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ORIGINAL ARTICLE

Postural influence of high heels among adult women: analysis by computerized photogrammetry

A influência postural do salto alto em mulheres adultas: análise por biofotogrametria computadorizada

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Abstract

Introduction: In our society, it is observed an increasing number of models, colors, styles, heights and types of high heels. **Objective:** To evaluate whether the use of high heel shoes results in postural changes, based on a set of variables measured through computerized photogrammetry. **Methods:** Twenty individuals who often used high heels (group 1) and 20 individuals who only used high heels sporadically (group 2) were photographed in the frontal and sagittal planes at three conditions: a) without using footwear; b) using stiletto heels; and c) using high platform heels. These photographs were randomized and analyzed by a blinded examiner, by means of photogrammetry. Statistical analysis was performed, using a 2x3 factorial analysis of variance to compare the frequency of high heel use with the type of shoe, at the 5% significance level. **Results:** Only the head protrusion angle showed a difference between groups 1 and 2 ($p<0.01$). The effect of the type of shoe observed in the alignment of the right knee, which only showed a difference between stiletto heels and barefoot ($p=0.03$). For the tibiotarsal angle variable, the effect was also observed for all types of footwear. The other angles evaluated did not present any differences regarding the frequency of high heel use and the types of shoe. **Conclusions:** The frequency and type of high heel practically did not change the static posture evaluated by photogrammetry.

Key words: posture; high heel; photogrammetry.

Resumo

Introdução: Em nossa sociedade, temos observado uma oferta cada vez maior de modelos, cores, estilos, altura e diversos tipos de salto. **Objetivo:** Avaliar se o uso de calçados de salto alto influencia nas alterações posturais com base em um conjunto de variáveis mensuradas por meio da fotogrametria computadorizada. **Métodos:** Vinte indivíduos que utilizam salto alto com freqüência (grupo 1) e 20 indivíduos que utilizam salto alto esporadicamente (grupo 2) foram fotografados no plano frontal anterior e sagital em três momentos: a) sem utilização de calçado, b) utilizando salto agulha e c) utilizando salto plataforma, sendo estas fotografias aleatorizadas e analisadas por um experimentador cego por meio da fotogrametria. A análise estatística foi realizada a partir da análise de variância em esquema fatorial 2x3, ou seja, comparando-se a freqüência do uso de salto com o tipo de calçado, com 5% de significância. **Resultados:** Apenas o ângulo protrusão da cabeça apresentou diferença quando comparados grupo 1 e 2 ($p<0,01$). O efeito do tipo de calçado ocorreu na variável alinhamento do joelho direito, sendo que houve diferença apenas entre o sapato agulha e os pés descalços ($p=0,03$); também para a variável ângulo tibiotársico, o efeito esteve presente em todos os tipos de calçado. Os demais ângulos avaliados não apresentaram diferenças entre a freqüência no uso de salto e os outros tipos de sapato. **Conclusões:** A freqüência do uso de salto e o tipo de salto praticamente não modificam a postura estática avaliada pela fotogrametria.

Palavras-chave: postura; salto alto; fotogrametria.

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Introduction

The foot is the bodily structure that interacts the most with the lower kinetic chain[1] and has some of the greatest structural varieties in the human body[2,3]. It functions as a compliant mechanism of reception and distribution of body weight, adapting to surface irregularities and acting as a rigid lever that propels the body forward during gait[4].

To be able to adapt to surface irregularities, bear the weight of the body and withstand the ground reaction force, the foot is comprised of three plantar arches (internal and external longitudinal arches, and transverse arch). These act as shock absorbers and distribute the loads on the feet to three regions: calcaneous (60% of the load), midfoot (8% of the load) and forefoot, mainly the 5th and 1st metatarsal head (32% of the load)[5,6].

Footwear gives support to the feet[7] and should be worn to enhance their functions, instead of interfering with the transmission of information from the pressures on the adequate support areas or during the movements needed while walking[8]. Footwear can often change the ideal alignment of the feet.

In our society, we find that most women have several pairs of shoes in their personal wardrobe. The footwear industry has an ever-increasing supply of colors, styles and types of heel. An aggravating factor of the current high-heel trend is its increasing presence in the lives of children and adolescents who are still in the developmental phase, and therefore in susceptible physical conditions[9].

Iunes et al.[10] analyzed gait in children who wore 5cm high-heeled platform shoes through electromyography and found increased muscular activity in the gastrocnemius and anterior tibial muscles. Other changes associated with frequent high-heel use are low back pain, halux valgus, callosity and muscular shortening.

With the advance of science, it is now possible to use the available electronic resources more effectively for postural reeducation with the purpose of improving evaluations, therapeutic interventions and preventive actions[9].

A method called computerized biostereometry or biophotogrammetry has been used to facilitate the work of health professionals. This method consists in the application of principles of short distance photogrammetry to the medical field to measure the shapes and dimensions of the human body[9].

This method is used in postural evaluations due to the advantages and effectiveness of its clinical application. Among the advantages are low-cost image interpretation system, high precision and reproducibility of results. There is also no contact with the patient or use of visible light, which avoids radiation exposure[9,11]. Considering the importance of appropriate support for the lower limbs, the aim of this study was to assess, by using computerized photogrammetry, whether the frequency of high heel use has any influence on postural changes, and whether the type of high heel interferes in the posture.

Methodology

Subjects

We analyzed forty women, chosen at random, who were willing to participate in this research. The participants were divided into two groups: group 1, formed by 20 women (mean age 23.5±2.86 years, mean mass 54.10±7.16 kg, mean height 1.61±0.05m) that wore high-heeled shoes everyday; group 2, formed by 20 women (mean age 22.55±2.68 years, mean mass 51.60±4.54 kg, mean height 1.60±0.03m) that wore high heels occasionally to social functions. The inclusion criterion was women who wear size 35 shoes. Exclusion criteria were neuropsychomotor changes, amputations and sequelae from fractures or rheumatoid arthritis. There were no sample losses during the study. All subjects received information about the project and signed a consent form, agreeing to take part in the research, according to Resolution 196/96 of the National Health Council. The study was approved by the Human Research Ethics Committee of Unifenas, protocol number 100/2005.

Footwear

The participants wore a pair of 6.5cm high-heeled platform sandals and a pair of 8.0cm stilettos, both size 35. Neither pair had been worn prior to the experiment.

Postural analysis

The subjects were photographed in the frontal, anterior frontal and sagittal planes. First, they wore a two-piece swimsuit and no shoes, then one of the previously described pairs of high-heeled shoes for the subsequent postural evaluation. A few anatomical points were marked out, including the occipital protuberance, C_4, C_7, T_7, T_{12}, L_3 and L_5 spinous processes, greater trochanter, anterosuperior iliac spine (ASIS), posteroinferior iliac spine (PIIS), tibial tuberosity (TT), head of the fibula, lateral malleolus, and head of the 5th toe[9].

These markings were made with white 0.9mm-diameter PIMACO labels and orange-colored plastic rods held in place with double-sided tape[9].

For the photo record, a Sony® (MAVICA FD 200) digital camera was placed, parallel to the ground, on a level tripod. Images were digitally stored in 1,600x1,200 pixel resolution. The anterior frontal and sagittal planes were photographed.

Subject positioning

For the photo record, subjects were placed in a previously marked position, at a standard distance from the camera, which was also previously marked. In this position, the subject was 15cm from the wall. In order to keep this distance, a 15cm wide, 60cm long and 0.5cm thick rubber marker was placed between the wall and the subjects. The distance between the camera and the subject was 2.4m and the tripod held the camera 1.0m above the ground[9]. Another rubber device, measuring 7.5cm in width, was placed between the subjects' feet to maintain the standard posture, as described by Kendall[7]. The room was well lit, with a blue, non-reflexive background, and gave the subject privacy during the shoot[9].

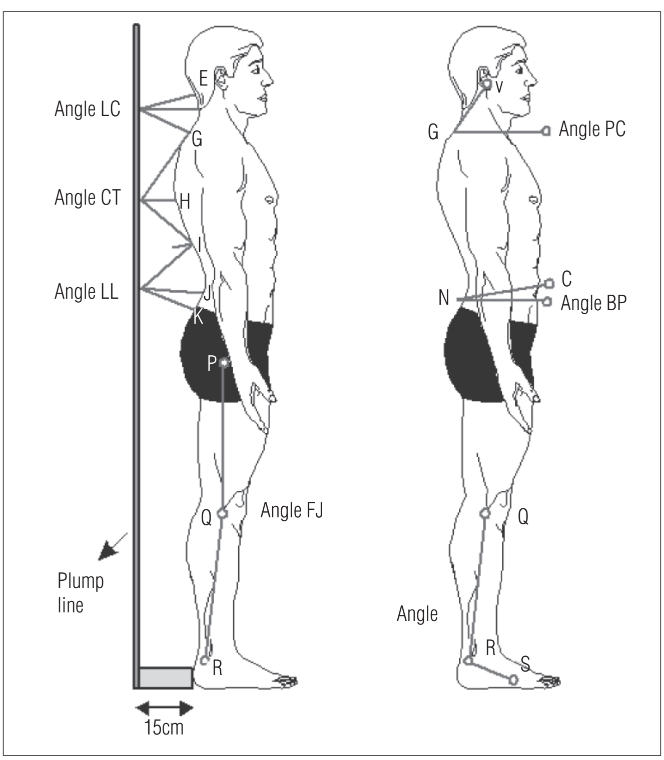

Figure 1. Points and angles evaluated in the right lateral view: C (ASIS), E (occipital protuberance), F (C_4 spinous process), G (C_7 spinous process), H (T_7 spinous process), I (T_{12} spinous process), J (L_3 spinous process), K (L_5 spinous process), N (PIIS), P (greater trochanter), Q (head of the fíbula), R (lateral malleolus), S (distal diaphysis of the 5^{th} metatarsal of 5^{th} toe), V (tragus), HP (head protrusion), CL (cervical lordosis), TK (thoracic kyphosis), LL (lumbar lordosis), PT (pelvic tilt), KF (knee flexion), TTA (tibiotarsal angle).

Image analysis

The images were analyzed with the application ALCimagem-2000 Manipulando Imagens version 1.5 through measures of the angles formed by lines drawn between the previously marked anatomical points. This analysis identified and quantified possible asymmetries and vertebral curvature angles.

In the anterior frontal plane, the measured and analyzed angles were between the two ASIS and the TT. These angles were formed by the line drawn between the right ASIS and the left ASIS and the horizontal line parallel to the ground. Another angle analyzed in this plane corresponded to the alignment of the right knee (rKA) and left knee (lKA). This angle was formed by the intersection of the straight line between points C (ASIS) and D (TT) and the line perpendicular to the ground. The greater the angle is, the greater the lower limb alignment[9].

In the sagittal plane, the angles previously described by Iunes[9] were analyzed. They are shown in Figure 1 and described below.

The head protrusion angle (HP) is formed by the intersection of the straight line between points V (tragus) and G (C_7 spinous process) and the line parallel to the ground. The smaller the angle is, the greater the protrusion.

The cervical lordosis angle (CL) is formed by the intersection of the line between point E (occipital protuberance) and the horizontal extension of point F (C_4 spinous process) on the plumb line and the line between point G (C_7 spinous process) and the horizontal extension of point F (C_4 spinous process) on the plumb line. The larger the angle is, the greater the rectification, and the smaller the angle, the greater the lordosis.

The thoracic kyphosis angle (TK) is formed by the intersection of the line between point G (C_7 spinous process) and the horizontal extension of point H (T_7 spinous process) on the plumb line and the line between point I (T_{12} spinous process) and the horizontal extension of point H (T_7 spinous process) on the plumb line. The greater the angle is, the greater the rectification, and the smaller the angle, the greater the kyphosis.

The lumbar lordosis angle (LL) is formed by the intersection of the line between point I (T_{12} spinous process) and the horizontal extension of point J (L_3 spinous process) on the plumb line and the line between point K (L_5 spinous process) and the horizontal extension of point J (L_3 spinous process) on the plumb line. The larger the angle is, the larger the rectification, and the smaller the angle, the greater the lordosis.

The pelvic tilt angle (PT) is formed by the intersection of the line between points N (PIIS) and C (ASIS) and the line parallel to the ground. The larger the angle is, the greater the anterior tilt.

The knee flexion angle (KF) is formed by the intersection of the line between points P (larger trochanter) and Q (lateral knee joint line) and the line between points Q and R (lateral malleolus).

The tibiotarsal angle (TTA) is formed by the intersection of the line between points R (lateral knee joint line) and S (lateral malleolus) and the line between points S and T (head of the 5th toe).

Statistical analysis

For each angle described in the methodology section, three consecutive measures were performed using photogrammetry, and the arithmetic mean was calculated. The statistical analysis was performed based on the analysis of variance for a completely random model, with 20 repetitions in a 2x3 factorial, i.e. by comparing the frequency of high heel use (regularly or occasionally) with the type of footwear (bare feet, high-heeled platform shoes or stilettos), with a 5% significance level.

Results

Few modifications in the posture of the examined women were found, regardless of frequency of use and type of high heel. For all the analyzed angles, there was no interaction between frequency of high heel use and the type of footwear ($p>0.27$, as seen in Tables 1, 2, 3).

However, taking into account the differences between the group that wore high heels regularly (group 1) and the group that wore high heels occasionally (group 2), only the HP angle that analyzes the positioning of the head showed a difference ($p<0.01$) in all types of footwear (Table 4). The smaller the measure of this angle, the more head protrusion there is (Figure 1).

Regarding the type of footwear (bare feet, platforms or stilettos), there was an effect on the rKA variable that evaluates the lower limb alignment. There was a difference only between stilettos and bare feet in group 1 ($p<0.05$) (Table 4). For the TTA variable that evaluates ankle positioning on the sagittal plane, the footwear type had an effect ($p<0.01$), and there was a difference in all three types of footwear, as expected (Table 4).

Discussion

In general, the exaggerated use of high-heeled footwear causes shortening of the calf musculature, leading frequent high-heel wearers to feel uncomfortable when wearing flat soled shoes. The elevation of the calcaneous leads to modifications in gait pattern and to foot instability[6,13,14].

There is an important relationship between heel height and overload on the arches of the foot. High heel use changes body

Table 1. Means of variables SA, IKA and TT with the frequency of high-heel use and the types of shoe, where SA is the symmetry of the ASIS, IKA is the alignment of the left knee, and TT is the symmetry of the tibial tuberosity.

Footwear	SA(°)		1KA(°)		TT(°)	
style	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Bare feet	1.92	1.29	175.39	175.3	1.87	1.75
Platform	2.13	1.32	176.21	175.75	1.59	1.66
Stilettos	2.09	1.96	176.28	175.79	1.5	1.69

Table 2. Means of variables CL, TK and LL with the frequency of high-heel use and the types of shoe, where CL is cervical lordosis, TK is thoracic kyphosis and LL is lumbar lordosis.

Footwear	CL(°)		TK(°)		LL(°)	
style	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2
Bare feet	32.45	35.16	84.88	84.42	56.06	57.35
Platform	33.96	33.99	83.21	83.29	58.54	56.67
Stilettos	33.81	34.93	81.8	83.28	57.6	58.65

Table 3. Means of variables PT and KF with the frequency of high-heel use and the types of shoe, where PT is pelvic tilt and KF is the position of the knee in the sagittal plane.

Footwear	PT(°)		KF(°)	
style	Group 1	Group 2	Group 1	Group 2
Bare feet	14.49	14.5	184.93	184.37
Platform	13.44	13.32	186.51	184.69
Stilettos	12.6	13.81	185.24	183.61

Table 4. Means of variables HP, rKA and TTA with the frequency of high-heel use and the types of shoe, where HP is head protrusion, rKA is the alignment of the right knee and TTA is the tibiotarsal angle.

Footwear	HP(°)		rKA(°)			TTA(°)		
style	Group 1	Group 2	Group 1	Group 2	Mean	Group 1	Group 2	Mean
Bare Feet	53.11	50.82	176.7	175.7	176.2ab	110.7	111.5	111.1a
Platform	52.94	51.1	177.2	176.7	177.0bc	129.9	127.6	128.8b
Stiletto	53.39	50.26	177.6	177.6	177.6cd	140.6	136.6	138.6c
Mean	53.15A	50.73B	-	-	-	-	-	-

Different lower case letters (vertical) and capital letters (horizontal) indicate significance ($p<0.05$) according to Bonferroni's test[12].

mass distribution, reducing the pressure on the calcaneous and shifting it to the forefoot. The weight born by the tip of the foot is in direct proportion to the height of the heel. Continuous use of high heels results in overload, which compresses the metatarsals[6,15].

Bienfat[15] states that there is no good static if the feet are not planted firmly on the ground. As a result, feet deformities and changes in loading also change static. This raises the issue that if wearing high heels changes the mechanics of the foot, it eventually generates muscular changes to the lower limbs and consequently produces ascending compensatory postural changes.

Marques[16] reports that a muscle group adapts itself to certain conditions and that there are variables involved in this mechanism. Therefore, it is expected that the frequent high heel use may generate adaptive postural changes.

We suggest that there is a necessity for quantitative studies and clinical investigations to evaluate the relationship between the prolonged use of high heels and orthopedic, joint, and degenerative changes. In the present study, we aimed to quantify the postural modifications produced by the high heel, having photogrammetry as a resource whose reliability has already been tested[9,11]. Contrary to what has been described by other authors[13] and to our expectations, the frequency of high heel use and the type of high heel had no correlation with modifications in the static posture.

Regarding the pelvic tilt, the literature states that high heels produce anterior pelvic tilt and an increase in lumbar lordosis[3,13,17]. However, some authors[14,18,19,20,21] have concluded in their studies that high heels cause posterior pelvic tilt and lumbar rectification.

Another study[14] performed a postural evaluation and specific tests for muscular shortening, pelvic mobility and lower limbs on 20 women that wore high and low heels. The subjects that frequently wore high heels reported more posterior pelvic tilt.

Bendix et al.[18] evaluated 18 women who wore several types of high heels and found lumbar lordosis by means of an inclinometer. They concluded that, as the height of the heel increased, the lumbar lordosis and of the posterior pelvic tilt decreased.

Manfio et al.[21] evaluated seven women without shoes, with low heels and with high-heeled shoes (85mm), by means of photographs and force platforms, and also found a decrease in anterior pelvic tilt with use of high heels compared to the barefoot women.

In the present study, we did not observe any changes in pelvic position when we evaluated the PB angle, as seen in Table 3, nor did we find any modification in lumbar lordosis (evaluated by the LL angle), when we analyzed the relationship between frequency of use and type of high heel, as seen in Table 2.

In the literature, wearing high heels is related to knee semiflexion, however, a recent study[22] evaluated adolescents with bare feet and high heels by means of photographs and showed that high heels did not change knee positioning. The same result was found in the present study, i.e. women who regularly wore high heels had a similar KF angle to the group of women that wore high heels occasionally. The same relationship was found when different types of high heels were compared (Table 3).

No studies were found that correlated head posture, cervical and dorsal regions, nor pelvic and knee asymmetry.

It must be noted that this study included young subjects. It would be useful to investigate a sample of women who have been wearing high heels for several years to verify whether these changes eventually occur.

Conclusions

With the present study, we observed that the frequency of use and type of high heel did not modify static posture in women, according to the photogrammetry evaluation. The only variable that differed between the women who frequently wore high heels and those who wore them occasionally was the head (HP angle). However, this variable did not change when different types of heel were worn. Stilettos modified the rKA in women who did not wear high heels regularly, and ankle positioning on the sagittal plane was the only variable modified with the use of the different types of footwear.

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