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Body Asymmetries in Dancers of Different Dance Disciplines

Asimetrías Corporales en Bailarines de Diferentes Disciplinas de Baile

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SUMMARY: Dance is an attractive sport discipline in which participation is increasing every year, unfortunately, the prevalence of injuries is also increasing. Various dance disciplines and dance techniques require body control, often in extreme anatomical positions that place a heavy strain on the musculoskeletal system. The aim of this research was to analyze body asymmetries of four different dance disciplines (standard and Latin American dance - STLA, acrobatic rock and roll - RNR, breakdance - BD and hip hop - HH), by using anthropometric (InBody 720; Biospace Co., Ltd) and 3D body measurements (NX-16; TC2) to establish possible later discomforts and injuries. T-test was performed to find differences between left and right extremities in all four dance disciplines. Results of the study showed that asymmetries are present in all of the studied dance disciplines. When comparing dance disciplines, we found out that STLA dancers are the most prone to develop body asymmetries (six out of nine paired variables), mainly because of the closed position. The position itself is the asymmetry and in which dancers remain for a very long time while training the technique of each dance. As dance is known for its asymmetrical movement of the body and it is expected that some of the asymmetries will appear after a few years of training. For a better understanding of possible consequences of asymmetries in dancers' bodies, further and more detailed analysis within each dance discipline is required.

KEY WORDS: Dance; Asymmetry; Anthropometry; Circumferences; Ballroom; Rock and roll; Hip hop; Breakdance.

INTRODUCTION

Dance is a physically challenging activity, with short sets of explosive movements (Angioi *et al*., 2009), requiring exceptional balance abilities (Armstrong & Relph, 2018), core stabilization (Watson *et al*., 2017), and muscle power (Mistiaen *et al*., 2012). In addition, a high level of athleticism and artistry is required for the performance of repetitive movements with consideration of aesthetic demands (Kakichová, 2011). It is desired for dancers to be able to perform a variety of dance movements equally well on both sides (Kimmerle, 2010), which is understandable since dancers are symmetrically and asymmetrically using extremities during dance training, practice and rehearsals. (Golomer *et al*., 2009). But in reality, the occurrence of preferred side, especially in balance tasks or explosive movements with bilateral landings, is quite common (Meuffels & Verhaar, 2008; Kimmerle). Dancers will in this case choose the side with better ability to maintain balance, the nondominant side will be used as support (Lin *et al*., 2013). Asymmetries may therefore occur in terms of better stability and strength of the standing leg and better mobility of the second lower limb (Kimmerle). Various dance techniques require control of the body in often extreme anatomical positions, which places a heavy strain on the musculoskeletal system. Therefore, the incidence of injuries in dance is increasing (Motta-Valencia, 2006), ranging between 20 and 84 % (Kenny *et al*., 2019). Urban dances involve in their movements many explosive and sudden movements in large amplitudes (Ojofeitimi *et al*., 2012), simultaneous twists and swings in different joints, jumps mostly from the dominant leg, and asymmetrical movements. Standard dances are danced in a closed dance position, where the dancers in the dance pair are in constant contact with each other and move in an apparent circle, counterclockwise (Zaletel & Prus, 2021). The movement is fluid, fast, with accentuated steps that coincide with the accents in the music, and the posture is rigid and constant. In doing so, the dancer is in a slight bend and twist, which often causes the dancer back pain and back injuries (Riding McCabe *et al*., 2014;

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Miletic *et al*., 2008). The choreographies of Latin American dances, unlike standard dances, take place in different dance directions, often also on the spot. The posture of the dance couple is open, the movement is characterized by lateral action, and the choreographies consist of a multiple turns, rapid changes of direction, and elements of balance in the dance pair (Zaletel *et al*., 2010). Asymmetrical choreographies are desirable, as they create expectation, interest, variety, and thus a higher rating in the audience and judges. Acrobatic rock and roll is a fast and explosive sport dance, with asymmetrically danced basic step (2x with one, 1x with the other leg). Acrobatics are also performed on the dominant side (when throwing a female dancer, the man's stronger hand is under the supporting one). The female dancers always rotate their acrobatics to the better side and jump with the same - a push-off leg from the male's hand.

With the large participation of pre-professional and elite dancers, which are due to their vigorous load subdued to various musculoskeletal injuries, the need for greater awareness of the importance of the pre-participation examination must be taken into the consideration. A multidisciplinary approach, including anthropometric measurements, musculoskeletal screening, and functional performance testing, can help to reduce the risk for possible future injuries. Anthropometrics are among the most commonly investigated risk factors for injuries in dance (Kenny *et al*., 2016), but there are no studies that would focus on the consequences of the preferred side, which could be seen by analyzing the anthropometric parameters. The main aim of our research was to analyze body asymmetries of four different dance disciplines (standard and Latin American dance - STLA, acrobatic rock and roll - RNR, breakdance - BD and hip hop - HH), by using anthropometric and 3D body measurements to establish possible later discomforts and injuries.

MATERIAL AND METHOD

Subjects. The study included 101 dancers from four different dance disciplines: STLA (n=19), RNR (n=19), HH (n=40) and BD (n=22). Male (n=44) and female (n=57) dancers were on average 18.99 ± 3.19 years old. The average body height of male dancers was 178.25 ± 5.98 cm, and 164.46 ± 5.95 cm for females. Their body weight was 71.88 ± 7.79 kg, and 58.18 ± 6.58 kg respectively. Dancers, included in the study, are a part of the Slovenian national dance team and are the most successful in their dance discipline not only at the national but also at the international level. Subgroups of STLA and RNR present the majority of adult competitive dancers in their dance discipline. Participation was based on applications for dance clubs and coaches; participation was voluntary. All the participants and parents were informed about the study protocol and signed a written consent before data collection. The study protocol was approved by the Ethics Committee of the University of Ljubljana, Faculty of Sport, Ljubljana, Slovenia (Ref. number: 1175/2017).

Anthropometric and 3D body scan measurements. Body height was measured with an anthropometer GPM (Switzerland), data of body composition were analyzed using bioelectrical impedance analysis (BIA), with InBody 720 Tetrapolar 8-Point Tactile Electrode System (Biospace Co., Ltd). With the latter, we extract measurements on body weight, body mass index (BMI), skeletal muscle mass (SMM), percentage of body fat (BF %), total body water (TBW), right and left arm lean mass (RALM, LALM), right and left leg lean mass (RLLM, LLLM). Other anthropometric measurements were obtained with a 3D body scanner NX-16 (TC2, Cary, North Carolina), validated by Simenko & Cuk (2016). The 3D body scanner NX-16 is a practical and non-invasive method for the assessment of body measurements, that produce a true-to-scale 3D body model in 8 seconds. The scanner uses photogrammetry technology, which projects patterns of structured white light onto the body. How the pattern is distorted by the shape of the body is then recorded by 32 cameras. From this, the body shape is digitally reconstructed from raw photonic point cloud data, which leads to a surface reconstruction of the body and allows for automatic landmark recognition as well as electronic tape measurements (Simenko & Cuk).

Statistical Analysis. The collected data were analyzed using the SPSS statistical software for Windows (Version 26.0.; SPSS, Inc., Chicago, USA); some graphical presentations were presented with Microsoft Excel 2019. The basic statistical parameters were calculated and data were presented according to the descriptive statistics. Numeric data were tested for normality of distribution using Shapiro-Wilk's test. Furthermore, we performed a paired sample T-test, with its statistical significance set at $p<0.05$.

RESULTS

Results among male dancers show significant differences only in one variable – body mass index (BMI), where RNR dancers have the highest value (Table I). For female dancers statistically, significant differences can also be observed in body weight, percentage of body fat, abdominal obesity degree, and visceral fat area (Table II).

Table I. Anthropometry and body composition of male dancers.

Variables	Male STLA		RNR		HH		BD		Total			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	H	Sig.
Age	18.01	1.39	20.03	3.73	21.00	2.94	20.24	4.03	19.53	3.32	3.84	.280
Height	179.49	5.53	178.68	7.32	176.88	6.13	177.53	5.68	178.7	5.73	1.29	.731
Weight	69.19	6.08	76.13	8.59	66.90	5.39	72.03	7.82	71.06	8.24	5.21	.157
BMI	21.46	1.39	23.89	2.79	21.42	2.02	22.87	2.44	22.26	2.48	7.97	**.047**
BF (%)	9.80	4.69	12.53	6.04	11.37	4.28	11.07	4.75	11.21	4.76	1.97	.579
SMM (kg)	35.45	3.72	37.99	4.46	33.36	3.18	36.39	3.57	35.79	4.03	3.89	.274
TBW (kg)	45.65	4.31	48.70	5.47	43.45	3.58	46.83	4.28	46.12	4.82	3.25	.355
WHR	0.79	0.25	0.81	0.04	0.81	0.02	0.83	0.06	0.81	0.04	7.21	.065
VISC	30.10	17.31	44.34	25.56	38.44	24.4	41.41	22.82	37.17	21.9	2.45	.485

BMI: body mass index, BF: percentage of body fat, SMM: skeletal muscle mass, TBW: total body water mass, WHR: abdominal obesity degree, VISC: visceral fat area, Sig. < 0.05.

Table II. Anthropometry and body composition of female dancers.

Variables	Female STLA		RNR		HH		BD		Total			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	H	Sig.
Age	17.93	1.48	17.43	1.34	18.8	3.43	17.53	0.59	18.13	2.35	0.76	.860
Height	167.21	5.25	160.26	6.84	165.00	5.37	162.38	7.99	164.84	5.98	6.73	.081
Weight	55.06	3.72	52.54	4.89	59.95	6.31	59.23	9.61	58.86	6.79	12.09	**.007**
BMI	19.68	0.55	20.45	1.22	22.02	2.02	22.37	2.04	21.67	2.38	15.61	**.001**
BF (%)	16.68	2.62	17.59	5.02	23.44	4.71	19.45	3.75	23.08	5.62	18.2	**.000**
SMM (kg)	25.30	1.93	23.84	2.94	25.22	2.36	26.52	4.70	24.86	2.59	2.47	.482
TBW (kg)	33.55	2.41	31.69	3.65	33.44	2.86	34.93	6.02	32.96	3.16	2.65	.449
WHR	0.79	0.02	0.81	0.01	0.85	0.04	0.83	0.02	0.84	0.04	18.49	**.000**
VISC	30.41	10.29	40.48	18.79	60.79	20.05	52.07	12.69	57.88	22.09	16.82	**.001**

BMI: body mass index, BF: percentage of body fat, SMM: skeletal muscle mass, TBW: total body water mass, WHR: abdominal obesity degree, VISC: visceral fat area, Sig. < 0.05.

Among male dancers, RNR dancers have the highest body weight, whereas their dance partners are the lightest among female dancers and the shortest. STLA dancers have the lowest percentage of body fat, while the highest values of body fat can be seen in female HH dancers, but not in males. The differences among female dancers were also found in waist-hip ratio and visceral fat area, where the values belong to STLA dancers. The highest average value of skeletal muscle mass among male dancers is found in RNR whereas in females, BD dancers are the strongest ones.

The data of body composition and 3D scan measurements of different body segments are presented in Tables III to VI. We selected and analyzed body segments, that we believe are under the constant influence of the training process and might indicate some asymmetries.

Table III. Body asymmetries among all dancers of different dance sexes.

Variable	Left Mean	Left SD	Right Mean	Right SD	df	t	p
Arm Lean Mass	2.81	0.81	2.85	0.82	100	-5.60	**.000**
Upper arm Girth	29.93	3.11	30.26	3.12	100	-3.17	**.002**
Elbow Girth	24.38	2.32	24.83	2.37	100	-5.65	**.000**
Forearm Girth	24.75	2.46	25.21	2.50	100	-7.54	**.000**
Wrist Girth	16.25	1.41	16.08	1.36	100	1.55	.126
Leg Lean Mass	8.12	1.72	8.12	1.72	100	-3.06	**.003**
Thigh Girth	59.00	5.03	58.93	4.82	100	0.50	.618
Knee Girth	37.53	2.30	37.78	2.26	100	-3.68	**.000**
Calf Girth	36.36	2.25	36.52	2.45	100	-3.38	**.001**

p < 0.05.

Male and female dancers of studied dance disciplines significantly differ among themselves between left and right sides in the majority of body segments. The right side is more developed which is reflected in higher values of arm and leg lean mass, furthermore in higher girth of elbow, forearm, knee, and calf. As studied disciplines differ in technical and physical aspects of dance and therefore body composition of a dancer is supposed to be in line with a certain demand, different asymmetries are expected. Based on a great number of asymmetries among all dance genres, with a predominantly dominant right side, we decided to analyze asymmetries separately by dance discipline.

Results of body asymmetries among STLA showed statistically significant differences both in anthropometric and body composition measurements between the left and right sides of the body (Table IV). Arm and leg lean mass, elbow, forearm, knee, and calf girth, were significantly higher on the right side.

Elbow, forearm, thigh, and knee girth were significantly higher on the right side of RNR male and female dancers (Table V).

HH dancers have statistically higher right arm lean mass, forearm, and knee girth (Table VI). Right arm and leg lean mass, right upper arm girth were statistically higher in BD dancers, whereas wrist girth was higher on their left side (Table VII).

Table IV. Body asymmetries among standard and Latin-American dancers.

Dance discipline/ STLA							
Variable	Left		Right				
	Mean	SD	Mean	SD	df	t	p
Arm Lean Mass	2.83	0.73	2.90	0.75	18	-3.57	**.002**
Upper arm Girth	29.21	2.80	29.29	2.71	18	-0.36	.725
Elbow Girth	23.98	2.06	24.87	2.16	18	-6.18	**.000**
Forearm Girth	24.31	2.26	24.99	2.22	18	-5.41	**.000**
Wrist Girth	15.91	1.24	16.10	1.07	18	-2.08	.053
Leg Lean Mass	8.67	1.58	8.72	1.64	18	-2.15	**.046**
Thigh Girth	57.97	4.63	58.06	4.09	18	-0.29	.777
Knee Girth	38.31	2.78	38.89	2.70	18	-3.76	**.001**
Calf Girth	37.31	2.08	37.60	2.10	18	-2.41	**.027**

$p < 0.05$.

Table V. Body asymmetries among rock and roll dancers.

Dance discipline/ RNR							
Variable	Left		Right				
	Mean	SD	Mean	SD	df	t	p
Arm Lean Mass	3.07	1.00	3.09	0.99	18	-1.46	.163
Upper arm Girth	30.59	4.04	31.03	3.93	18	-1.79	.090
Elbow Girth	24.89	2.97	25.60	2.83	18	-5.04	**.000**
Forearm Girth	25.33	3.05	26.12	3.06	18	-9.99	**.000**
Wrist Girth	16.13	1.81	16.31	1.29	18	-1.12	.276
Leg Lean Mass	8.59	2.33	8.60	2.28	18	-0.37	.716
Thigh Girth	59.01	5.68	59.42	5.38	18	-2.10	**.050**
Knee Girth	37.53	2.76	37.97	2.74	18	-3.19	**.005**
Calf Girth	37.37	2.75	37.54	2.67	18	-1.31	.206

$p < 0.05$.

DISCUSSION

Body characteristics in dance and other aesthetic sports have a significant effect on the performance of a dancer, dance couple, or group (Liiv *et al*., 2014) and vary according to dance genre needs. Different dance techniques require mastering the body in often extreme anatomical positions, which severely weigh down the musculoskeletal system (Motta-Valencia). STLA dancers tend to be the highest among dancers. They are also dancers with one of

Table VI. Body asymmetries among hip hop dancers.

Dance discipline/ HH							
Variable	Left		Right				
	Mean	SD	Mean	SD	df	t	p
Arm Lean Mass	2.32	0.43	2.36	0.42	39	-3.57	**.001**
Upper arm Girth	28.91	2.30	29.11	2.25	39	-1.26	.214
Elbow Girth	23.39	1.40	23.57	1.37	39	-1.70	.097
Forearm Girth	23.51	1.32	23.87	1.47	39	-3.24	**.002**
Wrist Girth	15.78	0.98	15.50	1.47	39	1.12	.270
Leg Lean Mass	7.13	0.97	7.14	0.97	39	-1.30	.200
Thigh Girth	58.92	4.16	58.88	4.44	39	0.20	.845
Knee Girth	37.33	2.15	37.58	1.89	39	-2.30	**.027**
Calf Girth	35.89	1.91	36.03	1.92	39	-1.97	.056

$p < 0.05$.

Table VII. Body asymmetries among breakdancers.

Dance discipline/ BD							
Variable	Left		Right				
	Mean	SD	Mean	SD	df	t	p
Arm Lean Mass	3.48	0.69	3.53	0.69	21	-2.64	**.015**
Upper arm Girth	31.83	2.88	32.54	2.78	21	-2.94	**.008**
Elbow Girth	26.08	2.27	26.40	2.47	21	-1.48	.154
Forearm Girth	26.87	2.19	27.07	2.30	21	-1.71	.101
Wrist Girth	17.49	1.16	16.90	0.96	21	5.79	**.000**
Leg Lean Mass	9.09	1.44	9.14	1.46	21	-3.07	**.006**
Thigh Girth	60.05	6.26	59.36	5.75	21	1.69	.107
Knee Girth	37.21	1.54	37.03	1.69	21	1.39	.180
Calf Girth	35.54	2.01	35.61	1.94	21	-0.93	.362

$p < 0.05$.

the lowest percentages of body fat and are at risk of developing eating disorders, like ballet and modern dancers. Because of the low weight also for aesthetic needs on the dance floor, the muscle mass of these dancers is very controlled. The low BMI allows them to move apparently without effort through the space, but the asymmetric dance posture (especially in standard), asymmetrical dance choreography which is perceived as most difficult and demanding, is pushing them towards the development of one side of the body. STLA dancers of the highest level – with more years of improving their technical skills to perfection and difficulty level – gradually develop more asymmetries, which can lead to many injuries. STLA dancers have the highest rate of low-back and feet injuries (Zaletel & Prus). Dancers perform and train in heels from a young age, therefore feet injuries are common. A lot of strain is also placed on the spine, especially in female dancers. Because the closed dance posture in standard dances is very unnatural and stiff, with dancers being in slight bend and twist, pain and injuries in the back can occur (Pellicciari *et al*., 2016). Male RNR dancers have the highest body weight among all dancers, and their partners have the lowest values among female dancers. The high body weight of male RNR dancers is probably the result of their high skeletal muscle mass. As males (RNR) have to be physically strong to perform all kinds of acrobatic movements such as lifts and throws, the physique of female dancers (short and light) aids to easier execution of the movement. Females (RNR) also have to control their body during difficult acrobatic figures, the success of which is correlated with a low percentage of body fat (Kostic *et al*., 2004; Miletic & Kostic, 2006). Like RNR male dancers, breakdancers also lean towards a more muscular type of dancers. Higher values can be seen in males as in females BD, which shows that a great development of muscle mass is required to conquer diverse and complex movements of breakdance (spins, twists, freezes, windmills etc.). Research that examines the anatomical asymmetries of the body segment is scarce or nonexistent, and most discuss and study the problem from a functional point of view (differences in strength and range of motion). We found that many asymmetries occur in all of the dance disciplines discussed. Thus, on the one hand, we can conclude that body asymmetries generally occur in dance through years of training and technical perfection, and on the other, asymmetries in the different dance disciplines could be understood and explained only by more detailed research.

Asymmetry of the lower limbs occurs in all dance disciplines; the more dominant leg (push-up) appears to be stronger, as indicated by larger lean mass on the leg (BD), larger thigh circumferences (RNR), knee girth (HH, RNR, STLA), and calf girth (STLA). RNR with high kicks strongly develops the thigh muscles, but performs twice more kicks on one leg. STLA dancers dance in high heels, which is a special phenomenon (larger calf circumference on one leg), which will need to be studied in more detail in further research. HH dancers often swing and bounce on their knees, rotating them in different directions, changing planes during the dance, and more successful HH dancers have the greater explosive power of their legs than less successful ones (Prus, 2015). Hip hop dancing techniques include fast and complex footwork, deep squats, twists, and quick changes in the direction of movement, most of the time in unnatural body positions.

An important part of the choreography is acrobatic elements, where dancers hit or collide with the ground with great force (Ojofeitimi *et al*.). All those rapid movements, rotations, and deviations in flexed and extended knee joints with jumping and landing present a high risk of knee injury in hip hop dancers. Asymmetries in dance also occur in the upper limb, especially in lean mass assuming of the dominant arm (STLA, HH, DB) and elbow circumference (STLA, RNR) and forearm girth (STLA, RNR, HH). Wrist circumference indicates asymmetry only in BD, which is logical given their one-arm supports performed on the ground. Thus, they carry their entire weight either in freezes or other acrobatic elements (flare, windmill, etc.). The most injured locations in BD are the wrist (69.0 %), fingers (61.9 %), and knee (61.9 %) (Cho *et al*., 2009). Approximately 70 % of all injuries in HH dance are time-loss injuries (Ojofeitimi *et al*.). The highest injury rate was found for breakdancers (3.8 injuries per injured dancer), followed by poppers/lockers (152 %, 2.3 injuries per dancer), and new schoolers (144 %, 2.3 injuries per dancer).

No study so far has examined other potentially important factors, such as anthropometric and body build indices or motor capacities, which may potentially be related to injury occurrence in dance. Specifically, hip hop dancers perform their movements while conquering their own body, with muscles at a functional disadvantage. Therefore, it is logical to expect that body dimensions (i.e., anthropometrics) and characteristics of body build may present as certain factors of influence on injury occurrence, as has been reported for other dance activities (Zaletel *et al*., 2017). Dance is more diverse than any other sport, and throughout all the different dance disciplines and styles has been perfected over the years. Each dance, with its own requirements of physical abilities, body image, body characteristics (e.g. anatomical limitations), has triggered the need for early specialization in one – most suitable – dance discipline. Early specialization and specific training load induce changes in young dancers, who are still growing and developing. We can assume, that in the early stages of dance training, asymmetries are less possible to have occurred, due to the complex and dynamic nature of dance, which comprises the whole body into its movement. Studies have proven that repetitive movements in athletes, where one side is more active than the other, causes significant differences in athletes' bodies, and can lead to overuse and various types of injuries. As dance is known for its asymmetrical movement of the dancer's body, the occurrence of some asymmetries, after a few years of training, is to be expected. Based on these assumptions, further analysis within each dance discipline is necessary, for a better understanding of possible consequences the training load has on dancers' bodies. While comparing dance disciplines with each other, we can see that STLA dancers are the most prone to develop body asymmetries. While dancers of more modern dance genres (e.g. jazz, modern, hip hop, breakdance) usually compete in one or more disciplines, STLA dancers more often compete in all 10 dances, whose characteristics require the refinement of the dance technique to the point of perfection. Therefore, we can assume that dancers and their instructors dedicate more time to the improvement of the technical aspects of choreography, and not as much to physical conditioning.

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RESUMEN: El baile es una disciplina deportiva atractiva cuya participación aumenta cada año, sin embargo también aumenta la prevalencia de lesiones. Varias disciplinas de baile y las técnicas de baile requieren el control del cuerpo en posiciones anatómicas extremas las cuales ejercen una gran presión sobre el sistema musculoesquelético. El objetivo de esta investigación fue analizar las asimetrías corporales de cuatro disciplinas de baile diferentes (baile estándar y latinoamericano - STLA, rock and roll acrobático - RNR, breakdance - BD y hip hop - HH), utilizando técnicas antropométricas (InBody 720; Biospace Co. ., Ltd) y mediciones corporales en 3D (NX-16; TC2) para establecer posibles molestias y lesiones posteriores. Se realizó la prueba T para determinar diferencias entre los miembros izquierdo y derecho en las cuatro disciplinas de baile. Los resultados de este estudio mostraron que las asimetrías se encontraron en todas las disciplinas de baile. Al comparar las disciplinas de baile, descubrimos que los bailarines de STLA son los más propensos a desarrollar asimetrías corporales (seis de nueve variables pareadas), principalmente debido a la posición cerrada. La posición en sí es asimétrica y en la que los bailarines permanecen durante mucho tiempo mientras entrenan la técnica de cada baile. Como el baile es conocido por el movimiento asimétrico del cuerpo, es posible que algunas de las

asimetrías aparezcan después de algunos años de entrenamiento. Se requiere un análisis más profundo y detallado dentro de cada disciplina de danza para una mejor comprensión de las posibles consecuencias de las asimetrías en los cuerpos de los bailarines.

PALABRAS CLAVE: Danza; Asimetría; Antropometría; Circunferencias; Baile de salon; Rock and roll; Hip hop; Breakdance.

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