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ORIGINAL RESEARCH

Factors that influence in the turnout in ballet dancers with knee pain

Fatores que influenciam no turnout em bailarinas clássicas com dor nos joelhos

Factores que influyen en el turnout em bailarinas com dolor em lãs rodillas

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ABSTRACT | The turnout, primary gesture in classical ballet, refers the 180º of the feet. The lateral rotation provides the greatest amount of degrees necessary to perform the position perfectly. If performed improperly, it can generate problems, specialy in the knees, causing pain. The aim of this study was to evaluate the factors that influence the implementation of turnout in adolescents ballet dancers with knee pain and to compare them to the dancers without pain. Twenty three (23) ballet dancers with knee pain and 26 ballet dancers without pain were evaluated for range of motion of external rotation of the hip, muscle strength, femoral neck anteversion and static and dynamic turnout. The angles were measured with a manual goniometer, and the strength of the abductor muscle groups, external rotators and hip extensors with isometric dynamometer. The analysis was performed using ANOVA and Mann-Whitney. Range of motion of external rotation of the hip, femoral neck anteversion and muscle strength were similar between groups. The dynamic turnout was lower in ballet dancers with knee pain (p=0.02) and ballerinas with angular deficits above 10% over the static group had lower turnout under the bilateral extensor muscle group (p=0.04 and 0.03, right left) and right abductor (p=0.03). Although anatomical factors can influence the lateral rotation of the turnout, the angle decreased dynamic turnout was related to the group of dancers with pain. This suggests that training based on proximal awareness of movement can prevent and minimize burdens on the knees of classical dancers teens.

Keywords | Dancing; Knee; Pain; Hip.

RESUMO | O *turnout*, gesto principal do balé clássico, refere-se à posição de 180º entre os pés. A rotação lateral do quadril fornece a maior quantidade de graus necessários para realizar a posição com perfeição. Se executada de forma inadequada, pode gerar compensações, preferencialmente nos joelhos, ocasionando dor. O objetivo deste estudo foi avaliar fatores que influenciam na execução do *turnout* em bailarinas clássicas adolescentes com dor nos joelhos e comparar a bailarinas sem dor. Foram avaliadas 23 bailarinas com dor e 26 bailarinas sem dor quanto à amplitude de movimento de rotação lateral do quadril, força muscular, à anteversão do colo femoral e ao *turnout* estático e dinâmico. Os ângulos foram mensurados com goniômetro manual, e a força dos grupos musculares abdutores, rotadores laterais e extensores do quadril com dinamômetro isométrico. A análise foi feita por meio do ANOVA e Mann-Whitney. A amplitude de movimento, a anteversão do colo femoral e a força muscular foram semelhantes entre os grupos. O *turnout* dinâmico foi menor no grupo de bailarinas com dor (p=0,02), e bailarinas com déficits angulares acima 10% em relação ao *turnout* estático apresentaram menor força do grupo muscular dos extensores bilateral (p=0,04 e 0,03, direita e esquerda) e abdutores direito (p=0,03). Embora fatores anatômicos possam influenciar na rotação lateral do *turnout*, a diminuição angular do *turnout* dinâmico esteve mais relacionada ao grupo de bailarinas com dor. Tal fato sugere que o treinamento baseado na conscientização proximal do movimento pode prevenir e minimizar as sobrecargas nos joelhos de bailarinas clássicas adolescentes.

Descritores | Dança; Joelho; Dor; Quadril.

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RESUMEN | El *turnout*, principal gesto del ballet clásico, se refiere a la posición de 180º entre los pies. La rotación lateral de la cadera proporciona una mayor cantidad de grados necesarios para realizar la posición perfectamente. Si se realiza de forma inadecuada, puede generar compensaciones, preferentemente en las rodillas, generando dolor. El objetivo de este estudio fue evaluar los factores que influyen en la ejecución del *turnout* en bailarinas clásicas adolescentes con dolor en las rodillas y comparar las bailarinas y sin dolor. Se evaluaron a 23 bailarinas con dolor y 26 bailarinas sin dolor en cuanto al rango de movimiento de rotación lateral de la cadera, la fuerza muscular, a la anteversión del cuello femoral y al *turnout* estático y dinámico. Los ángulos fueron medidos con un goniómetro manual, y la fuerza de los grupos musculares abductores, rotadores externos y extensores de la cadera con dinamómetro isométrico. El análisis se realizó por medio del ANOVA y Mann-Whitney. El rango de movimiento, la anteversión del cuello femoral y la fuerza del músculo fueron similares entre los grupos. El *turnout* dinámico fue menor en el grupo de bailarinas con dolor (p=0,02), y las bailarinas con déficits angulares superiores a 10% en relación al *turnout* estático presentaron menor fuerza del grupo muscular de los extensores bilaterales (p=0,04 y 0,03, derecha e izquierda) y abiductores derecho (p=0,03). Aunque los factores anatómicos pueden influir en la rotación lateral del *turnout*, la disminución del ángulo del *turnout* dinámico se relacionó con el grupo de bailarinas con dolor. Tal hecho sugiere que el entrenamiento basado en la conciencia proximal del movimiento puede prevenir y minimizar las sobrecargas en las rodillas de bailarinas clásicas adolescentes.

Palabras clave | Danza; Rodilla; Dolor; Cadera.

INTRODUCTION

The *plié*, main movement of classical ballet, reaches the final position of 180º of the feet, known as the turnout. In order to perform the movement without articulate compensations, it is essential that the lateral rotation of the lower limbs reaches 70º for the hips, 5º for the knees and 15º for the ankles, condition that defines the hips as the primary articulating element[1-4].

Some author consider that muscle strength, flexibility and the articulate position of the lower limbs, specially the hip, are intimately related to the turnout[3,5-9]. This way, when one of these factors fails, compensatory strategies kick in, preferably on the knee, through the screwing movement[3,10,11] in order to achieve the necessary lateral rotation.

The inappropriate execution technique, combined with biomechanical imbalances, result in the primary factor of chronic musculoskeletal injuries of lower limbs[2,3,7,9,12-15]. For Gamboa *et al.*[16], pre-professional ballet dancers between 12 and 18 years of age represent a group which is more susceptible to injuries.

Thus, as a result of the compensatory mechanism, there is an overload of the joint, resulting in knee pain, especially in the tibiofemoral and patellofemoral joints[9,11]. Thus, the prevalence of knee injuries is high, representing approximately 20% of all lower limbs injuries[16,17] and having atraumatic and chronical characteristics.

At the same time, the causes of knee injuries have been related to muscle strength deficit of the maximum and medius gluteus. Once these two muscles are hip stabilizers, they are responsible for controlling rotational movements at knee level. Besides that, they primarily act in lateral rotation, extension and hip abduction movements, being essential in the performance of the turnout[13,18-21].

Thus, the objective of this study was to evaluate the factors which influence the execution of the turnout movement by adolescent classical ballet dancers with knee pain (DP) compared to dancers without knee pain (DWP).

METHODOLOGY

Subjects

Forty-nine ballet dancers of the *Escola Municipal de Bailado* in São Paulo, between 12 and 16 years of age, were evaluated. They were all females, practitioners of classical ballet, with minimum experience time in the modality of 5 to 10 years and training duration of at least 15 and at most 40 hours a week.

The size of the sample was based on the parameters of muscle strength, in a previous study with 23 ballet dancers with and without knee pain. The strength found varied at about 2.2 points in kilogram-force (kgf). For the strength deficit, a variation of 20% was considered, being 1.4 points enough to evidence the difference between the groups.

The participants were divided into two groups: dancers with knee pain (DP) n=23 and dancers without knee pain (DWP) n=26. These latter ones did not report complaints concerning pain in the lower limbs over the past six months. In the DP group, pain was defined as anterior localized pain in the tibiofemoral and/or patellofemoral joints, unilaterally or in both knees, for at least 4 weeks, originated by trauma, present during or right after practicing classical ballet dance, granting its association to the exercise.

Ballet dancers with knee pain resulting of sprains or falls on the lower limbs were not considered. Besides, the minimum intensity of pain considered was 4 points on the Visual/Verbal Numeric Pain Scale (VNS Pain)[21-23], which characterizes moderate to intense pain.

Dancers with a history of surgery, illnesses or previous hip, ankle, lumbar spine and sacroiliac joint fractures were excluded. The study was approved by the Research Ethics Committee of the *Universidade Estadual de Campinas* (protocol No. 114968), and the parents or legal guardians of the subjects signed an Informed Consent.

Procedure

It is a cross-sectional observational study, based on a single individualized evaluation. It consisted of an interview through a questionnaire, which registered data on demographic information, previous injuries, characteristics of the pain (intensity and duration of the pain), time of classical ballet practice and amount of weekly training. The intensity of the pain was registered by the VNS Pain, considering the average score over the last 24 hours.

Also, a physical evaluation of the lower limbs of the dancers was carried out for comparison purposes between groups of range of motion (ROM), femoral neck anteversion (FA), muscular strength (MS) and angulation of the turnout. The assessments were conducted by two physical therapists with two years of experience.

The reproducibility of the ROM, FA and MS tests was verified one month before the evaluations. Five healthy and sedentary individuals were assesses and re-assessed within a ten-day interval. The results showed intraclass correlation coefficients of 0.95 for ROM, 0.90 for the Craig test, 0.89 for the muscle strength test in the groups of lateral rotators and 0.95 for extensors and abductors.

Physical evaluation

Range of motion of the lateral hip rotation

The passive and active ROM of the lateral hip rotation was evaluated with a universal goniometer (Carci, 20 cm) in prone position, knee flexed at 90º. A non-elastic belt was used at the major trochanter height in order to avoid compensation. The angle formed between the midpoint of the patella and the tibial tuberosity was considered[1,11,24].

Femoral neck anteversion

The angle of the femoral neck anteversion was evaluated through the hip rotation angle, known as the Craig test[25]. At prone position and with the knee flexed at 90º, the evaluator palpates the major trochanter and, at the same time, performs passive rotations of the hip. The movement ends when the major trochanter is positioned more prominently. Values below 8º indicate femoral retroversion, above 15º the excessive femoral anteversion, and the interval between 8 and 15º was considered normal femoral anteversion.

Muscle strength

For the assessment of the lateral rotators (LR), abductors (ABD) and extensors (EXT) of the hip, we used a Manual Dynamometer (Jackson Evaluation System Model da Lafayette Instrument Co.)[19]. These groups were chosen for their muscular action of the maximum and medius gluteus in the mains gesture of classical ballet, the turnout. The maximum gluteus has a tridimensional action, the main one being the lateral rotator, extensor and contributing to abduction. The lateral rotation is also performed primarily by the piriformis, the internus obturator, the superior and inferior twins, and the quadratus femoris muscles. The external obturator, the sartorious, the long head of the biceps, and the posterior fibers of the medius gluteus muscles, on the other hand, have secondary action.

In extension, the maximum gluteus, the posterior head of the adductor magnus and the ischiotibials primarily perform the movement; the secondary action is performed by the middle portion and the posterior medius gluteus and by the anterior head. The abduction is performed by the medius gluteus, the minimum gluteus and the fascia lata tensor. The piriformis, the Sartorius, the rectus femoral and the maximum gluteus also assist in the process secondarily[18].

The abduction was measured in a lateral decubitus position, hips at 20º of abduction, 10º of neutral rotation and extension and knee extension[20] (Figure 1). The dynamometer was positioned 2 cm from the superior lateral condyle. In lateral rotation, the dancers stayed in position for the ROM of lateral hip rotation assessment, and the equipment was placed close to the medial malleolus[26]. Keeping this position, with a slight lateral rotation, the extensors of the hip were evaluated with the dynamometer positioned at the distal and posterior region of the thigh[19,20].

The evaluations were performed on a stretcher and inelastic bands were placed in order to avoid compensations, to restrain movements during the test and to stabilize the equipment, ensuring isometry. During the test, the contralateral limb was positioned so that it would relax and not influence the evaluation.

Two submaximal tests were performed prior to the maximum isometric strength test[19]. The duration of the contraction was 5 seconds, with 60 seconds of rest for the assessment of the same muscle groups on the contralateral side. At the end, the strength values, measured in kgf, were normalized[27]. In order to calculate the torque of the ABD and EXT muscle groups, it was considered the distance between the major trochanter to the knee articular line and the LR, from the knee articular line to the lateral malleolus.

Turnout

The dancer performed the movement of the first position, *plié*, on top of a cardboard sheet on the ground, aiming at the 180º feet position, called static turnout (ST). In the dynamic turnout (DT), the participant performed three consecutive leaps, keeping their feet in the first position[24,28]. The evaluator circled, with a pen, the outline of the feet in both evaluations. The angles formed from the two lines, from the mid calcaneus to the distal phalanx of the second toe on each foot[3,24], measured by a universal goniometer (Carci, 20 cm), were defined for these variables. As a warm-up, the dancers performed three movements of static and dynamic turnouts prior to the tests.

The compensated turnout (CT) was also considered, representing the compensations performed by the distal articulations, knees and ankles[24,29], through the equation [static turnout angle – (Σ passive external rotations)] and the angular difference between the static and dynamic turnouts.

In all evaluations, the average value for the three measures was considered, with up to 10% difference between them[19].

Data analysis

In the continuous variables, the descriptive statistics were calculated. The XLSTAT 2012 software was used.

Figure 1. Evaluation of the muscular strength of the hip. (A) Abductors, (B) Lateral rotators, (C) Extensors

In order to verify the homogeneity between groups, normality tests were used (Shapiro Willks), ANOVA. In the AM variables, muscular strength and turnout angulations, the groups were compared by the side, through the ANOVA.

For the FA variable, we performed the nonparametric test of Mann-Whitney. Contingency tables were built and association χ^2 tests and Fisher exact tests were performed. The odds ratio and the prevalence were used in the interpretation of the results to verify the association between excessive FA and the DP group. The significance level used was 5% ($p<0.05$).

Table 1. Mean distribution of the demographic variables

	DP (n=23) Mean±SD	DWP (n=26) Mean±SD	p-value
Age	14.6±1.1	13.9±0.9	0.12
Height (m)	1.59±0.06	1.59±0.05	0.83
Weight (kg)	47.8±6.4	46.2±4.1	0.28
Hours/week	24.8±8.9	20.8±10.1	0.14
Years of practice	8.5±2.3	7.7±1.7	0.17
Bilateral pain	74% (17)	–	
Onset time (years)	1.4±0.4	–	
VNS Pain (0-10)	4.9±1.7	–	

SD: standard deviation; DP: dancers with pain; DWP: dancers without pain; Onset time (years): mean time for the onset of pain; VNS Pain: Visual Numeric Pain Scale

RESULTS

The demographic data and the characteristics of the pain in the DP group are presented in Table 1. Tables 2 and 3 show the angular values of the ROM, FA and muscular strength. The excessive FA was analyzed as for their muscular strength and compared to the other groups, without difference between them.

The excessive FA was similarly prevalent between the groups (81 and 75%, right and left sides, respectively). Besides that, the odds ratio was 1.49, i.e., the chance of a dancer having excessive FA on their right side was almost 1.5 times higher for the DWP group when compared to the DP one, and the confidence interval for the odds ratio varied from 0.48 to 4.60. Meanwhile, on the left side, the chance of the dancer having excessive FA was 1.73 times higher for the DWP, confidence interval from 0.55 to 5.47.

The DT and the difference between the turnouts were significantly lower in the DP group. The percentage difference of the static turnout in relation to the dynamic one was grouped in deficits of up to 10% (D1), between 10 and 20% (D2) and above 20% (D3). In the DP group, 74% (n=17) presented deficits between 10 and 20%, only 21.7% (n=5) had a deficit lower than 10%, and one dancer had a percentage higher than 20%. In group of DWP on the other hand, 50% (n=13) of the dancers had deficits of up to 10%, 42.3% (n=11) between 10 and 20%, and two dancers had a deficit higher than 20%, without statistical difference between groups.

The DP were weaker in relation to the DWP group as for their bilateral extensors in group D1 (p=0.04, for the right and p=0.03, for the left) and in the group D2 for the right abductors and extensors (p=0.03 and 0.04, respectively) (Table 4).

Table 2. Mean values and standard deviation of range of movement, muscular strength and turnouts

		Right			Left		
		DP Mean±SD	DWP Mean±SD	p-value	DP Mean±SD	DWP Mean±SD	p-value
ROM (º)	Passive	44.6±11.1	41.7±8.4	0.31	44.3±11.8	40.3±9.5	0.2
	Active	44.6±13	40.1±8.6	0.15	43.8±10	39.5±10.4	0.15
MS (kgf)	Abductors	25.7±10.3	28.1±8.6	0.38	25.4±8.9	26.2±8.4	0.74
	Lateral rotator	10.7±2.3	10.6±2.1	0.79	11.1±2.1	10.5±1.6	0.29
	Extensors	25.1±7.4	28.2±7.6	0.15	23.8±8.2	28.4±8.4	0.05
			DP Mean±SD		DWP Mean±SD		
Turnout (º)	Static turnout		150.0±11.1		153.4±14		0.35
	Dynamic turnout*		128.3±10.4		135.6±10.7		0.02
	Comp. turnout		61.7±21.3		71.4±19.2		0.10
	Dif. turnouts*		21.7±8.8		14.8±11.9		0.04

DP: dancers with pain; DWP: dancers without pain; ROM: range of movement of the lateral hip rotation; MS: muscular strength; Comp. turnout: compensated turnout; Dif. turnouts: Difference between turnouts; SD: standard deviation. *significance level (p<0.05)

Table 3. Femoral neck anteversion: distribution and muscular strength

	DP		DWP		p-value	
	Right	Left	Right	Left	Right	Left
	n (%)	n (%)	n (%)	n (%)		
Excessive	11 (48)	12 (52)	15 (58)	17 (65)	0.16	0.24
Normal	9 (39)	9 (39)	10 (38)	8 (31)		
Retroversion	3 (13)	2 (9)	1 (4)	1 (4)		
	Excessive MS and FA					
	Mean±SD	Mean±SD	Mean±SD	Mean±SD		
LR (kgf)	10.2±1.4	11.3±2.2	10.58±2.2	10.48±1.5	0.29	0.09
ABD (kgf)	26.6±10.5	26.8±8.3	30.5±8.5	26.2±8.9	0.13	0.41
EXT (kgf)	27.6±7.2	26.7±8.7	28.5±7.7	28.2±9.2	0.37	0.31

MS: muscular strength; FA: femoral neck anteversion; LR: lateral rotators muscle group; ABD: abductors muscle group; EXT: extensors muscle group; DP: dancers with pain; DWP: dancers without pain; SD: standard deviation

Table 4. Distribution of the mean values of muscular strength in relation to the three deficit levels of the dynamic turnout

		Abductors		Lateral rotators		Extensors	
		DP Mean±SD	DWP Mean±SD	DP Mean±SD	DWP Mean±SD	DP Mean±SD	DWP Mean±SD
Right (kgf)	D1	24.5±9.7	25.6±8.8	9.3±2.6	10.8±2.2	20.7±1.4	26.32±2.1*
	D2	26.15±1.5	30.4±2.6*	11.13±2.2	10±1.9	26.4±1.7	29.4±2.1*
	D3	23.5	31.3±3.9	11.1	12.4±0.8	24.6	33.4±4.5
Left (kgf)	D1	25.3±10.6	23.8±7.7	10.1±1.6	10.7±1.5	19.1±2.8	27.9±2.2*
	D2	25.6±8.9	27.2±8.6	11.3±2.1	10.1±1.8	25±2.3	28.5±4.5
	D3	22.8	36.3±5.9	12.4	11.8±1.4	25.5	31.6±9.9

D1: angular deficit of up to 10%; D2: angular deficit between 10 and 20%; D3: angular deficit above 20%. *significance level ($p<0.05$). DP: dancers with pain; DWP: dancers without pain

DISCUSSION

This study observed that the dynamic turnout presented smaller angulation in teenager classical dancers with pain in the knees. Although anatomic factors, such as range of movement, femoral neck anteversion and muscular strength influence the execution of the turnout, it was not possible to establish the deficit relation of these variables in the population of dancers with pain complaints.

Considering the ROM and the FA, similar angular values between groups were verified, a fact which corroborates the results of the works of Gupta *et al.*[7], Gamboa *et al.*[16] and Negus *et al.*[24]. The same way, the distribution of FA was similar, and the excessive FA prevailed in both groups. For Hamilton *et al.*[5], factors such as capsular stretching and femoral neck anteversion could influence the lateral rotation of the hip during the performance of basic ballet moves. However, these two anatomic conditions did not influence the turnout, considering that the angular values were similar among the dancers.

In relation to muscular strength, the excessive FA of the lever arm (femoral head – major trochanter) is lower, which decreases the abductor and side rotator muscle torque of the hip[30]. Such condition was not observed, once the muscular strength was similar between the groups, both for the analysis of the excessive FA and for its individual analysis.

In the static and compensated turnout, the results of the present study corroborate with the studies of Gamboa *et al*.[16] and Negus *et al*.[24] and do not grant association to the DP group. Besides, for Negus *et al*.[24], the higher positive value for the difference between the static and dynamic turnouts suggest a relation with the occurrence of non-traumatic, severe injuries, resulting from a lower dynamic control of the hip in the sportive gesture.

In the dynamic turnout, the angular decrease in the lateral rotation between the feet after three consecutive leaps implies fails in the control of the hip in supporting the lateral rotation associated to the movement. Furthermore, when muscular strength was verified for dancers who presented a deficit higher than 10% for the static turnout, the extensors were observed weaker in relation to the DP group.

In the universe of classical ballet dancers, the initiation in the modality is very precocious, at around three and four years of age. At this age range, ballet dancers worry solely about keeping a wide amplitude between their feet. As they grow up, the awareness on their lateral hip rotation during the performing of the basic movement, turnout, should be stimulated. Once the lateral hip rotation does not keep its range of movement, the knee is overloaded, with valgus stress, affecting mainly the articulate and myotendinous structures of the femorotibial and patellofemoral joints[31,32].

CONCLUSION

Although intrinsic factors, such as range of movement, femoral neck anteversion and the strength of muscle groups of lateral rotators, abductors and extensors may influence the turnout lateral rotation, the present study evidences that the inability of the hip in sustaining the lateral rotation during dynamic turnout was more related to the group of adolescent classical ballet dancers with knee pain.

Thus, in the presence of rotational deficit, one should adopt preventive strategies of proximal awareness of the sportive gesture in basic classical ballet moves, as the turnout. The educational intervention by the teachers is vital in the correction of movements throughout the learning phase and the improvement of the modality in adolescence.

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