INFLUENCE OF FOOTWEAR AND BREAST SUPPORT ON THE TRUNK MOVEMENTS DURING RUNNING

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The purpose of the study was to analyze the influence of footwears and breast supports on the spine movements during running. Seventeen women performed a treadmill run using different combinations of footwear (barefoot, minimalist and traditional) and breast support (bare breast, everyday bra and sports bra). Spine movements were registered using optoelectronic cameras that recorded reflective markers fixed from the cervical to the sacral regions. From the 3D coordinates of the markers, the geometric curvatures of the spine were calculated in the sagittal plane at each instant of time in the gait cycle, as well as the neutral curve (mean posture of the spine). Results showed that the sports bra and footwear caused greater curvatures in the thoracic and lumbar regions, respectively, suggesting that women change their posture depending on the sportswear used.

KEYWORDS: kinematics, spine, exercise, barefoot, sportswear.

INTRODUCTION: Running is one of the most popular physical exercises in the world and has a large number of practitioners (Manero et al., 2016). Women comprise the group with the highest growth of participation in running events (Chorley, Cianca, Divine, & Hew, 2002). Despite that, little attention has been given to an important factor which affects women's participation, performance, and comfort during running, which is the adequate breast support (Brown, White, Brasher, & Scurr, 2014), and its effects on spine posture. It is clear in the literature that large breasts contribute to back pain and poor posture (Findikcioglu, Findikcioglu, Ozmen, & Guclu, 2007; Schinkel-Ivy & Drake, 2016). However, little is known about the influence of breast support on the behavior of the spine in dynamic situations such as running, and the consequences of a combination with a proper footwear.
It is known that traditional running footwear has a damping system, able of reduce impacts (Bonacci et al., 2013). Divergent studies reported that minimalist shoes or even barefoot running may reduce the risk of injury and reflect a more economical running pattern when compared to traditional footwear (Lieberman, 2012; Tam, Astephen Wilson, Noakes, & Tucker, 2014). Most studies with sports shoes have been concerned about analyzing the differences between different models and their relationships with lower limb injuries, with little attention to their effects on spine posture.
During locomotion, foot contact with the ground generates an impulsive shock wave that is transmitted from the lower extremities through the spine and, as previously demonstrated, the effectiveness of shock absorbing shoes on dampening this shock wave during gait has been discussed controversially (Ogon, Aleksiev, Spratt, Pope, & Saltzman, 2001). To the best of our knowledge, no studies have addressed the effects of using both sports bra and footwear on spine movements, with a focus on the thoracic region where the breasts are and on the sagittal plane, in which the mass concentration associated with the breast was diagnosed as the cause of increased thoracic kyphosis and lumbar lordosis (Findikcioglu et al., 2007) that may contribute to the risk of spinal injury (Schinkel-Ivy & Drake, 2016).
For the analysis of the spine posture, the model of geometric curvatures has been suggested. This model allows the analysis of the geometric curvature at different levels of the spine during dynamic situations such as running (Campos, de Paula, Deprá, & Brenzikofer, 2015), and may

help to understand the influence of different sportswear on the spine movements during running. Therefore, the aim of this study was to analyze the influence of different footwear and breast support combination on the vertebral spine during running. We hypothesized that the changes on curvatures of the spine would be smaller with traditional footwear, since the use of this footwear model can reduce the impacts that the body suffers during the running and that, because sports bra reduces the movements of the breasts, less alterations on the spine during running would be detected.

METHODS: Seventeen women were selected, according to the sample size calculation, with a mean (SD) age of 23.41 (3.75) years old, height of 1.66 (0.06) m, mass of 68.62 (9.18) kg and cup breast size ranging between categories B (6 participants), C (6 participants) and D (5 participants). The inclusion criteria were: to be physically active to run on a treadmill. Participants were excluded from the study if they presented previous musculoskeletal injuries in the lower limbs, performed surgical procedures on the breasts, were pregnant or breastfeeding. The experimental procedures of the study were approved by the IRB.
After anthropometry, reflective markers were fixed on the participant's spine, according to the protocol described in the literature (Campos et al., 2015).The breast support conditions were bare breast, an everyday bra (bra of the participant herself) and a high-performance dri-fit sports bra (Nike Pro Rival). The footwear conditions were barefoot, minimalist (Nike Free Distance 2) and traditional running footwear (Adidas Response Boost LT). Participants performed the tasks of walking on a treadmill (INBRAMED) at 5 km/h for 1 minute, followed by running at 7 km/h and finally running at 10 km/h, remaining approximately 30 seconds at each speed. To avoid fatigue the participants performed a rest period of 3 minutes between the conditions.
All pairwise combinations between breast support (bare breast, everyday bra and sports bra) and footwear (barefoot, traditional and minimalist) were analyzed. The bare breast and barefoot running conditions were performed to verify how much the use of materials (bra and footwear) are effective, as reference values. During bare breast, a paper adhesive protector was fixed on the nipples. The order of conditions was randomized between the participants. Spine movements were analyzed using three cameras of the Optitrack System®, in grayscale video mode, positioned behind the participant to register reflective markers fixed on the vertebrae, from the cervical to the sacral regions. The reconstructed spine points were projected on the sagittal plane of the trunk and the spine curvatures were calculated as described in Campos et al. (2015).
The following dependent variables were selected: neutral curvature (NC) in thoracic and lumbar region, which consists of the mean curvature during the stride cycle; maximum lumbar curvature (MLC) and maximum thoracic curvature (MTC), which consists of the maximal values of curvature found during the stride cycle. The unit of measurement of the geometric curvature adopted was m^{-1}. Positive values indicate anterior concavities (kyphosis), and negative values indicate posterior concavities (lordosis). Values close to zero represent a rectification of the spine. The variables were compared using the Generalized Estimating Equation test with gamma distribution and logarithmic link function as fixed parameters. Subsequent comparisons were performed by Bonferroni post hoc. Statistical analyzes were performed with SPSS software (v. 21) (IBM Corp., Armonk, NY, USA) with significance of 5%.

RESULTS: Table 1 presents descriptive data for the dependent variables according with the different footwear and breast support conditions. The results showed a main effect in the breast support condition for MTC (Wald=7.201, $p=0.02$) with a lower value for bare breast (i.e. a spine rectification) compared to the sports bra. Main effect was also verified in the footwear condition for the lumbar NC (Wald=24.420, $p<0.001$) and MLC (Wald=17.178, $p<0.001$), with greater values in the barefoot condition compared to other conditions.
Thoracic NC (Wald=32.498, $p<0.001$) and lumbar NC (Wald=6.806, $p=0.003$) presented the main effect for velocity, with higher values at 5 km/h compared to 7 km/h and 10 km/h. Main effect for velocity was also identified for MLC (Wald=24.733, $p<0.001$): higher values at 10

km/h were found, compared to the other speeds. Finally, no interactions between support, footwear and velocity were found.

Table 1: Main effect of support, footwear and velocity of the variables in the sagittal plane. The values represent the geometric curvature (m^{-1}), expressed as mean (standard deviation). Positive values indicate anterior concavities (kyphosis), and negative values indicate posterior concavities (lordosis). Values close to zero represent a rectification of the spine.

	Main effect - Breast Support		
Variables	Bare Breast	Everyday Bra	Sports Bra
MTC (m^{-1})	4.33 (0.79)	4.39 (0.83)	4.42 (1.00)[a]
	Main effect - Footwear		
	Barefoot	Minimalist	Traditional
NC Lumbar (m^{-1})	-7.61 (4.02)	-7.05 (3.65)[c]	-6.98 (3.65)[c]
MLC (m^{-1})	-10.48 (5.57)	-9.82 (5.09)[c]	-9.74 (4,99)[c]
	Main effect - Velocity		
	5 km/h	7 km/h	10 km/h
NC Thoracic (m^{-1})	3.66 (0.88)	3.45 (0.87)[e]	3.43 (0.89)[e]
NC Lumbar (m^{-1})	-7.81 (3.97)	-6.76 (3.57)[e]	-7.06 (3.73)[e]
MLC (m^{-1})	-9.76 (4.62)	-9.69 (5.15)	-10.59 (5.81)[ef]

Symbols represent differences ($p<0.05$) between conditions, being a: different from Bare Breast; b: different from everyday Bra; c: different from Barefoot; d: different from Minimalist; e: different from 5 km/h and f: different from 7 km/h. NC: neutral curvature, MTC: maximum thoracic curvature, MLC: maximum lumbar curvature.

DISCUSSION: The results showed no interaction effect between support conditions, speed and footwear. Despite that, the breast support, footwear and velocity, individually, were able to cause postural adaptations. These adaptations, although minimal, are of great relevance to runners. We verified that the thoracic region was more rectified in the bare breast condition, suggesting that participants performed a strategy to move less this region to minimize the impact of walking and running with bare breast. Women may have performed adaptations throughout the body to relieve the discomfort of breast movement that was not supported. This outcome corroborates studies that indicate that women feel more discomfort in situations of lower breast support (Mason, Page, & Fallon, 1999; White, Mills, Ball, & Scurr, 2015). Therefore, running without proper breast support may induce changes in posture. One can argue that maintaining this changed posture in long-term activities may cause pain, which should be the result of research in future studies.

In the barefoot condition, the lumbar region was less rectified compared to traditional or minimalist footwear condition, suggesting that both footwear conditions were effective to reduce the effects of the running impacts on the lower back. These findings corroborate previous studies that demonstrated that both traditional and minimalist footwear are able to absorb the impacts of running (Bonacci et al., 2013; Lieberman, 2012; Ogon et al., 2001).

Regarding the main effect for velocity, we verified that the general adaptation (identified by the NC) implies a rectification of the thoracic and lumbar spine; however, when the maximal curvatures were investigated, an increased value in the lumbar region was diagnosed, which suggests that, at high speeds, peaks of lumbar lordosis may happen during running. Thus, the hypothesis that the curvatures changes of the spine would be smaller with traditional footwear was accepted. The use of footwear can reduce the impacts that the foot suffers during the running and changes the way of contact in the ground (Bonacci et al., 2013; Lieberman, 2012; Ogon et al., 2001). Additionally, the use of the sports bra reduces the movements of the breasts. Thus, the combination between proper breast support and footwear imply less alterations in the spine during running. This study provided a better understanding of how the

spine behaves during the running and how the use of appropriate sportswear can affect the spine. In addition, our results may contribute to the women running training and, subsequently, allow the use of running as a form of intervention to improve the quality of life of women and postural deviations.
The study has the following limitations: a) the control of the everyday bra condition was not performed (each participant used her own bra); b) there was no assessment about pain on the spine during the tests.

CONCLUSION: In general, the results of this study suggest that, when the women wear the sports bra, they do not need to compensate at thoracic spine because the sports bra itself provides support. If the appropriate support is not used, greater demand to rectify the spine may be necessary, which may justify the fact that women complain about discomfort in the spine during running. Finally, the study also presented that the barefoot running increases the curvatures in the lumbar spine. On the other hand, similar curvatures were found when participants ran with traditional or minimalist footwear.

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