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Postural adjustments in young ballet dancers compared to age matched controls

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A B S T R A C T

Objectives: The purpose of the study was to use photogrammetry to evaluate the posture of ballet practitioners compared to an age-matched control group.
Design: One hundred and eleven 7- to 24-year-old female volunteers were evaluated and were divided into two groups: the ballet practising group (n = 52) and the control group (n = 59), divided into three subgroups according to age and years of ballet experience.
Results: Dancers with 1–3 years experience compared to controls of the same age shows alterations in External Rotation Angle ($P < 0.05$). Dancers 4–9 years experience show alterations in Lumbar Lordosis, Pelvis Tilt Angle and Navicular Angle Right and Left ($P < 0.05$). Dancers with over 9 years experience show alterations in External Rotation and Navicular Angle Left ($P < 0.05$).
Conclusions: Research shows there are differences between dancers and controls. In the groups 1–3 years and over 9 years of experience, the External Rotation Angle is greater. In the group 4–9 years of experience the Lumbar Lordosis Angle is greater and Pelvis Tilt, Navicular Angle Left and Right are smaller. In more than 9 years of ballet experience, the Navicular Angle Left is smaller.

1. Introduction

Classical ballet presents movements that do not overload the body; however, the extreme movement amplitudes may contribute to changes in both biodynamics and posture (Gupta, Fernihough, Bailey, Bombeck, Clarke, & Hopper, 2004). The classical technique is always performed in *en deors* (external rotation of the hip), which contributes to a higher elevation of the lower limb *a la second* (in hip abduction), which is essential to the performance of all classical technique and movements (D'Hemecourt & Luke, 2012). When the dancer has limited external rotation, there are several compensatory mechanisms to achieve the desired rotation, including external rotation of the tibia while the knee is flexed, which is associated with an anterior pelvic tilt. However, these compensations can increase the risk of injury (D'Hemecourt & Luke, 2012). Although, dancers exhibit lower peak ground-reaction forces than other athletes, they generally attenuate landing force over a longer period of time. The dissipation of impact forces may help this population avoid serious lower extremity injuries (Orishimo, Kremenic, Pappas, Hagins, & Liederbach, 2009).

The posture required in the practise of classical ballet can be associated with the development of a pattern of musculoskeletal adaptations such as spine hyperextension and increased hip movement amplitude and overload during jumps and landings on a single foot (*en pointe*) (D'Hemecourt & Luke, 2012). The full pointe position requires ankle plantar flexion with the toes in a neutral position relative to the longitudinal axis of the foot. In this position the intrinsic muscles of the foot and the muscles of the ankle need to be strong. In addition, the five basic positions in ballet are based in turnout or outward rotation of the feet. The ideal turnout demonstrates 180° of external rotation starting at the hips and resulting in the feet being easily placed in an 180° position on the floor (Kadel, 2006), which contributes to the execution of the ballet classic technique.

The mechanism of postural changes and their compensations are important for understanding the relationship between a dancer's posture and injuries (Bruyneel, 2011; Hincapié, Morton, & Cassidy, 2008; Macintyre & Joy, 2000; Solomon, Brown, Gerbino, & Micheli, 2000).

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The practise of classical dance typically begins during childhood, which the evidence suggests that musculoskeletal injury is an important health issue for dancers at all skill level (Hincapié et al., 2008). Changes in the alignment of the longitudinal axis of the long bones before the age of 11 may contribute to changes in posture (D'Hemecourt & Luke, 2012). However, these aspects are seldom studied (Bruyneel, 2011; Hincapié et al., 2008; Solomon et al., 2000). Inadequate adaptation of the musculoskeletal system can result in injury (Arendt & Kerschbaumer, 2003). The incidence of injury may be related to an increase in the performance effort of the ballet practitioner (Shah, 2008) and contemporary dancers (Angioi, Metsios, Koutedakis, Twitchett, & Wyon, 2009), years of dancing experience, practise frequency, training intensity (Bruyneel, 2011; Hincapié et al., 2008; Shah, 2008; Solomon et al., 2000), repetitive movements (Bruyneel, 2011; Macintyre & Joy, 2000), inappropriate training prior to bone maturity (Amari et al., 2009), lack of flexibility and range of motion (Macintyre & Joy, 2000) and poor physical fitness levels (Angioi et al., 2009). Moreover, factors such as space, temperature, ventilation and floor type may contribute to musculoskeletal injuries (O'Loughlin, Hodgkins, & Kennedy, 2008). However, most of these studies did not correlate the aforementioned aspects with angular measurements of the regions of the body affected by the practise of ballet. Postural assessment may reveal whether participation in ballet induces adaptations and identify which regions of the body are most affected by these adaptations, providing important information for the understanding of injuries that affect the musculoskeletal system of this population.

Thus, the aim of this study was to use photogrammetry to quantitatively evaluate the posture of ballet practitioners compared to age-matched control.

2. Method

2.1. Participants

One hundred and eleven female volunteers participated in this study and the subjects and their parents signed an informed consent that had been approved by the Research Ethics Committee of Federal University of Alfenas on Human Beings under Protocol no. 085-2/2010. The volunteers were divided into two groups: the ballet practising group ($n = 52$) and the control group ($n = 59$). Volunteers within the ballet practicing group were further divided into three sub-groups according to their years of ballet experience: Group 1, from 1 to 3 years of experience; Group 2, from 4 to 9 years of experience; and Group 3, more than 9 years of experience (Table 1). The control group were further divided into three age, weight, and height-matched subgroups. Volunteers in the ballet practicing groups participated in two to three 60- to 90-min ballet classes per week. All dancers belonged to the same vocational institution, had practised dance for at least one year and were at least 7 years old. The control volunteers belonged to two regular schools. Volunteers who were related or had a history of lower limb or spine fracture were excluded from the study. No injury data was collected.

Considering the Pelvis Tilt Angle as the main variable, a power effect of 1.00 and an effect size of 1.80 ($\alpha = 0.05$) were obtained from a sample size of 111 subjects divided in six groups as described earlier. The GPower® 3.1.7 software (Franz Faut, Universität Kiel Germany, 2008) was used for this analysis (Cohen, 1988, Nakagawa, S.& Cuthill, 2007).

2.2. Apparatus

A SONY® Cyber-shot digital camera with a 7.2 megapixel resolution was positioned on a level tripod, parallel to the floor and at a height of one meter, with a distance of 2.4 m between the camera lens and the volunteer (Iunes, Bevilaqua-Grossi, Oliveira, Castro, & Salgado, 2009). The volunteer was positioned standing upright, with the upper limbs beside the body and 0.075 m between the medial malleoli. The distance between the medial malleoli was maintained with the aid of ethyl vinyl acetate (EVA) marker. The volunteers were photographed in an anterior view (frontal plane) and a right lateral view (sagittal plane).

For the photographic record of the feet, the camera was positioned on a level tripod, parallel to the floor and at a height of 0.45 m, with distance of 0.24 m between the camera lens and the podoscope. The digital images were stored and then analysed on a personal computer using ALCimagem -2000 Version 1.5 software (Lima, Barauna, Sologurem, Canto, & Gastaldi, 2004).

2.3. Procedure

To take photographs in the sagittal plane (Fig. 1A), the lower limbs were positioned in parallel, and the following anatomical points were marked with an orange flexible rod (length = 0.06 m) by the same assessor: the anterior superior iliac spine (ASIS); the posterior inferior iliac spine (PIIS); the spinous processes of T_{12}, L_3 and L_5; the greater trochanter; the fibular head; and the lateral malleolus. The following angles were measured: lumbar lordosis (LL), which is formed by the intersection of the direct line connecting the T_{12} spinous process with the L_3 spinous process and the direct line connecting the L_3 spinous process with the L_5 spinous process; Pelvic tilt, which is formed by the intersection of the direct line connecting the PIIS with the ASIS and the horizontal plane (Iunes et al., 2009); and knee flexion (KF), which is formed by the intersection of the direct line connecting the greater trochanter with the fibular head and the direct line connecting the fibular head with the lateral malleolus.

To take photographs in the frontal plane (Fig. 1B), the following anatomical points were marked on the skin of the volunteers with white self-adhesive labels: the ASIS, the centre of the patella, the tibial tuberosity and the medial malleolus (a flexible plastic rod was

Table 1
Mean values (95% CI) of sample characteristics.

Variables	Groups (n)	Ballet (n = 52)	Groups (n)	Control (n = 59)	p
Age	B1 (9)	11.22[a] (8.66–13.55)	C1 (9)	11.00 (8.74–11.91)[a]	0.590
	B2 (21)	11.55[b] (9.66–12.43)	C2 (22)	11.22[b] (9.69–12.30)	0.805
	B3 (22)	17.73 (16.56–19.26)	C3 (28)	17.14 (15.88–18.73)	0.906
BMI	B1 (9)	19.44 (16.90–21.98)	C1 (9)	18.01(14.91–19.42)	0.063
	B2 (21)	17.52[b] (16.72–18.30)	C2 (22)	17.37 (16.84–19.64)	0.190
	B3 (22)	20.72 (19.91–21.52)	C3 (28)	20.03 (18.42–20.46)	0.139

BMI = Body mass index; Mann–Whitney test.
[a] Group 1vs Group 3.
[b] Group 2 vs Group 3.