Body asymmetries as risk factors for musculoskeletal injuries in dancesport, hip-hop and ballet dancers?

Monika Pavlović (1,2), Nina Ogrinc (3), Nejc Šarabon (2,4,5,6)

(1) University of Ljubljana, Faculty of Health Sciences, Ljubljana, Slovenia, (2) University of Primorska, Faculty of Health Sciences, Izola, Slovenia; (3) Conservatory of Music and Ballet Ljubljana, Ballet College, Ljubljana, Slovenia, (4) Ludwig Boltzmann Institute for Rehabilitation Research, Vienna, Austria; (5) InnoRenew CoE, Human Health Department, Izola, Slovenia; (6) S2P, Science to Practice, Ltd., Laboratory for Motor Control and Motor Behavior, Ljubljana, Slovenia.

Abstract

Our study aimed to determine the incidence and expression of body asymmetries in dancers of three different dance styles: dancesport (n = 14), hip-hop (n = 21) and ballet (n = 20) and to examine how body asymmetries (muscle strength and power, stability and range of motion) are associated with musculoskeletal injuries occurring over the past 12 months. In this cross-sectional and retrospective study, maximal isometric voluntary contraction was measured for trunk, hip, knee and ankle movements. Participants performed a single leg stance, unilateral landing, weight bearing symmetry, squat and countermovement jump on force platforms. Passive range of motion was measured for hip, knee and ankle with two-arm goniometer or digital inclinometer (hip flexion, extension and rotations). A retrospective questionnaire was used to collect data on musculoskeletal injuries occurring in the last 12 months. Different dance styles were associated with different body asymmetries, including strength asymmetries (hip flexion and external rotation), agonist/antagonist asymmetries (trunk flexion/extension, hip abduction/adduction, ankle dorsi/plantar flexion) and hip adduction and internal rotation range of motion asymmetries. Moreover, strength asymmetries of hip flexion, adduction and abduction/adduction as well as stability asymmetries were associated with the total number of musculoskeletal injuries. In conclusion, the incidence of body asymmetries (> 10%) in dancesport, hip-hop and ballet dancers was confirmed, as well as the association of some asymmetries with self-reported injuries occurring over the last 12 months. The cause-effect relationship should be clarified by further studies.

Key Words: Dancing; ballroom; symmetry; muscle imbalance; injury.

Eur J Transl Myol 32 (4): 11020, 2022 doi: 10.4081/ejtm.2022.11020

Symmetry, as an aspect of body geometry, can be defined as the quality of harmony in size, shape and form when the body is divided into two parts in a single plane.[1] In terms of complexity of the movement task or the involvement of the body segments, body asymmetries can be divided into local and global asymmetries. Local asymmetries are further divided into asymmetries between the left and right side of the body (contralateral) and asymmetries between opposing muscle groups of the same side of the body (agonist/antagonist). Global asymmetries, on the other hand, are manifested as inconsistencies in the performance of a larger body part during more complex movement tasks. Both local and global asymmetries depend on movement skills such as strength and power, balance and stability, and mobility and flexibility,[2] and can be defined as functional asymmetries. All those movement skills are crucial for successfully executing dance movements.[3] The International Dance Organization divides dance styles into three main groups: performing arts disciplines (ballet, jazz dance, modern and contemporary dance, oriental, etc.), street dance disciplines (hip hop, electric boogie, disco, break dance, etc.) and couple dance disciplines (Couple Dance Formations, Latin Show, Salsa, etc.). Dance styles within individual group are distinguished from each other mainly by the way of movement. For example, in ballet movements are more commonly performed at the right side of the body, which may lead to body asymmetries.[4] Dancers perform many repetitive and, in terms of mobility, extreme movements, resulting in high forces affecting mainly lower limbs and spine.[5,6] Hence, lower limbs and spine are the most commonly injured areas in dancesport,[7] ballet,[8] and hip hop dancers.[9] Besides extreme mobility and force exposure, injuries might be the consequence of these risk factors combined with other such as age, smoking, gender, somatotype, low percentage of body fat, menstrual cycle, inappropriate environment and footwear.[6,10–14]

Body asymmetries have previously been studied in sports science to understand their relation with injuries in different athletes (most commonly soccer players, rugby players, collegiate athletes, CrossFit participants, netball players, basketball and volleyball players, ski racers, sprinters). Previous studies of body asymmetries in dancers consider the presence of musculoskeletal injuries as a consequence of asymmetries,[15,16] yet we did not find any research that combines different aspects of asymmetries and their correlation with the musculoskeletal injuries.

The present study aimed to determine the incidence and expression of body asymmetries in muscle strength and power, stability, and range of motion (RoM) in dancers of three different dance styles: dancesport, hip-hop and ballet. We also examined the association of body asymmetries with self-reported musculoskeletal injuries occurring in the past 12 months. We hypothesized that (1) clinically relevant (> 10%) body asymmetries occur in dancesport, hip-hop and ballet dancers, (2) local, global and ability asymmetries will differ significantly ($p < 0,05$) between the dancers with more and fewer self-reported injuries, (3) local, global and functional asymmetries will differ significantly ($p < 0,05$) between dancers of different dance styles, (4) dancers with fewer self-reported injuries will have significantly ($p < 0,05$) fewer and less severe body asymmetries than dancers with more injuries occurring in the last 12 months.

Materials and Methods

Fifty-five dancers (n = 55) participating in three different dance styles: dancesport (n = 14), hip-hop (n = 21) and ballet (n = 20) participated in this study (Figure 1). Dancesport and hip-hop dancers have been actively participating in national and international dance competitions, while ballet dancers have been either attending Conservatory of Music and Ballet Ljubljana (n = 7) or have been members of Slovene National Ballet Theater in Ljubljana (n = 13). Dancers who matched the following inclusion criteria participated in the study: (1) were 16 years or older, (2) trained one of the aforementioned dance styles for the last three years (or more) at least three times per week. Participants with acute injuries/pain at the time of measurements were excluded from the study. All participants provided written informed consent. Measurements lasted approximately 180 minutes per participant. The study protocol (Figure 1) was approved by the Slovenian ethics committee (number of approval: 0120-99/2018/5) and was compliant with the Helsinki declaration. All dancers in figures gave their permission to be recognizable in case of publication.

All data on groin pain and training characteristics were collected using a single self-reported recall questionnaire for musculoskeletal injuries occurring in the last 12 months. The questionnaire was partially based on existing instruments, such as OSTRC questionnaire,[17] and was expanded according to the purpose of the present study. This questionnaire starts with questions about the training process (average number of training sessions per week, average duration of each training session, duration of the warm-up, presence of stretching and/or stabilization exercises in the warm-up and stretching exercises in the final part of the training, the most common type of stretching and the performance of separate strength training sessions). This is followed by a section on acute injuries, where subjects report the name and mechanism of the injury, possible absence from training caused by injury, whether the injury required surgery/rehabilitation (yes/no) and where, how and when the injury occurred. All the mentioned data is reported for every acute injury present in the last year. Follows the section about chronic injuries with a table stating different parts of the body (neck, shoulders, upper arm, elbow, forearm, wrist, upper back, lower back, chest, abdomen, hip/groin, thigh, knee, shin, ankle/foot), where participants should report whether they have had any chronic injury/pain in the last year (yes/no). If the answer is positive, they indicate the level of pain (scale 1 - 10; 1 - mild; 10 - severe pain), the pain causing any absence from training (yes/no), whether the pain occurred several times (yes/no) and how many times (if the answer is yes).

Passive RoM measurements of hip, knee and ankle movements were performed in accordance with the international clinical evaluation protocols (Figure 2, see supplementary material),[18] using either a manual two-arm goniometer or digital inclinometer (Baseline) for hip flexion, extension and rotations. To reduce the measurement error, all measurements were performed by the same investigators, one of whom performed the passive joint motion and the other marked important anatomical landmarks on the body and measured the RoM three times. A third investigator had written down the results. The average of three measurements for each movement was used for further data analysis, using the difference between the measured ROM and the starting position as the final result.

On force platforms (9260AA, Kistler, Winterthur, Switzerland), participants performed three repetitions of five tests (Figure 3, see Supplementary material): single leg stance test,[19] unilateral landing,[20] squat jump and countermovement jump,[21] and weight-bearing symmetry,[22] during standing, semi-squat and deep squat. Single leg stance and symmetry tests were performed

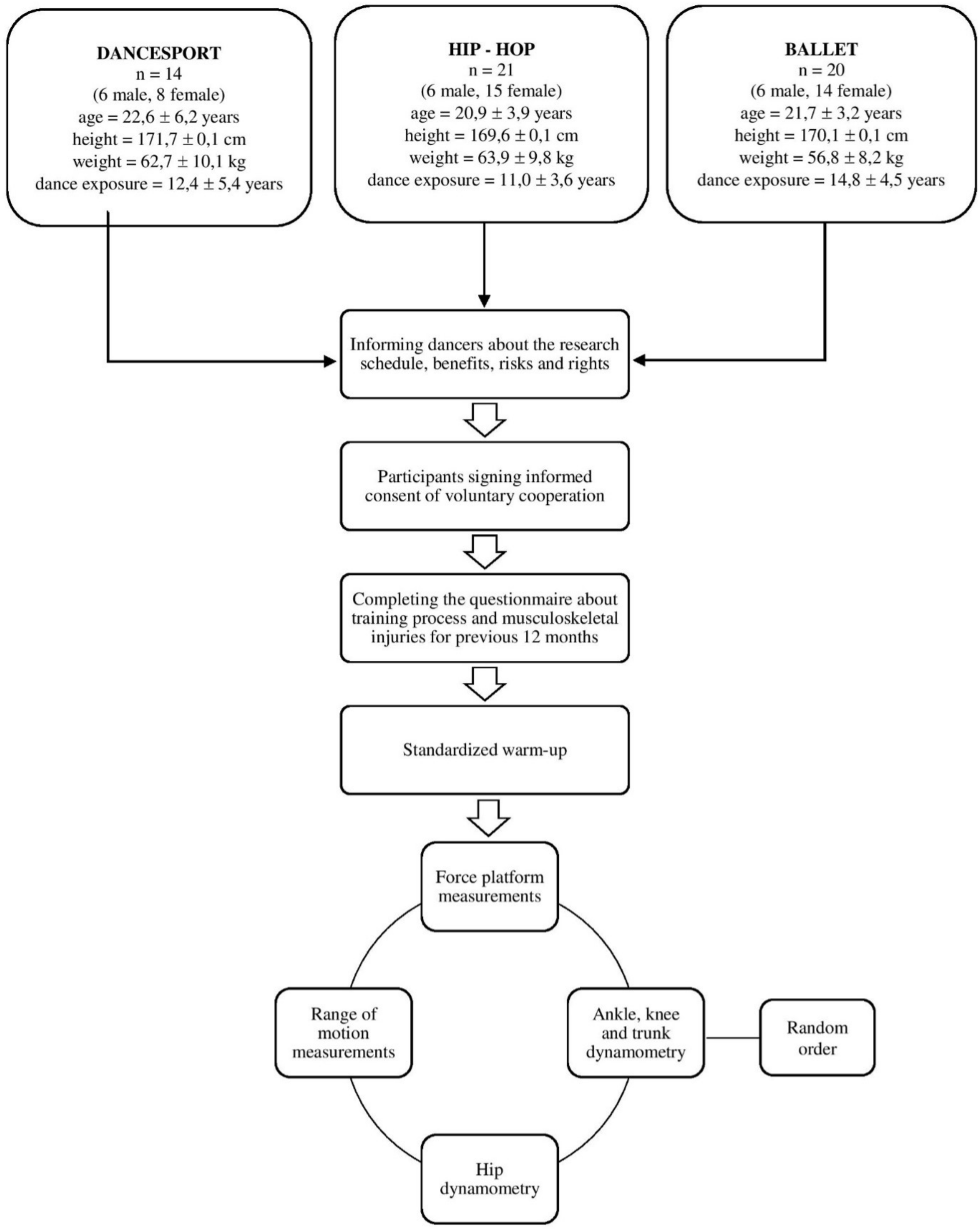

Fig. 1 Study protocol diagram.

barefoot, while for squat jump, countermovement jump and landing ballet dancers were wearing ballet shoes and hip-hop and dancesport dancers were wearing sneakers. During the 30-s single leg stance test, we observed the total centre of pressure movement (as well as the centre of pressure movement in anterior-posterior and medial-lateral direction).[19] Landing was performed unilaterally from a box (with a height of 35 cm),

Eur J Transl Myol 32 (4): 11020, 2022 doi: 10.4081/ejtm.2022.11020

Table 1. *Post-hoc analysis results*

		Dancesport – ballet			Dancesport – hip-hop			Hip-hop – ballet		
		p-value	95% CI	d	p-value	95% CI	d	p-value	95% CI	d
RTD	Hip_{Flex}	**0.001**	10.266, 44.883	1.447	0.573	10.266, 44.883	0.495	**0.015**	–44.883, –10.266	0.869
Max torque	Hip_{ExtRot}	0.593	1.605, 5.191	0.464	0.761	-1.795, -4.934	0.376	**0.026**	0.316, -6.409	0.879
Max torque ratio	Trunk $_{FlexExt}$	**0.037**	0.673, 28.681	0.989	0.525	-21.572, 6-160	0.510	0.526	-5.585, 19.527	0.405
	Hip $_{AbdAdd}$ (left)	**<0.001**	-43.088, -13.490	1.983	**0.01**	3.625, 32.932	1.311	0.203	3.259, 23.279	0.523
	Hip $_{AbdAdd}$ (right)	**< 0.001**	-48.243, -18.353	2.293	**0.025**	1.619, 31.215	1.026	**0.009**	-0.282, -3.481	0.901
	Ankle $_{d/pFlex}$ (left)	**0.001**	-15.549, -4.744	1.628	1.000	-4.272, 5.660	0.097	**< 0.001**	5.391, 14.384	2.371
	Ankle $_{d/pFlex}$ (right)	**< 0.001**	-15.549, -4.744	1.628	1.000	-5.722, 4.977	0.105	**< 0.001**	5.675, 15.363	1.723
RTD ratio	Ankle $_{d/pFlex}$ (left)	0.532	-12.812, 3.601	0.425	**< 0.001**	-22.169, -5.593	1.401	**0.01**	1.845, 16.707	1.095
	Ankle $_{d/pFlex}$ (right)	0.513	-13.138, 3.538	0.403	**< 0.001**	10.702, 27.544	2.150	**< 0.001**	6.772, 21.873	1.846
RoM	Hip_{Add}	**0.044**	-20.358, -0.196	0.128	1.000	-6.930, 13.034	0.457	**0.160**	-16.264, 1.814	0.587
	Hip_{IntRot}	**0.013**	1.396, 14.719	0.972	0.738	-9.725, 3.466	0.371	0.139	1.044, 10.091	0.781

Legend: CI – confidence interval, RTD – rate of torque development, Flex – flexion, Ext – extension, ExtRot – external rotation, IntRot – internal rotation, Add – adduction, AbdAdd – Abduction/Adduction, d/pFlex – dorsi/plantar flexion

holding the position for 5-s after landing. We observed dynamic postural stability index and directional components (vertical, anterior-posterior and medial-lateral) in line with previously presented measures.[23]
Maximum voluntary contraction was evaluated during isometric contraction for trunk, hip, knee and ankle muscles (Figure 4, see Supplementary material), using computer-aided electronic dynamometers (S2P, Science to Practice, Ltd., Ljubljana, Slovenia). Participants were instructed to reach their maximum torque for hip, knee and ankle movements as fast as possible, while trunk isometric contraction was performed to maximum regardless of the speed of execution. Throughout the repetitions, participants were vocally encouraged and had to hold the contraction until they were stopped by the investigator (3–5-s). Each task was repeated three

times with a 20-s rest period between repetitions; the highest achieved value among three sets for each participant was used for further data analysis. Hip flexion and extension strength were evaluated unilaterally, while the strength of other lower extremity muscles was evaluated bilaterally. The results were normalized with 2/3 of the individual body weight.[24]

Trunk, ankle and knee dynamometers (S2P, Science to Practice, Ltd., Ljubljana, Slovenia) collected signals with frequency of 1000 Hz. Force sensor Bending beam load cell 1-Z6FC3/200kg (HBM, Darmstadt, Germany) was built-in to work as a torque sensor. Collected signals were processed using Analysis and reporting software – ARS (S2P, Science to Practice, Ltd., Ljubljana, Slovenia) with the use of 5-ms moving average filter. Hip dynamometer - Muscle Board (S2P, Science to Practice, Ltd., Ljubljana, Slovenia) equipped with amplifier INSAmp (Isotel, Logatec, Slovenia), and paired with MuscleBoard 2.0.0.0 (S2P, Science to Practice, Ltd., Ljubljana, Slovenia) software collected signals with frequency of 450 Hz. Digital-analogue converter Board S2P 02 (S2P, Science to Practice, Ltd., Ljubljana, Slovenia) was used. Force platforms 9260AA (Kistler, Winterthur, Switzerland) collected ground reaction force signals with frequency of 1000 Hz. The ground reaction force signals were processed using Measurement, Analysis and Reporting Software (MARS) (Kistler, Wintherthur, Switzerland), which enables data acquisition as well as data management and offers reporting tools. Amplifying-converter unit DAQ type 5695B (Kistler, Wintherthur, Switzerland) was used. Force signals were filtered using average moving filter in 5-ms time window, while the centre of pressure signals were filtered using a second-order Butterworth low-pass filter with a cut off frequency of 10 Hz.

Asymmetry indexes were calculated using the formula *((stronger – weaker) / stronger) × 100.*[25] To enable the use of the same formula for all measured parameters and to avoid negative values, we adjusted the formula for the purpose of this study to *(greater value – smaller value) / greater value) × 100*. The commonly used criterion of 10% for the presence of clinically relevant asymmetries was used.[26,27]

To calculate the percentage of dancers with body asymmetries, the results were divided into five groups of functional asymmetries: maximum torque and rate of torque development (trunk, hip, knee and ankle dynamometry), stability (single leg stance test and unilateral landing), explosive muscle power (squat and countermovement jump) and RoM (hip, knee and ankle). Agonist/antagonist asymmetries were calculated as quotients (multiplied by 100): flexion/extension (trunk, knee and hip), dorsi/plantar flexion (ankle), abduction/adduction (hip), internal/external rotation (hip).[28,29] Based on the obtained self-reported number of low back and lower limbs acute and chronic musculoskeletal injuries, we divided the dancers to more and less injured. We defined more injured dancers as those who reported four or more injuries in the previous 12 months (n = 15), while less injured dancers reported from zero to two injuries (n = 27). Dancers who reported three injuries were excluded from further analysis. To obtain the correlation of injuries with the number and severity of body asymmetries, we have considered the total number of contralateral and agonist/antagonist asymmetries and divided the results into three groups of functional asymmetries: (1) strength and power, (2) RoM, (3) stability. To analyze the influence of different dance styles, dancers were divided into different dance style groups (hereinafter referred to as “sub-group”).

Data analysis was performed using Microsoft Excel 2013 (Microsoft, Redmond, Washington, USA) and IBM SPSS Statistics 25 (IBM, Armonk, New York, USA). Descriptive statistics (mean, SD and standard error, minimum and maximum values) were calculated for all variables. Differences between groups were calculated with a two-tailed t-test for independent samples, the effect size was interpreted using Cohen’s d as follows: small at d = 0–0.2; medium at d = 0.2–0.5 and large at d > 0.5.[30] To determine the difference in the selected outcome biomechanical metrics between dance styles, analysis of variance (ANOVA) was used, followed by post-hoc tests (Bonferroni correction). Squared eta (η^2) represents effect size (small at $\eta^2 = 0.1$; medium at $\eta^2 = 0.25$ and large at $\eta^2 = 0.4$).[30] Pearson correlation coefficient was used to determine the correlation between variables, with r^2 representing the effect size (small at $r^2 = 0.01$; medium at $r^2 = 0.03$ and large at $r^2 = 0.25$).[31] The level of statistical significance was set at $p < 0.05$ for all tests.

Results

In total 55 participants completed the measurements. Due to technical issues with equipment, one hip-hop dancer did not perform measurements on the force platforms, and data recording for the landing test for one dancesport dancer failed.

Asymmetry indexes for rate of torque development during maximum voluntary hip flexion were statistically significant different (with high effect size) between different dance styles (F = 8,565; p = 0,001; η^2 = 0,895). Moreover, maximum torque asymmetry index for external hip rotation was statistically significant different between sub-groups of dancers (F = 3.729; p = 0.031; η^2 = 0.789). Asymmetries for trunk flexion/extension maximum torque occurred in most hip-hop dancers (81.0%), followed by ballet (71.4%) and dancesport dancers (64.3%). Mean values of trunk flexion/extension maximum torque differed between different style groups of dancers with high effect size (F = 3.382; p = 0.042; η^2 = 0.772). Mean values of maximum torque for abduction/adduction differed between sub-groups of dancers with a high effect size for left (F = 11.240; p < 0.001; η^2 = 0.918) and right hip (F = 15.407; p < 0.001; η^2 = 0.939). Mean values of

Table 2. *Body asymmetries and musculoskeletal injuries.*

		Asymmetries > 10%				**Acute and chronic injuries (%)**		
		Dancesport (%)	Hip-hop (%)	Ballet (%)		Dancesport	Hip-hop	Ballet
	Max torque	26.0	24.7	31.4	Low back and hip	64.3	76.7	80.0
	RTD	56.4	55.2	67.5	Upper leg and knee	42.9	66.7	60.0
	Muscle power	14.3	55.8	6.3	Lower leg and feet	64.3	42.9	95.0
	RoM	37.4	11.3	35.4				
						Pearson correlation coefficient (n = 55)		
						r	p-value	r^2
	Stability	49.4	40.7	48.3		0,337	0,012	0,114
Max torque	Hip_{Add}	0	14.3	5.0		-0.288	0.033	0.083
Max torque	Hip_{AbdAdd} (left)	33.3	52.4[3]	66.7		0.281	0.038	0.079
Max torque	Hip_{AbdAdd} (right)	42.9	66.7	61.9		0.358	0.007	0.128
RTD	Hip_{Flex}	64.3	85.7	95.0		0.351	0.009	0.123

Legend: RTD – rate of torque development, Add – adduction, Abd – abduction, AbdAdd – Abduction/Adduction ratio, Flex – flexion, RR – recommended agonist/antagonist ratio, RoM – range of motion

maximum torque for dorsi/plantar flexion differed between the three dance styles with a high effect size for left ($F = 14.148$; $p < 0.001$; $\eta^2 = 0.934$) and right ankle ($F = 17.438$; $p < 0.001$; $\eta^2 = 0.946$). Mean values of rate of torque development for ankle dorsi/plantar flexion also differed between sub-groups of dancers with a high effect size for left ($F = 9.474$; $p < 0.001$; $\eta^2 = 0.905$) and right ankle ($F = 18.608$; $p < 0.001$; $\eta^2 = 0.949$). Index asymmetry for hip adduction RoM differed between sub-groups of dancers with high effect size ($F = 3.605$; $p = 0.034$; $\eta^2 = 0.783$). Furthermore, internal hip rotation RoM asymmetry differed between sub-groups of dancers with high effect size ($F = 4.759$; $p = 0.013$; $\eta^2 = 0.826$). Post-hoc analysis results are presented in Table 1.

Maximum force asymmetry indexes for squat jump differed between dancers ($F = 3.252$; $p = 0.048$; $\eta^2 = 0.763$). However, post-hoc analysis did not detect statistically significant differences between any of the three dance styles. Also, no statistically significant differences between groups were found for other muscle power asymmetries ($F = 0.221$–1.735; $p = 0.187$–0.803; $\eta^2 = 0.181$–0.634). Other asymmetry indexes that were not mentioned in the results were not statistically significant for muscle strength ($F = 0.044$–2.948; $p = 0.061$–0.957; $\eta^2 = 0.043$–0.747), stability ($F = 0.118$ – 1.642; $p = 0.204$ – 0.889; $\eta^2 = 0.106$ – 0.622) or RoM ($F = 0.013$–2.356; $p = 0.105$–0.988; $\eta^2 = 0.012$–0.702) asymmetries. Percentage of dancers showing contralateral asymmetries higher than 10% is presented in Table 2.

We also analysed the incidence of musculoskeletal injuries of low back and lower limbs occurring in the last 12 months. Ballet dancers (n = 20) reported the most injuries (12 acute and 56 chronic), followed by hip-hop dancers (n = 21), who reported 10 acute and 35 chronic injuries. The least injuries (5 acute and 27 chronic) were reported by dancesport dancers (n = 14). To compare injuries within groups, the percentage of injured dancers was calculated (Table 2).

When linking different aspects of body asymmetries with injuries, we detected a statistically significant correlation between the total number of injuries and stability asymmetries and specific asymmetry indexes (Table 2). Other aspects of asymmetries showed no statistically significant correlations with total number of injuries ($r = 0.102 – 0.262$; $p = 0.053 – 0.994$; $r^2 = 0.010 – 0.069$). When comparing more and less injured dancers, statistically significant differences were observed for three variables (Table 2). Differences in the variables that are not mentioned were not statistically significant ($t(40) = –2,051$–$2,013$; $p = 0,051$–$0,987$; $d = 0,002$–$0,469$).

Discussion

This study investigated the incidence and expression of body asymmetries in muscle strength and power, stability, and RoM in dancesport, hip-hop and ballet dancers and evaluated the correlation of aforementioned

Table 3. *Comparison between agonist/antagonist ratio and total number of injuries reported.*

		Agonist/antagonist ratio (%)			**Independent samples t-test (n = 42)**			
		Less injured (n = 27)	More injured (n = 15)	RR (%)	t (40)	p-value	d	95% CI
Max torque	Hip_{AbdAdd}	93,0 ± 20,6	108,3 ± 19,1	95 [21]	2.364	0.023	0.365	2.221, 28.422
	$Ankle_{pFlex}$	24,1 ± 7,3	19,0 ± 6,0	33 [23]	2.287	0.028	0.353	0.590, 9.563
RoM	$Knee_{Flex}$	/	/	/	2.162	0.037	0.334	0.051, 1.523

Legend: AbdAdd – Abduction/Adduction ratio, pFlex – plantar flexion, RR – recommended agonist/antagonist ratio, RoM – range of motion, Flex – flexion

asymmetries with self-reported musculoskeletal injuries occurring over the past 12 months. The results support the hypothesis that clinically relevant (> 10%) body asymmetries occur in dancers (Table 2). Statistically significant differences were observed between more and less injured dancers for three variables (maximum torque of hip abduction/adduction ratio, maximum torque of ankle plantar flexion and knee flexion RoM) (Table 3), as well as a statistically significant correlation of certain aspects of body asymmetries with the total number of injuries (Table 2). Furthermore, statistically significant differences were observed between different dance styles (Table 1), which supports the hypothesis that asymmetries differ between sub-groups of dancers.

A high percentage of dancers (48 – 65%) of all three dance styles exceed the 10% criterion for the presence of body asymmetries for ankle dorsiflexion maximum torque. When comparing dance styles for dorsi/plantar flexion asymmetries, significant differences were found between ballet dancers compared to hip-hop and dancesport dancers (Table 1). All (100%) ballet dancers exceed the recommended dorsi/plantar flexion ratio (33%)[32] for more than 10%, followed by 93% of dancesport dancers and 74% of hip-hop dancers. This may occur due to stronger plantar flexor muscles compared to dorsiflexors, possibly resulting from dancing at the tips of toes for ballet dancers and high heels for dancesport dancers, which shifts weight to the front of the foot and consequently increases the load of plantar flexors. The results also show a significant difference between more and less injured dancers. More injured dancers deviate to a greater extent from the recommended agonist/antagonist ratio (Table 2). By eliminating these deviations, certain injuries (such as ankle instability and/or sprain, ankle impingement syndrome, medial tibial stress syndrome etc.) may be prevented or reduced.

Hip abduction/adduction asymmetries for maximum torque also differ between dance styles, with weaker hip abductors in dancesport dancers, and stronger hip abductors compared to hip adductors in ballet dancers. Hip-hop dancers deviate from the recommended ratio the least. To the best of our knowledge, there are no previous studies examining this issue with dancers, but weaker hip abductors were already observed in elite soccer players,[33] but not young soccer and basketball players.[34] Weakness of hip adductors is one of the possible factors that can lead to the snapping hip syndrome.[35] That could explain 45% of ballet dancers reporting pain or hip injuries in the last 12 months, while the same injuries were reported by only 14% of dancesport dancers.

The asymmetries of the trunk maximum torque flexion/extension are also common in dancers. Our results show that the differences are most common in hip-hop dancers (81%), followed by ballet (71%) and dancesport dancers (64%). Despite that, low back pain in the past 12 months was most commonly reported by ballet dancers (70%), followed by dancesport (64%) and hip-hop dancers (60%). In contrast, another study reported the highest incidence of low back pain in hip-hop dancers.[36] Besides influencing the low back pain, reduced trunk muscle strength can also increase the risk of lower limb injuries.[37] Therefore, it is important to make a comprehensive evaluation rather than focusing on just one parameter of individuals' physical performance. It is also important to question whether asymmetries are increasing the risk of injury, and whether the generally accepted agonist/antagonist ratios are valid and reliable for all populations.[38]

Stability asymmetries are the most evident in hip-hop dancers (56%), followed by dancesport (49%) and ballet dancers (48%). A weak positive correlation of stability asymmetries with the total number of injuries was observed (Table 2). It is important to note that significant differences in stability were reported when comparing uninjured ballet dancers to those who have suffered at least one ankle sprain in the last year.[16] The question then arises – whether and/or which asymmetries are the cause or the consequence of an injury.

Practical implications

i) Dancers' body asymmetries differ between dance styles and should be treated differently in future practice/research.
ii) Hip flexion, adduction and abduction/adduction strength asymmetries as well as stability asymmetries could present possible risk factors for musculoskeletal injuries in dancesport, hip-hop and ballet dancers.
iii) Hip abduction/adduction and ankle plantar flexion strength asymmetries differed between more and less injured dancers.

In conclusion, the results confirm the incidence of clinically relevant (> 10%) body asymmetries in dancesport, hip-hop and ballet dancers, as well as the correlation of some asymmetries with self-reported injuries occurring in the last 12 months. Based on our results, future research should clarify occurrence and causes and effects of musculoskeletal injuries in dancers. Guidelines can then be developed to reduce the risk of musculoskeletal injuries in dancers, allowing safer and more effective dance engagement.

List of acronyms

AbdAdd – Abduction/Adduction ratio,
Add – adduction
ANOVA – analysis of variance
CI – confidence interval
d/pFlex – dorsi/plantar flexion
Ext – extension
ExtRot – external rotation
Flex – flexion
IntRot – internal rotation
pFlex – plantar flexion
RoM – range of motion
RR – recommended agonist/antagonist ratio
RTD – rate of torque development

Contributions of Authors

All authors have read and approved the final edited typescript.

Acknowledgments

The authors thank the dancers who volunteered for the study.

Funding

The authors were supported by Slovenian Resarch agency through the project TELASI-PREVENT [L5-1845] (Body asymmetries as a risk factor in musculoskeletal injury development: studying aetiological mechanisms and designing corrective interventions for primary and tertiary preventive care). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Publication Statement

We confirm that we have read the Journal’s position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

Corresponding Author

Nejc Sarabon, University of Primorska, Faculty of Health Sciences, Polje 42, SI-6310 Izola, Slovenia.
ORCID ID: 0000-0003-0747-3735
E-mail: nejc.sarabon@fvz.upr.si

E-mails and ORCID iD of co-authors

Monika Pavlović: monika.pavlovic@zf.uni-lj.si .
ORCID iD: 0000-0002-4456-0945
Nina Ogrinc: nina.ogrinc@kgbl.si
ORCID iD: 0000-0002-2410-5718

References

1. Maloney SJ. The Relationship Between Asymmetry and Athletic Performance: A Critical Review. J Strength Cond Res. 2019 Sep;33(9):2579-2593. doi: 10.1519/JSC.0000000000002608.
2. Muehlbauer T, Gollhofer A, Granacher U. Associations Between Measures of Balance and Lower-Extremity Muscle Strength/Power in Healthy Individuals Across the Lifespan: A Systematic Review and Meta-Analysis. Sports Med. 2015 Dec;45(12):1671-92. doi: 10.1007/s40279-015-0390-z.
3. Kimmerle M. Lateral bias, functional asymmetry, dance training and dance injuries. J Dance Med Sci. 2010;14(2):58-66.
4. Farrar-Baker A, Wilmerding V. Prevalence of Lateral Bias in the Teaching of Beginning and Advanced Ballet. J Danc Med Sci [Internet]. 2006;10(3–4):81–84. Available from: http://www.ingentaconnect.com/content/jmrp/jdms/2006/00000010/F0020003/art00002
5. Sutton-Traina K, Smith JA, Jarvis DN, Lee SP, Kulig K. Exploring Active and Passive Contributors to Turnout in Dancers and Non-Dancers. Med Probl Perform Art. 2015 Jun;30(2):78-83. doi: 10.21091/mppa.2015.2013.
6. Leanderson C, Leanderson J, Wykman A, Strender LE, Johansson SE, Sundquist K. Musculoskeletal injuries in young ballet dancers. Knee Surg Sports

Traumatol Arthrosc. 2011 Sep;19(9):1531-5. doi: 10.1007/s00167-011-1445-9. Epub 2011 Feb 22.
7. Pellicciari L, Piscitelli D, De Vita M, D'Ingianna L, Bacciu S, Perno G, Lunetta L, Rosulescu E, Cerri CG, Foti C. Injuries Among Italian DanceSport Athletes: A Questionnaire Survey. Med Probl Perform Art. 2016 Mar;31(1):13-7. doi: 10.21091/mppa.2016.1003.
8. Smith TO, Davies L, De Medici A, Hakim A, Haddad F, Macgregor A. Prevalence and profile of musculoskeletal injuries in ballet dancers: A systematic review and meta-analysis. Phys Ther Sport [Internet]. 2016;19:50–6. doi.org/10.1016/ j.ptsp.2015.12.007
9. Ojofeitimi S, Bronner S, Woo H. Injury incidence in hip hop dance. Scand J Med Sci Sports. 2012 Jun;22(3):347-55. doi: 10.1111/j.1600-0838.2010.01173.x. Epub 2010 Aug 30.
10. Allen N, Nevill A, Brooks J, Koutedakis Y, Wyon M. Ballet injuries: injury incidence and severity over 1 year. J Orthop Sports Phys Ther. 2012 Sep;42(9):781-90. doi: 10.2519/jospt.2012.3893. Epub 2012 Jul 19.
11. Armstrong R, Relph N. Screening Tools as a Predictor of Injury in Dance: Systematic Literature Review and Meta-analysis. Sports Med Open. 2018 Jul 18;4(1):33. doi: 10.1186/s40798-018-0146-z.
12. Russell JA. Preventing dance injuries: current perspectives. Open Access J Sports Med. 2013 Sep 30;4:199-210. doi: 10.2147/OAJSM.S36529.
13. Novosel B, Sekulic D, Peric M, Kondric M, Zaletel P. Injury Occurrence and Return to Dance in Professional Ballet: Prospective Analysis of Specific Correlates. Int J Environ Res Public Health. 2019 Mar 3;16(5):765. doi: 10.3390/ijerph16050765.
14. Zaletel P, Sekulić D, Zenić N, Esco MR, Šajber D, Kondrič M. The association between body-built and injury occurrence in pre-professional ballet dancers - Separated analysis for the injured body-locations. Int J Occup Med Environ Health. 2017 Feb 21;30(1):151-159. doi: 10.13075/ijomeh. 1896.00818. Epub 2017 Jan 25..
15. Gildea JE, Hides JA, Hodges PW. Size and symmetry of trunk muscles in ballet dancers with and without low back pain. J Orthop Sports Phys Ther. 2013 Aug;43(8):525-33. doi: 10.2519/jospt.2013.4523. Epub 2013 Apr 30.
16. 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 Jun;39(6):1324-31. doi: 10.1177/03635 46510393943. Epub 2011 Feb 18.
17. Leppänen M, Pasanen K, Clarsen B, Kannus P, Bahr R, Parkkari J, Haapasalo H, Vasankari T. Overuse injuries are prevalent in children's competitive football: a prospective study using the OSTRC Overuse Injury Questionnaire. Br J Sports Med. 2019 Feb;53(3):165-171. doi: 10.1136/bjsports-2018-099218. Epub 2018 Aug 14.
18. Clarkson H. Range of motion assessment and measurement. In: Joint motion and function assessment: A research-based practical guide. Lippincott Williams & Wilkins; 2005.
19. Raymakers JA, Samson MM, Verhaar HJ. The assessment of body sway and the choice of the stability parameter(s). Gait Posture. 2005 Jan;21(1):48-58. doi: 10.1016/j.gaitpost.2003.11. 006.
20. Ross SE, Guskiewicz KM, Yu B. Single-leg jump-landing stabilization times in subjects with functionally unstable ankles. J Athl Train. 2005 Oct-Dec;40(4):298-304.
21. Bosco C, Ito A, Komi PV, Luhtanen P, Rahkila P, Rusko H, Viitasalo JT. Neuromuscular function and mechanical efficiency of human leg extensor muscles during jumping exercises. Acta Physiol Scand. 1982 Apr;114(4):543-50. doi: 10.1111/j.1748-1716.1982.tb07022.x.
22. Webster KE, Austin DC, Feller JA, Clark RA, McClelland JA. Symmetry of squatting and the effect of fatigue following anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2015 Nov;23(11):3208-13. doi: 10.1007/s00167-014-3121-3. Epub 2014 Jun 17
23. Wikstrom EA, Tillman MD, Smith AN, Borsa PA. A new force-plate technology measure of dynamic postural stability: the dynamic postural stability index. J Athl Train. 2005 Oct-Dec;40(4):305-9.
24. Jaric S. Role of body size in the relation between muscle strength and movement performance. Exerc Sport Sci Rev. 2003 Jan;31(1):8-12. doi: 10.1097/00003677-200301000-00003.
25. Nunn KD, Mayhew JL. Comparison of three methods of assessing strength imbalances at the knee. J Orthop Sports Phys Ther. 1988;10(4):134-7. doi: 10.2519/jospt.1988.10.4.134.
26. Schiltz M, Lehance C, Maquet D, Bury T, Crielaard JM, Croisier JL. Explosive strength imbalances in professional basketball players. J Athl Train. 2009 Jan-Feb;44(1):39-47. doi: 10.4085/1062-6050-44.1.39.
27. Cunha RM, Neves EB, Resende TIS de, Nora FG da SA, Rosa B, Noleto MV, et al. Muscle strength imbalance between hamstring and quadriceps among professional dancers. Biosci J. 2016;1085–91.
28. Aagaard P, Simonsen EB, Magnusson SP, Larsson B, Dyhre-Poulsen P. A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am J Sports Med. 1998 Mar-Apr;26(2):231-7. doi: 10.1177/03635465980260021201.

29. Althorpe T, Beales D, Skinner A, Caputi N, Mullings G, Stockden M, et al. Isometric hip strength and strength ratios in elite adolescent and senior Australian Rules Football players: an initial exploration using fixed-point dynamometry. J Sci Med Sport [Internet]. 2018;21(2018):S81. doi.org/10.1016/j.jsams.2018.09.185.
30. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009 Jan;41(1):3-13. doi: 10.1249/MSS.0b013e31818cb278.
31. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale, New Yersey: Lawrence Erlbaum Associates; 1988.
32. Trzaskoma Z, Ilnicka L, Wiszomirska I, Wit A, Wychowański M. Laterality versus ankle dorsi- and plantarflexion maximal torques. Acta Bioeng Biomech. 2015;17(2):131-41.
33. Thorborg K, Serner A, Petersen J, Madsen TM, Magnusson P, Hölmich P. Hip adduction and abduction strength profiles in elite soccer players: implications for clinical evaluation of hip adductor muscle recovery after injury. Am J Sports Med. 2011 Jan;39(1):121-6. doi: 10.1177/036354651037 8081. Epub 2010 Oct 7.
34. Marušič J, Šarabon N. Hip adduction and abduction strength in youth male soccer and basketball players with and without groin pain in the past year. PLoS One. 2022 Oct 5;17(10):e0275650. doi: 10.1371/journal.pone.0275650.
35. Oh J, Kang M, Park J, Lee JI. A possible cause of snapping hip: intrapartum obturator neuropathy. Am J Phys Med Rehabil. 2014 Jun;93(6):551. doi: 10.1097/PHM.0b013e3182a52047.
36. Viktoria KB, Alekszandra M, Gabriella K, Brigitta S, Pongrác Á, Melinda J. The Examination of Muscle Balance in Dancers. Univers J Public Heal. 2016;4(4):171–8.
37. Rickman AM, Ambegaonkar JP, Cortes N. Core stability: implications for dance injuries. Med Probl Perform Art. 2012 Sep;27(3):159-64.
38. Maly T, Mala L, Bujnovsky D, Hank M, Zahalka F. Morphological and Isokinetic Strength Differences: Bilateral and Ipsilateral Variation by Different Sport Activity. Open Med (Wars). 2019 Feb 20;14:207-216. doi: 10.1515/med-2019-0014.

Disclaimer

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article or claim that may be made by its manufacturer is not guaranteed or endorsed by the publisher

Submission: November 18, 2022
Accepted for publication: November 19, 2022