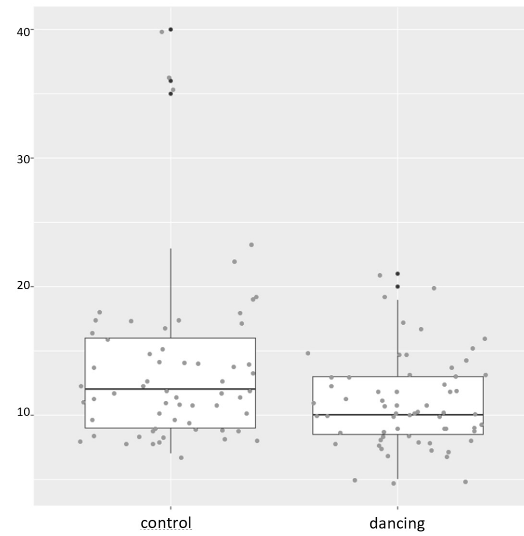

Figure 4. COP average velocity, mm/sec – eyes closed

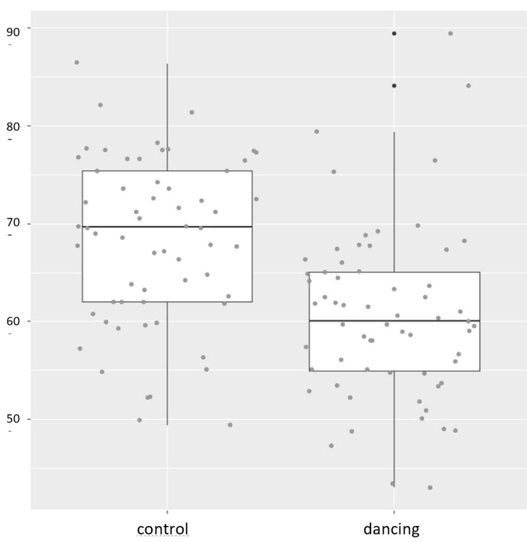

Figure 5. Maximum, N, walking/left leg

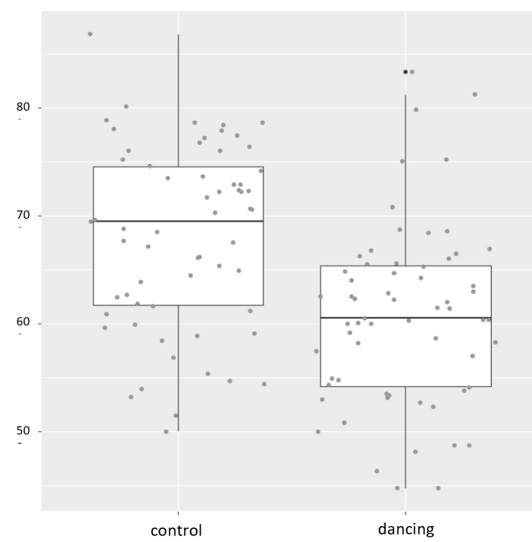

Figure 6. Maximum, N, walking/right leg

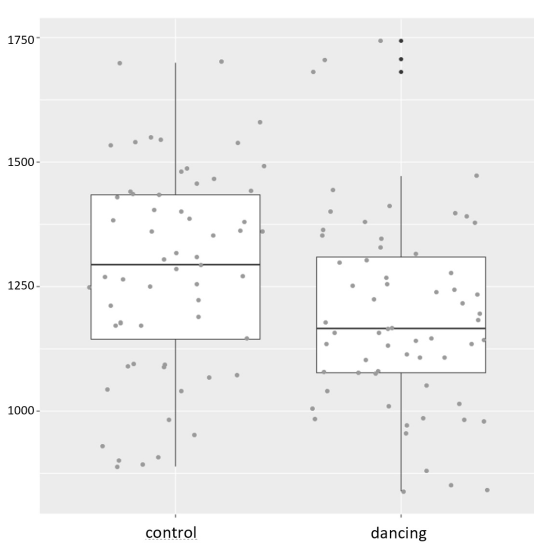

Figure 7. Maximum, N, running/left leg

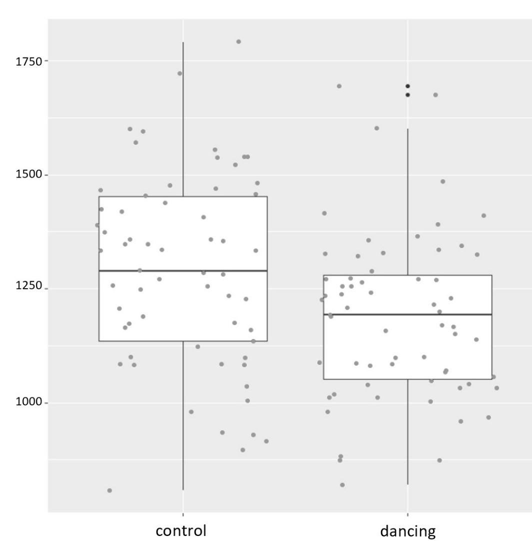

Figure 8. Maximum, N, running/right leg

and non-dancers is at a similar level, but dance does seem to facilitate an increased level of automatic control in the antero-posterior plane [15].

In the literature, there are studies comparing the static balance of dancers and non-dancers in the bipedal and single-legged positions using a force platform. The authors found significant differences in balance between dancers and the control group in the tandem position and standing on one leg with eyes closed. In their opinion, regular dancing for several years improves static balance [5]. Dancers adapt faster after disturbing their balance and performing complex movements imitating dance than non-dancers [16]. Interesting considerations also concerned balance studies in dancers' and non-dancers' different foot positions [10, 17]. According to Harmon et al., dancing and experience gained in this field do not affect balance and motor control in the sixth position. Better balance results were noted when standing in the first ballet position. However, no differences were determined in the regular training habits of the dance and non-dance groups, which prevented precise determination of the contribution of specific aspects of physical training [17].

Hugel conducted an analysis of balance in selected classical dance positions on the half-toes and the pointe shoes [10]. The results in this area indicate the importance of visual stimuli, which, as previously indicated, are important in classical ballet. Notably, from the pointe shoes presented in the paper, classical dancers performed better than control subjects in conditions with open eyes. Similar results obtained on the pointe shoes with their eyes open or closed suggest that training in classical ballet develops specific balance modalities that cannot be transferred to postural control in everyday life situations [10]. Vision is an essential factor when undertaking balance tasks of great difficulty, which is of concern, among others, in classical dance [2]. Visual information is vital in maintaining a stable body position [4, 18]. In the case of the study by Michalska et al., when performing simple motor tasks, professional dancers have higher values of postural sway characteristics compared to non--dancers [4]. At the same time, they are characterized by higher values of the tremor component, steady standing, and leaning positions. The study by Coker et al. demonstrated that dancers showed a higher center of pressure velocity, indicating lower control during the performance of a static dance task (parallel relevé retiré) and a dynamic dance task (fondu relevé en croix) under low light conditions [19]. A slightly different thesis was put forward by Golomer et al. [20]. The authors suggested that professional dancers were less dependent on vision for dynamic postural control because dance training likely shifts sensorimotor dominance from vision to proprioception. Dancers can be trained to adopt proprioceptive strategies to maintain dynamic balance, consequently improving their balance. Such findings may encourage closed-eye training in everyday dance classes due to its potential to enhance dancers' balance control [9].

There are also many studies in the literature on the influence of physical activity on balance [8], as well as comparisons of dancers with representatives of other disciplines. In the study by Gerbino et al., dancers demonstrate better static balance skills in 5 out of 20 balance tests than soccer players [21]. In another example, in balance tests and trials with eyes open, judokas and dancers performed better than the control group, which indicates a positive effect of training on sensorimotor adaptations. However, with eyes closed, only judokas maintained a significantly better posture [22]. Comparisons of dancers within different dance techniques will also be interesting from the point of view of dance itself [23]. Dance is a discipline that requires excellent balance, and exercises in the field of coordination and motor skills are strongly associated with training programs of almost all types and forms of dance [24]. Kapodistria et al. [25] claim, based on the conducted research, that dance programs are an effective method for developing static and dynamic balance in young children. According to many authors [9, 26, 27], balance training cannot be separated from the activity of which it is an integral part, nor from the environment in which it is performed. Balance is skill-specific and should be practiced using the same technical skills required in dance performances and concerts. In training dancers, it therefore seems appropriate to choose a balance training program that is specific to dance practice [9, 26, 27]. An important issue in relation to dance training focused on balance skills and learning to jump may serve to protect against anterior cruciate ligament injury [24].

Conclusions

The study results confirm the hypothesis that women who dance have better static balance than those who do not participate in dance classes. It can be assumed that dancing improves static balance. Training can affect better cushioning, reducing the load on the musculoskeletal system and consequently reducing the risk of injuries. During walking, we are able to control our bodies; when running, automaticity appears. The study provides new evidence regarding balance in dancers and non-dancers. However, several limitations have not been fully explained and require further analysis.

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