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Original Article

BIOMECHANIC OF BALLROOM DANCE: CORPORATE ADAPTATIONS WITH DIFFERENT FOOTWEAR

BIOMECÂNICA DA DANÇA DE SALÃO: ADAPTAÇÕES CORPORAIS COM DIFERENTES CALÇADOS

Laís dos Santos Saraiva do Pilar[1], **Karini Borges dos Santos**[1,2], **André Luis Felix Rodacki**[1] and **Jerusa Petróvna Resende Lara**[1]

[1]Federal University of Paraná, Paraná-PR, Brazil.
[2]University of Brasília, Distrito Federal-DF, Brazil.

RESUMO
O objetivo deste estudo foi comparar a amplitude articular, angulação da coluna e deslocamento do centro de massa durante execução do samba de gafieira com e sem salto alto em diferentes velocidades. Adicionalmente, a reprodutibilidade do movimento foi testada. Quinze dançarinas experientes realizaram uma sequência de passos de samba de gafieira nas condições: salto alto (7,5 cm) e sapatilha em duas velocidades de execução de acordo com o compasso das músicas (72 e 96bpm). A análise cinemática foi realizada no sistema Vicon® com 11 câmeras (100 Hz). Vinte e um marcadores reflexivos foram posicionados sobre o corpo das participantes a fim de calcular o centro de massa e ângulos articulares dos membros inferiores e coluna. A reprodutibilidade foi determinada pelo coeficiente de correlação intraclasse e a comparação entre condições foi testada por uma análise de variância Two way, com os fatores calçados e velocidade. Os resultados indicaram para uma reprodutibildade de moderada a muito alta em todas as variavéis analisadas. Não foram encontradas diferenças entre as curvaturas da lombar, torácia e deslocamento do centro de massa. Não houve interação entre tipos de calçado e velocidade de execução dos passos, porém analisando os fatores principais, ocorreu uma diminuição do ângulo de plantiflexão do tornozelo esquerdo com o aumento da velocidade. Os ângulos de tornozelo apresentaram diminuição significativa em situação do uso de sapatilhas, quando comparados ao salto. Conclui-se que o salto alto não altera a curvatura da lombar, deslocamento de centro de massa e amplitude articular do joelho e quadril na execução do samba de gafieira.
Palavras-chave: Dança. Cinemática. Salto alto.

ABSTRACT
The aim of this study was to compare the joint amplitude, spine angulation and displacement of the center of mass during the execution of gafieira samba with and without high heels at different speed. In addition, the reproducibility of the movement was tested. Fifteen experienced dancers performed a sequence of gafieira samba steps under the conditions: high heels (7.5cm) and flats at two speeds according to the beat of music (72 and 96bpm). Kinematic analysis was performed on the Vicon® system with 11 cameras (100 Hz). Twenty-one reflective markers were positioned over the participants' bodies to calculate the center of mass and joint angles of the lower limbs and spine. Reproducibility was determined by the intraclass correlation coefficient and the comparison between conditions was tested by a Two-way Analysis of Variance, with the factors footwear and speed. The results indicated to a moderate to very high reproducibility in all variables analyzed. No differences were found between lumbar curvature, thoracic and displacement of the center of mass. There was no interaction between types of footwear and step execution speed, but analyzing the main factors, there was a decrease in the left ankle plantiflexion angle with increasing speed. The ankle angles showed a significant decrease under the condition flats when compared to high heels. In conclusion, high heels do not alter lumbar curvature, displacement of the center of mass and knee and hip joint amplitude in the execution of gafieira samba.
Keywords: Dance. Kinematics. High heels.

Introduction

Samba de gafieira is a popular partner dance that requires constant body adjustments to maintain posture and balance during the performance[1]. Among women, keeping balance may be even more challenging when wearing heels. Studies on variations in heel height in relation to the forefoot, both in gait and upright position, reveal that heels might alter the alignment of the spine, mainly in the lumbar region, which in turn, affects the pattern of movement and balance[2,3]. However, there is still no consensus over the changes brought by heels to the behaviour of the column. Pegoretti et al. (2005)[4], with participants who walked on an ergometric treadmill, report that lumbar lordosis straightened progressively as heel height increased. On the other hand, Minossi et al. (2012)[5] , when analyzing young participants in orthostatic position, found no significant differences for thoracic and lumbar angles in upright posture when wearing 9cm heels compared to when barefoot.

The possible misalignment of the spine, together with the maintenance of the plantar flexion imposed by heels and with the constant movement of the spine, may constitute obstacles to the stability of posture, since these factors may interfere directly on the body's center of mass. Each individual has their own balance, lateral and anteroposterior alignment of the spine, which may vary due to age, weight, sex, and especially body morphology[6]. Studies related to the maintenance of balance usually seek to identify the causes of instability for the prevention of falls, strategies of posture maintenance and interaction of the sensory systems involved in this maintenance[7,8]. Among the external factors that can interfere in this joint balance, the increase in heel height in relation to the forefoot stands out[9].

The study of center of mass displacement in relation to the heel support may provide information to control risks and adverse effects, such as: discomfort, fatigue, imbalance and alterations during movements such as walking exercises[10]. According to Tencer (2004)[11], shoes with heels higher than 2.5cm increase the difficulty of body control and the risk of lateral imbalance. Therefore, posture, alignment of the column, and variation of the position of the center of mass are directly related to each other. The disturbance in balance and body control caused by heels may increase during the performance of more challenging movements than walking, such as dancing.

In ballroom dance, it is usual for movements to be repeated at different speeds. Movement speed may vary according to the tempo of a song and may influence in the range-of-motion of movements. Studies confirm that an increase in speed causes changes in the pattern of execution of movements. An example of this is the relationship between the change in speed with the lumbar curvature angle or the biomechanical pattern of movements, based on the study of gait[12,13]. The effect of footwear on the speed of execution of steps in ballroom dance has not yet been explored in the literature and there are reported discrepancies on the adaptations of the lumbar spine according to heel height. Thus, this study aims to contribute to the expansion of scientific knowledge in the area, considering the assortment of footwear available in the market for consumers and dancers.

The major objective of this study was to compare the range-of-motion, lumbar spine angle and center of mass displacement during the performance of *samba de gafieira* with and without heels at different speeds. However, to analyze possible influences of footwear and speed, we must ensure that the differences found are related to these variables, and not to the subject under analysis. Therefore, a secondary objective of this study was to evaluate the repeatability of the variables of interest, in order to guarantee a higher degree of reliability when measuring the data. The hypothesis of this study is that the lumbar and thoracic curvatures will become straighter during the execution of the ballroom dance steps, depending on the speed of execution.

Method

Participants

The sample consisted of 15 female volunteers (age: 27.0 ± 4.1 years; height: 1.60 ± 0.72m; mass: 52.0 ± 8.0Kg), who practiced *samba de gafieira* and had experience with other ballroom dances (5,0 ± 3,2 years of experience). The participants signed a written informed consent form and the experimental procedures of the study were approved by the Institutional Ethics Committee (CAAE: 00679418.3.0000.0102).

Procedures and data analysis

Each dancer performed a sequence of *samba de gafieira* steps (*base step, jump, manteiga, parting*) at two speeds (72 and 96 rpm), with two types of shoes: i) heels (7.5 cm high) and ii) flats. The execution speed of each step was controlled by the beats per minute (bpm) of two different songs. The beats were calculated using the Abyssmedia BPM Counter software (v. 1.6.0.0). The participants were instructed to perform the steps in the rhythms of the selected songs, 72 and 96 bpm. The sequence of footwear combined with the speed was chosen randomly. The volunteers used their own footwear and were led by the same partner. To determine repeatability, a dancer was asked to repeat the experimental procedures for five days, with a 24-hour interval between them.

For the kinematic analysis, the Vicon® motion capture system with 11 cameras (VICON ® Motion Systems Ltd) was used, with an acquisition frequency of 100 Hz. As shown in Figure 1, 21 reflective markers were bilaterally attached to the volunteers' bodies at the following anatomical points: acromion (P1,P2), lateral epicondyle of the ulna (P3,P4), styloid process (P5,P6), iliac spine (P18,P19), sacrum (P9), lateral epicondyle of the femur (P12,P13), lateral malleolus (P16,P17), first metatarsal head (P20,P21), calcaneus (P7,P8), and recognition points on the thighs and legs between the anatomical points (P10,P11,P14,P15). The Plug-in-Gait model was used for the composition of the 21 markers; 15 markers were placed on the lower limbs and 6 on the upper limbs - only to define the beginning and end of the segment, in order to calculate the center of mass of the body. In addition, 3 rods containing two markers each (Figure 1B) were fixed to the spine in vertebrae C7, T12 and L5. The calculations of the thoracic and lumbar curvature angles were made through the angle between the vectors, defined by the rods fixed in the mentioned prominences. Through the three-dimensional coordinates over time of each of the markers of each rod, it was possible to obtain a vector for C7, T12 and L5 (Figure 1C).

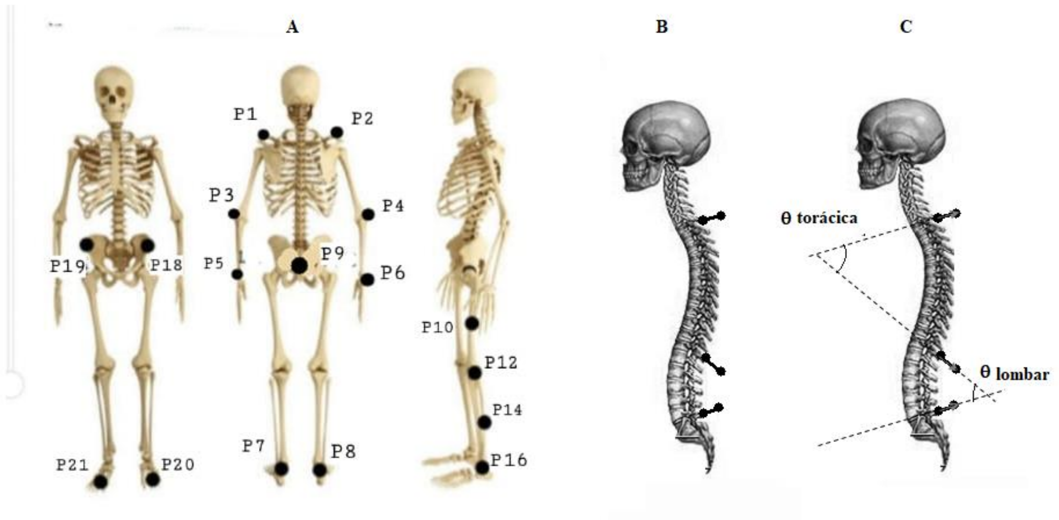

Figure 1. A: Illustration of the protocol for markers of the upper and lower limbs; B: rods for definition of column markers. C: Vectors associated to the rods and calculation of thoracic and lumbar angles
Source: The authors

The three-dimensional coordinates were filtered with a second-order Butterworth low-pass filter, with a cutoff frequency of 10Hz. The calculations of the spine angles and center of mass (CM), taking into account the segments of the lower and upper limbs, were performed in MATLAB. The bilateral joint angles of the ankle, knee, hip and pelvis were calculated using the Nexus software. The variables analyzed during the entire movement were: i) three-dimensional CM displacement; ii) maximum and minimum joint angles of the ankle, knee, hip and pelvis; and iii) maximum, minimum and mean angles of lumbar and thoracic curvature.

To analyze the repeatability, the intraclass correlation coefficients[14] were calculated for the following variables: i) spine angles (thoracic and lumbar); ii) CM displacement; and ii) hip, knee, ankle and pelvis joint angles. For interpretative purposes, reliability was considered poor (up to 0.25), low (0.26 - 0.49), moderate (0.50 - 0.69), high (0.70 - 0.89), and very high (above 0.90), according to the reference values described by Domholdt[15].

Statistical analysis

Initially, the data were processed by means of standard descriptive statistics (mean and standard deviation) for each of the conditions: footwear types and speed. The Shapiro-Wilk test was used to test the normality of the data. The analysis of variance (Two-way ANOVA), in which the factors were types of footwear (heels and flats) and different speeds (72 and 96 bpm), was used to compare the groups. In addition, the coefficient of variation was calculated. The η^2 (eta squared) was calculated to measure the effect size. The SPSS software (Inc., Chicago, IL) was used for statistical analysis with a significance level of $p<0.05$.

Results

Repeatability

The results for repeatability of the two types of footwear evaluated at the two speeds of movement for center of mass, spine angles, and joint angles are illustrated in Figure 2. We can observe values of ICC between 0.98 in the mediolateral direction and 1.00 in the anteroposterior direction of the CM displacement, which classifies the experiment with a very high reliability rate. The values were categorized with high repeatability for thoracic (0.81 - 0.87) and ranged from moderate to high for lumbar (0.53 - 0.82) spines. The values for the joint angles were classified as very high (0.92 - 1.00) regardless of the joint. The repeatability values for the variables CM displacement, spine angles and joint amplitude were independent of the conditions analyzed (footwear and speed).

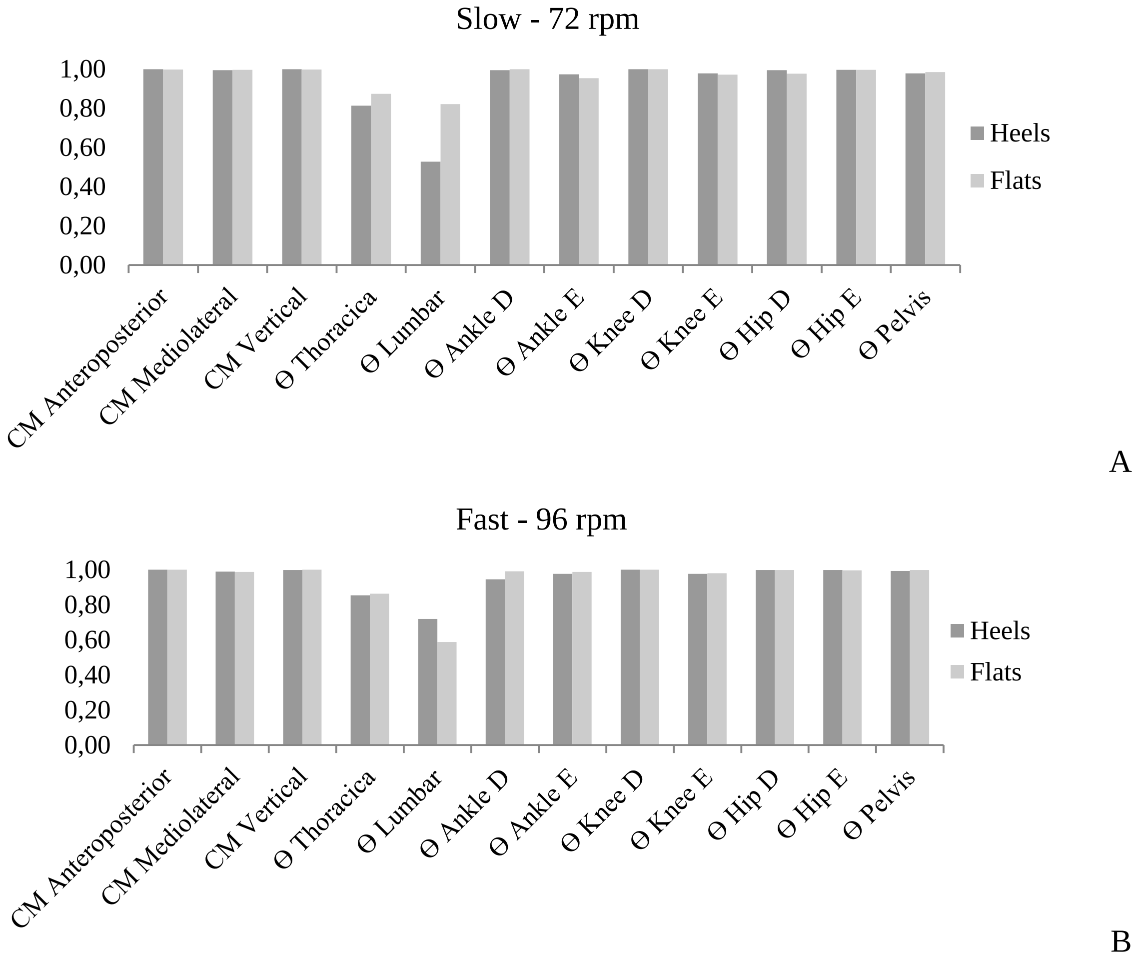

Figure 2. Repeatability (ICC) of center of mass displacement, spine angles, and lower limb joint amplitudes for the two speeds of ballroom dance steps: Slow (A) and Fast (B)
Source: The authors

Interaction between types of footwear and steps speed

There were no significant interactions ($p<0.05$) between the type of footwear and the speed of execution of the steps for any of the variables studied, but there were differences in the main factors, that is, in the types of footwear and speed of execution.

Comparison: Flats x Heels

No significant differences were found when comparing the center of mass displacement and the spine angles for both footwear (heels and flats) at different speeds (Table 1).

When comparing lower limb angles, significant differences were found only for ankle angulation values (Table 2). For the right ankle, such results were related to the footwear (minimum and maximum values). The plantar flexion angles, in the situation where the dancers wore flats, were significantly lower ($p = 0.05$; ES 0.09) compared to when heels were used, regardless of the speed with which the step was executed. The dorsiflexion angle (maximum angles) in the scenario where flats were used was higher ($p = 0.00$; ES = 0.61) compared to heels, regardless of speed.

For the left ankle, only the dorsiflexion angle in the scenario with flats was higher ($p = 0.00$; ES = 0.73) compared to heels, regardless of speed (Figure 3).

Comparison: Step execution speed (72 and 96 bpm)

Significant differences were found (p=0.05 and ES=0.07) for both speeds of execution of the step, regardless of the footwear used, for the minimum angle of the left ankle. For both footwear, the plantar flexion angle in fast speed (96 bpm) was lower (p=0.07; ET 0.73) than in slow speed (Figure 3).

Table 1. Comparison of the center of mass displacement, maximum, minimum, mean and average amplitude values of thoracic and lumbar angles during a sequence of *samba de gafieira* at different speeds and with different footwear

		Speed	**Slow (72rpm)**		**Fast (96rpm)**		**Footwear**	**Sp**	**Inter**
		Footwear	**Heels**	**Flats**	**Heels**	**Flats**	***p* (ES)**	***p* (ES)**	***p* (ES)**
CM Displacement [m]	**AP**	**mean(SD)**	2,13 (0,17)	2,21 (0,24)	2,18 (0,17)	2,22 (0,15)	0,18	0,57	0,70
		CV	7,98	10,86	7,80	6,76	(0,32)	(0,01)	(0,00)
	ML	**mean(SD)**	0,33 (0,09)	0,33 (0,09)	0,31 (0,10)	0,35 (0,08)	0,40	0,89	0,49
		CV (%)	27,27	27,27	32,26	22,86	(0,01)	(0,00)	(0,01)
	VT	**mean(SD)**	0,33 (0,09)	0,10 (0,02)	0,10 (0,02)	0,10 (0,02)	0,51	0,37	0,44
		CV (%)	27,27	20,00	20,00	20,00	(0,01)	(0,01)	(0,01)
Thoracic Angle [°]	**Min**	**mean(SD)**	21,12 (10,93)	19,84 (10,45)	22,52 (10,33)	21,84 (10,23)	0,70	0,53	0,91
		CV	51,75	52,67	45,87	46,84	(0,00)	(0,01)	(0,00)
	Max	**mean(SD)**	47,23 (10,32)	47,23 (7,93)	48,88 (10,38)	52,90 (21,62)	0,57	0,30	0,57
		CV	21,85	16,79	21,24	40,87	(0,01)	(0,02)	(0,01)
	Mean	**mean(SD)**	33,49 (9,23)	33,63 (8,87)	34,39 (8,81)	34,54 (8,06)	0,95	0,69	1,00
		CV	27,56	26,38	25,62	23,34	(0,00)	(0,00)	(0,00)
	Ampl	**mean(SD)**	26,12 (10,08)	27,39 (6,21)	26,36 (9,27)	31,05 (22,68)	0,40	0,58	0,63
		CV	38,59	22,67	35,17	73,04	(0,01)	(0,01)	(0,00)
Lumbar Angle [°]	**Min**	**mean(SD)**	15,92 (8,68)	15,43 (7,52)	15,58 (8,14)	15,66 (8,41)	0,92	0,98	0,89
		CV	54,52	48,74	52,25	53,70	(0,00)	(0,00)	(0,00)
	Max	**mean(SD)**	35,98 (9,48)	36,02 (8,10)	38,33 (10,63)	37,70 (9,14)	0,90	0,41	0,89
		CV	26,35	22,49	27,73	24,24	(0,00)	(0,01)	(0,00)
	Mean	**mean(SD)**	24,3 (8,76)	24,8 (8,82)	24,69 (8,36)	24,33 (8,93)	0,98	0,99	0,85
		CV	36,05	35,56	33,86	36,70	(0,00)	(0,00)	(0,00)
	Ampl	**mean(SD)**	20,06 (7,43)	20,59 (5,93)	22,75 (8,17)	22,04 (9,73)	0,97	0,32	0,77
		CV	37,04	28,80	35,91	44,15	(0,00)	(0,02)	(0,00)

Note: CM - Center of Mass ; AP - Anteroposterior; ML Mediolateral; VT - Vertical; CV - Coefficient of Variation; Sp - Speed; Int - Interaction; ES - Effect Size; p<0.05
Source: The authors

Table 2. Maximum and minimum angular range/amplitude values of the lower limb joints during a *samba de gafieira* sequence at different speeds and with different footwear

			Slow		Fast		Footwear	Sp	Int
		Variable	**Heels**	**Flats**	**Heels**	**Flats**	***p* (ES)**	***p* (ES)**	***p* (ES)**
Right Ankle	**Min**	**mean(SD)**	-51,12 (19,42)	-35,28 (17,02)	-45,01 (12,56)	-41,22 (16,73)	0,05	0,99	0,21
		CV	37,99	48,24	27,90	40,59	(0,09)	(0,00)	(0,03)
	Max	**mean(SD)**	8,90 (9,30)	34,69 (8,39)	10,34 (14,78)	34,43 (8,21)	0,00	0,83	0,79
		CV	104,49	24,25	142,94	23,85	(0,61)	(0,00)	(0,00)
Left Ankle	**Min**	**mean(SD)**	-36,37 (17,04)	-30,59 (18,64)	-29,69 (8,24)	-21,12 (13,13)	0,08	0,05	0,73
		CV	46,85	60,93	27,75	62,17	(0,06)	(0,07)	(0,00)
	Max	**mean(SD)**	7,63 (6,85)	36,32 (8,52)	9,99 (5,66)	38,28 (12,47)	0,00	0,37	0,93
		CV	89,78	23,46	56,66	32,58	(0,73)	(0,02)	(0,00)
Right Knee	**Min**	**mean(SD)**	-18,41 (11,22)	-18,13 (11,22)	-16,99 (11,39)	-17,91 (10,60)	0,91	0,78	0,84
		CV	60,95	61,89	67,04	59,18	(0,00)	(0,00)	(0,00)
	Max	**mean(SD)**	137,21 (14,53)	137,65 (16,58)	133,34 (18,50)	137,58 (12,78)	0,61	0,67	0,68
		CV	10,59	12,05	13,87	9,29	(0,01)	(0,00)	(0,00)
Left Knee	**Min**	**mean(SD)**	-13,39 (4,81)	-13,87 (5,37)	-12,70 (6,60)	-13,28 (6,27)	0,75	0,70	0,97
		CV	35,92	38,72	51,97	47,21	(0,00)	(0,00)	(0,00)
	Max	**mean(SD)**	40,21 (15,00)	41,88 (14,45)	41,51 (14,64)	45,40 (15,22)	0,52	0,57	0,79
		CV	37,30	34,50	35,27	33,52	(0,01)	(0,01)	(0,00)
Right Hip	**Min**	**mean(SD)**	-10,19 (5,14)	-875,00 (5,94)	-8,14 (6,11)	-11,45 (12,17)	0,68	0,89	0,30
		CV	50,44	0,68	75,06	106,29	(0,00)	(0,00)	(0,02)
	Max	**mean(SD)**	35,07 (6,65)	37,75 (13,19)	37,17 (6,37)	44,56 (17,41)	0,15	0,20	0,50
		CV	18,96	34,94	17,14	39,07	(0,05)	(0,04)	(0,01)
Left Hip	**Min**	**mean(SD)**	-12,96 (8,15)	-15,17 (8,13)	-12,89 (8,01)	-17,68 (16,09)	0,15	0,81	0,79
		CV	62,88	53,59	62,14	91,01	(0,04)	(0,00)	(0,00)
	Max	**mean(SD)**	28,77 (16,68)	42,70 (37,91)	30,10 (17,72)	34,96 (21,14)	0,15	0,62	0,48
		CV	57,98	88,78	58,87	60,47	(0,04)	(0,00)	(0,01)
Pelvis	**Min**	**mean(SD)**	-15,46 (11,42)	-22,09 (12,16)	-19,44 (12,51)	-23,93 (20,59)	0,15	0,46	0,78
		CV	73,87	55,04	64,35	86,04	(0,04)	(0,01)	(0,00)
	Max	**mean(SD)**	17,09 (10,10)	69,19 (132,34)	16,45 (10,03)	21,74 (13,70)	0,13	0,96	0,78
		CV	59,10	191,27	60,97	63,02	(0,04)	(0,00)	(0,00)

Note: SD - standard deviation; CV - Coefficient of variation; Speed; Int - Interaction; TE - effect size**;** p <0.05
Source: The authors

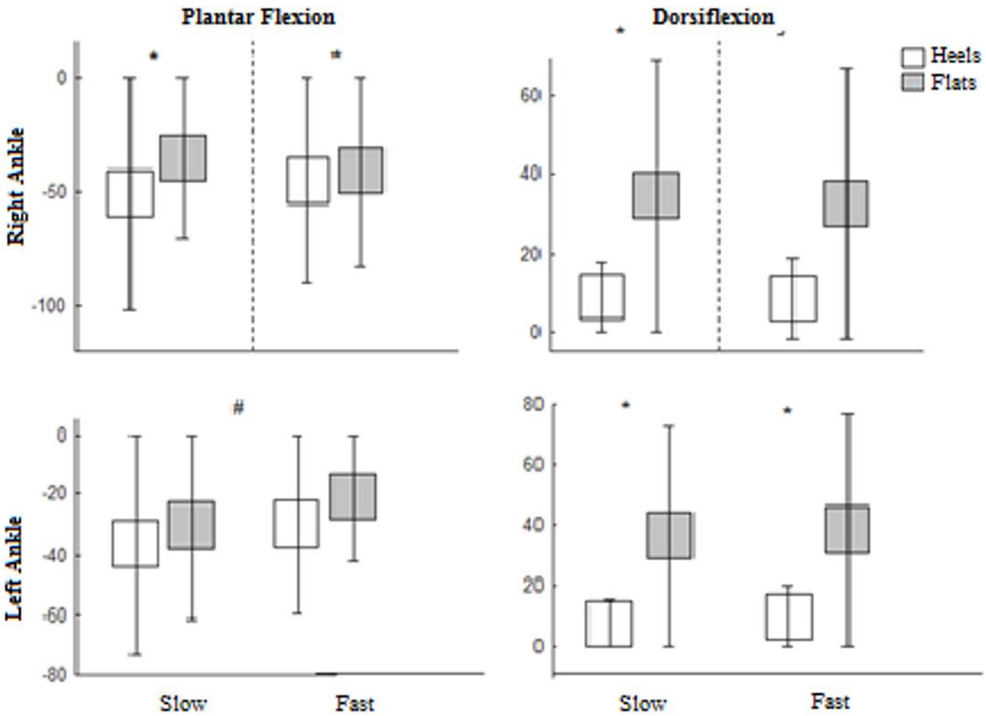

Figure 3. Comparison between footwear and samba steps speed. *Significant difference between footwear. #Significant difference between speeds
Source: The authors

Discussion

The purpose of this study was to verify possible influences of footwear on range-of-motion, spine curvature and center of mass displacement during a performance of *samba de gafieira*. In addition, the repeatability of the execution of the movement was tested.

The repeatability was moderate to very high, suggesting a low variability in repeating the performed movements, what may be due to the dancers' experience with ballroom dance and in the use of high heels. Also, the dancers wore their own shoes, which reduces possible variations related to familiarization. Carter et al. (2018)[16] verified intraclass correlation coefficients ≥ 0.70 during the execution of a ballet sequence for the metatarsophalangeal joint in the sagittal plane and at all inter-segmental angles, except for the frontal planes of the tibia-hindfoot and of the hindfoot-midfoot. On the other hand, the inter-rater repeatability in Carter's study varied from weak to excellent for the 3D segment rotations attributed to inconsistencies in the positioning of markers performed by two different researchers. In this study, the markers were placed by only one person in order to avoid inter-rater measurement variability.

The high repeatability found ensures that the results of the comparisons refer to the conditions tested (footwear and speed) and not to the subject's variability in the execution of the movements. The comparisons showed that regardless of footwear and execution speed, the values do not significantly change the balance when performing the dance sequence. It is known that, while walking, the foot support is 60% on the forefoot and 40% on the hindfoot. With the use of heels, the forefoot support increases according to the height of the heel[17]. That is, the body's center of mass is projected forward and triggers compensatory changes[18]. However, in this study, the displacement of the center of mass did not present significant changes between the conditions analyzed, what may be justified by the level of experience of the participants in ballroom dance and in the use of high heels.

No significant differences were found in both footwear and speed situations for lumbar and thoracic angulation values. Equivalent results were found in the literature for gait evaluation. In Minossi's study (2011)[5], spinal angulation did not present significant differences when comparing gait with and without heels (9 cm). On the other hand, Baaklini et al. (2017) [19] reported a decrease in lumbar thoracic spine angles when comparing gait with low and high heels (4cm and 10cm, respectively). Different methods of assessing lumbar curvature, footwear type and heel height may explain the controversial results. No other studies assessing the influence of heels on dance movement were found. The results indicate that heels up to 7.5cm are not sufficient to alter the angulation of the spine in experienced dancers.

As for the analysis of joint angles of the lower limbs, no significant interactions were found between type of footwear and speed for any of the variables studied, which suggests that the results analyzed do not depend on the type of footwear if the step is performed at different speeds. However, when comparing the speeds independently of the footwear, it was noticed that the plantar-flexion angle of the left ankle was lower when the steps were performed at a faster speed. This finding suggests that the dancers do not have enough time to increase ankle range-of-motion because they perform the steps faster, having to switch to the next step, while in slower executions this range increases.

Regarding the angle of the lower limbs, only the ankle showed significant differences between conditions. Such result was expected since heels force a sharp plantar flexion[18]. It was found in the literature that, when measuring one's posture wearing stiletto and platform heels via computerized photogrammetry, there was a difference in knee alignment between the stilettos and bare feet, and in the positioning of the ankle in all footwear evaluated[20]. Limana et al. (2012)[21] compared ankle kinematics in different footwear and found that, with increasing heel height, there is an increase in ankle angle during plantar flexion in gait.

The dance sequence requires that the right and left ankles perform distinct movements at certain times, and the speed condition of the movements resulted in significant differences only to the left side due to an asymmetry of the sequence. The single difference when comparing footwear was that participants presented a slight plantar flexion during the execution of the dance moves when wearing flats, since they use the forefoot to dance.

The other angles of the lower limbs did not present significant differences when comparing the execution of the dance sequence with or without heels at different speeds. The distance between the rater and the participants, and the fact that it was a laboratory experiment may justify such findings. The rater's distance and the markers fixed to the dancers' bodies may have influenced the naturalness of the movements, which may differ from dance events situations. Also, at dance events, there is a large number of people sharing the same space, leading is not agreed upon beforehand, and the variation of steps and space between pairs varies constantly. Laboratory analysis, on the other hand, requires greater control and standardization. In addition, with the system used in this study, pair contact would result in occlusion of reference markers. Further studies are needed to extend research into the biomechanics of ballroom dance in situations closer to normal practice.

Conclusions

The repeatability for the movements of samba de gafieira was high, i.e., there is a high likelihood of repeating the movement and obtaining similar results. When comparing the interference of the footwear in the movement, we conclude that heels do not alter the balance during the dance sequence and there is no rectification or increase of the lumbar spine angle with the use of heels. Regarding the joint angles, the heels only increase the plantar flexion angle of the ankle. It is suggested that heels do not alter the execution of samba de gafieira movements in the evaluated conditions.

References

1. Barreto JF. Sistema estomatognático y esquema corporal. Colomb Med 1999;30(4):173-180.
2. Furtado AC, Oliveira EC, Schmidt EMM, Xavier KCR, Martins LS, Arantes MVC, et al. Estudo da marcha humana em diferentes tipos de calçados. XI Encontro Latino Americano de Iniciação Científica e VII Encontro Latino Americano de Pós-Graduação. Paraíba: Universidade do Vale do Paraíba; p.1071-1074.
3. Opila KA, Wagner SS, Schiowitz S, Chen J. Postural alignment in barefoot and high-heeled stance. Spine 1988;13(5):542-547. DOI: 10.1097/00007632-198805000-00018
4. Pegoretti C, Brenzikofer R, Wittig DS, Benetti FA, Deprá PP, Campos MH. A influência do aumento da altura dos saltos dos calçados na lordose lombar. Rev Cienc Med 2012;14(5):425-432.
5. Minossi CEdS, Candotti CT, Bacchi CdA, Noll M, Casal MZ. Avaliação da coluna lombar e torácica nas situações com salto alto e com os pés descalços com o instrumento arcômetro. Fisioter Pesqui 2012;19(3):196-203. DOI: 10.1590/S1809-29502012000300002
6. Vialle R, Levassor N, Rillardon L, Templier A, Skalli W, Guigui P. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. J Bone Joint Surg Am 2005;87(2):260-267. DOI: 10.2106/JBJS.D.02043
7. Duarte M, Zatsiorsky VM. Patterns of center of pressure migration during prolonged unconstrained standing. Motor control 1999;3(1):12-27. DOI: 10.1123/mcj.3.1.12
8. Bankoff ADP, Beckedorf RG, Schmidt A, Ciol P, Zamai CA. Static body balance analysis through an electronic baropodometer. Conexões 2007;4(2):19-30.
9. Menant JC, Perry SD, Steele JR, Menz HB, Munro BJ, Lord SR. Effects of shoe characteristics on dynamic stability when walking on even and uneven surfaces in young and older people. Arch Phys Med Rehabil 2008;89(10):1970-1976. DOI: 10.1016/j.apmr.2008.02.031
10. Chien H-L, Lu T-W, Liu M-W. Control of the motion of the body's center of mass in relation to the center of pressure during high-heeled gait. Gait Posture 2013;38(3):391-396. DOI: 10.1016/j.gaitpost.2012.12.015
11. Tencer AF, Koepsell TD, Wolf ME, Frankenfeld CL, Buchner DM, Kukull WA, et al. Biomechanical properties of shoes and risk of falls in older adults. J Am Geriatr Soc 2004;52(11):1840-1846. DOI: 10.1111/j.1532-5415.2004.52507
12. Yang Y-T, Yoshida Y, Hortobágyi T, Suzuki S. Interaction between thorax, lumbar, and pelvis movements in the transverse plane during gait at three velocities. J appl biomech 2013;29(3):261-269. DOI: 10.1123/jab.29.3.261
13. Mann L, Teixeira CS, Mota CB. A marcha humana: interferências de cargas e de diferentes situações. Arq Ciências Saúde UNIPAR 2008;12(3):257-264. DOI: 10.25110/arqsaude.v12i3.2008.2543
14. Bernardi M, Castellano V, Ferrara MS, Sbriccoli P, Sera F, Marchetti M. Muscle pain in athletes with locomotor disability. Med Sc Sports Exerc 2003;35(2):199-206. DOI: 10.1249/01.MSS.0000048635.83126.D4
15. Domholdt E. Physical therapy research: Principles and applications. Philadelphia: W B Saunders Co; 1993. DOI: 10.4236/jamp.2018.612223
16. Carter SL, Sato N, Hopper LS. Kinematic repeatability of a multi-segment foot model for dance. Sports Biomech 2018;17(1):48-66. DOI: 10.1080/14763141.2017.1343864
17. Carrasco AC. Estudo da distribuição da pressão plantar e da oscilação corporal em relação ao peso da bolsa e ao uso de salto alto em mulheres. São José dos Campos: Universidade do Vale do Paraíba; 2010.
18. Cronin NJ. The effects of high heeled shoes on female gait: a review. J Electromyogr Kinesiology 2014;24(2):258-263. DOI: 10.1016/j.jelekin.2014.01.004
19. Baaklini E, Angst M, Schellenberg F, Hitz M, Schmid S, Tal A, et al. High-heeled walking decreases lumbar lordosis. Gait Posture 2017;55:12-14. Doi: 10.1016/j.gaitpost.2017.03.035. DOI: 10.1016/j.gaitpost.2017.03.035
20. Iunes D, Monte-Raso V, Santos C, Castro F, Salgado H. A influência postural do salto alto em mulheres adultas: análise por biofotogrametria computadorizada. Rev Bras Fisioter 2008;12(6):441-446. DOI: 10.1590/S1413-35552008005000003

21. Limana MD, Deprá PP, Capelini JC, Mori MLGTS. Efeito agudo do calçado de diferentes alturas sobre o comportamento angular do tornozelo. Fisioter Pesqui 2012;19(3):222-227.

Author's **Orcid**:
Laís dos Santos Saraiva do Pilar: https://orcid.org/0000-0002-0043-9967
Karini Borges dos Santos: https://orcid.org/0000-0002-4815-7774
André Luis Felix Rodacki: https://orcid.org/0000-0002-4585-497X
Jerusa Petróvna Resende Lara: https://orcid.org/0000-0002-2250-2234

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Author address: Laís dos Santos Saraiva do Pilar. Coração de Maria 92, Bairro Jardim Botânico, PR, CEP 80215-370. E-mail: laisantosavi@gmail.com