ORIGINAL ARTICLE

Influence of shoe heel height on venous function in young women

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ABSTRACT

Background: The influence of shoe heel height on venous function is still a controversial subject in the international literature. The importance of ergonomics for quality of life is a universally accepted factor, and situations that impair it, such as prolonged permanence in the supine position, shoe quality and workplace conditions may interfere with the individual's health.

Objective: To analyze the influence of shoe heel height on lower limb venous drainage using air plethysmography.

Method: Fifteen asymptomatic women with mean age of 24.6 years, wearing shoes of appropriate size were examined in three different situations: barefoot (0 cm), medium heels (3.5 cm) and high heels (7 cm). Body mass index was < 25 and the subjects were classified according to the CEAP International Classification based on clinical (C0 or C1), etiologic (Ep), anatomic (As) and physiopathological (Pr) criteria. The values of venous filling index (VFI), ejection fraction (EF) and residual volume fraction (RVF) were divided into three categories according to heel height and compared to one another by repeated means analysis of variance (ANOVA).

Results: EF was decreased and RVF was increased in the high heel group compared to the barefoot group ($p < 0.005$). These parameters did not differ between the medium heel group and the other groups. VFI showed a similar behavior in the three situations evaluated.

Conclusion: High heels reduce muscle pump function, as demonstrated by the fall in EF and increase in RVF, and their continued use may provoke venous hypertension in the lower limbs, possibly representing a predictive factor of venous disease symptoms.

Keywords: Plethysmography, ergonomics, lower limbs, venous insufficiency.

RESUMO

Contexto: A influência da altura do salto de sapatos na função venosa é ainda assunto controverso na literatura mundial. A importância da ergonomia na qualidade de vida é um fator consagrado e situações que a prejudiquem como permanência prolongada na posição supina, qualidade dos calçados e condições do local de trabalho podem interferir na saúde do indivíduo.

Objetivo: Estudar a influência da altura do salto do sapato na drenagem venosa dos membros inferiores, utilizando-se a pletismografia a ar (PGA).

Método: Quinze mulheres, com idade média de 24,6 anos, assintomáticas, utilizando calçados de tamanhos apropriados, foram examinadas em três momentos: descalças (0 cm), salto médio (3,5 cm) e alto (7 cm). Apresentavam índice de massa corporal < 25 e foram classificadas de acordo com a Classificação Internacional CEAP, em critérios: clínico (C0 ou C1), etiológico (Ep), anatômico (As) e fisiopatológico (Pr). Os valores do índice de enchimento venoso (IEV), da fração de ejeção (FE) e da fração de volume residual (FVR) foram separados em três categorias pela altura do salto e comparados entre si, utilizando-se a análise de variância para médias repetidas (ANOVA).

Resultados: Houve diminuição da FE e aumento da FVR no grupo de salto alto em relação ao grupo descalço ($p < 0,005$). Não ocorreu diferença desses parâmetros entre o grupo de salto médio e os outros grupos. O IEV comportou-se de maneira semelhante nas três situações avaliadas.

Conclusão: O salto alto diminui a função de bomba muscular demonstrado pela queda da FE e aumento da FVR, podendo, com o seu uso contínuo, provocar hipertensão venosa nos membros inferiores, o que poderia ser preditivo de sintomatologia na doença venosa.

Palavras-chave: Pletismografia, ergonomia, membros inferiores, insuficiência venosa.

Introduction

High heels, widely used among women due to their esthetic value, is no longer exclusive of special moments and has become a daily option in work environment.

Variations in form, consistency and material used in shoe manufacturing, especially heel height, may have an influence on women's health. Volunteers that wore soft shoes after wearing rigid shoe soles had not only more reported comfort, but also reduction in edema and in ankle impact after wearing them for only 2 hours.[1]

Ergonomics and working conditions, with regard to posture (sitting, standing and walking), and type of shoes and soil rigidity influence symptoms of tiredness, lumbar and plantar pain. Such complaints were objectively confirmed based on electromyographic measurements of the legs and paravertebral lumbar muscles and by means of pressure and impact sensors installed on shoes.[1-3]

Air plethysmography (APG) was used to demonstrate correspondence of complaints of pain and fatigue in the lower limbs of workers wearing hard shoes and standing upright for a long time, showing that complaints of fatigue are associated with increased leg volume.[4] Shoe heel thickness and hardness have orthopedic implications, such as formation of calcaneal exostosis.[5] But not everything regarding lower limb health is limited to type of shoe, soil characteristic or individual's position: walking speed, when increased, raises plantar pressure peaks,[6] and biophysical structure also interferes with complaints of pain and fatigue, since they are more common in shorter individuals or in those with more mass.[7]

Despite the available knowledge, there is no specific information in the literature about the influence of high-heeled shoes in venous drainage of the lower limbs.

Thus, this study aimed at investigating the influence of shoe heel height (3.5 and 7 cm) in venous drainage of the lower limbs in young women in relation to the bare foot position, by using APG.

Method

Fifteen asymptomatic women aged 20-30 years were studied (mean age = 24.6 years). They had body mass index < 25 and were classified according to CEAP International Classification, used as a standard in the study of chronic venous disease, in clinical (C0 or C1), etiologic (Ep), anatomic (As) and physiopathological (Pr) criteria.[8]

The examinations were performed at the Laboratory of Noninvasive Vascular Investigation of the Course of Vascular Surgery at Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo, Brazil, in the afternoon and by two examiners. Maneuvers were started after demonstration of the examination to the volunteer and after gaining her understanding and trust.

APG was performed in three moments with each volunteer: bare foot (0 cm), medium heels (3.5 cm) and high heels (7 cm). All the participants were wearing shoes of appropriate size and signed a consent term approved by the Research Ethics Committee of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo, process no. 15.309/2005.

Calf muscle pump function was studied by APG. The SDV 3000 (Angiotec®, Belo Horizonte, Brazil) device was used, with computer-automated calibration.

To perform the examination, the laboratory temperature was maintained between 22 and 24 ºC. An examination bed was used at a height close to 55 cm to facilitate patient's mobilization from supine to orthostatic position.

APG consisted of a device connected by cables to a computer, and a polyurethane hose measuring 2.5 m in length, connected to a 35-cm cuff and approximately 5-L capacity, made of the same material as the hose.

The examination was performed with the patient in the supine position for vein emptying, maintaining her leg elevated at 45º and slightly flexed knee. The patient's foot was supported by the ankle at a 20-cm height in relation to the examination table. A pneumatic cuff of an appropriate size was placed in the patient's leg, involving the whole leg extension, from the knee to the ankle, without exceeding leg limits, thus allowing a good contact of the cuff with the skin. The latter, in its turn, caused minimal occlusion of superficial veins.

The device was then automatically gauged. Cares were taken to prevent the cuff from being in contact with the support of foot elevation and with the examination table, so that the reading made by the device and, consequently, the examination result were not altered.

After an electronic command, the cuff was automatically inflated until selected pressure of 6 mmHg, and the data were transmitted to the pressure transducer, located in the device, amplifying the signal and registering it as a graph in the computer screen.

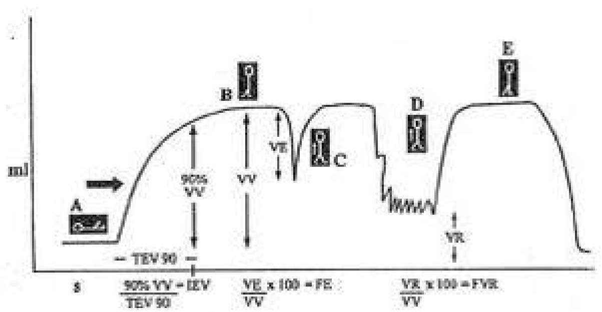
A basal volume value was obtained and then the patient was requested to raise her leg aided by the examiner, standing on the unassessed limb. The patient placed her hands on a walking device for better balance. Increased leg volume was observed until reaching a plateau, indicating that the veins were full. The difference between initial and plateau volume represents functional venous volume (VV).

Next, the patient was requested to stand on both feet and perform a plantar flexion movement, causing calf muscle contracture, resuming then initial rest position or relaxation of assessed limb. Decrease observed in the graph curve corresponds to ejected volume (EV), resulting from calf muscle contraction.

After this movement, a new plateau is reached (usually more elevated than the initial plateau) and the patient was requested to perform 10 movements of plantar flexion in a velocity of one movement per second. Decreased volume was also recorded. Residual volume (RV) was calculated based on final basal value in relation to remaining volume at the end of movements.

After plantar flexions were over, the patient was requested to resume rest position and relax assessed limb until reaching a new venous filling plateau. After leveling, with the aid of the examiner, the patient returned to supine position on the examination table with the foot on the support, and total limb emptying was recorded, shown by a graph leveling corresponding to final volume (FV).

Volume/time graph is seen on the computer screen. Once the graph was created, markings using the software cursor were performed, corresponding to initial volume (ZERO), venous volume (VV), ejected volume (EV), refilling volume (ReV), minimal residual volume (RV min) and finally final volume (FV). The software automatically marked the time spent to reach 90% of venous volume (90% VV) (Figure 1).



90%VV = 90% of venous volume; A = volunteer lying down; B = volunteer in orthostatic position 10 times; E = orthostatic position again; EF = ejection fraction; EV = ejected volume; RVF = residual volume fraction; RV = residual volume; VFI = venous filling index; VFT 90 = 90% venous filling time; VV = functional venous volume.

Figure 1 - Example of A) normal curve and B) positions of volunteers to obtain each measurement; C) volunteer performing a tip-toe elevation movement; D) volunteer repeating the value[9]

After markings were placed in the graph, the computer automatically processed the calculations for venous filling index (VFI), ejection fraction (EF) and residual volume fraction (RVF).[9]

After the procedure described above was finished with the volunteer bare foot, the same routine was repeated with the volunteer wearing shoes in both feet, first with a 3.5-cm heel and then with a 7-cm heel, resulting in three graphs per volunteer. The cuff was always placed in the left leg.

VFI is the variation of volume produced in the limb divided by the corresponding time in seconds, when passing from the supine to the orthostatic position, calculated using the formula VFI = 90% x VV / VFT 90 and expressed in mL/s.

We studied the calf pump function using the data obtained from the variables EF and RVF.

EF provides an estimate of venous reflux during physical activity and the changes that result in less ejected blood. EF is the percentage of total venous volume, ejected in a single calf muscle contraction. It is calculated by the formula EF = (EV / VV) x 100, where EV is ejected volume and VV is venous volume.

RVF is linearly related to outpatient venous pressure (OVP), measuring it noninvasively, i.e., measured by the formula RVF = (RV / VV) x 100, where RV is residual volume.[10]

VFI < 2, EF > 40% and RVF < 35% are normal values in the literature.[11]

To compare the values of variables VFI, EF and RVF between plain, medium and high heels, variance analysis was used for repeated measurements (ANOVA), considering significance level of $p < 0.05$ by Bonferroni *post hoc* test.[12]

Results

VFI, EF and RVF values were divided into three categories according to heel height: bare foot (0 cm), medium heels (3.5 cm) and high heels (7 cm). To facilitate reading and understanding of results, those values are presented in tables and figures. There was reduction in venous drainage demonstrated by EF reduction (Figure 2 and Table 1) and increase in RVF (Figure 3 and Table 2) for the high-heel group (7 cm) compared with the bare foot group (0 cm).

There was no significance difference in these parameters between the medium-heel group and the other groups, although there has been a strong tendency in reduced EF and increased RVF in this group compared with the bare foot group.

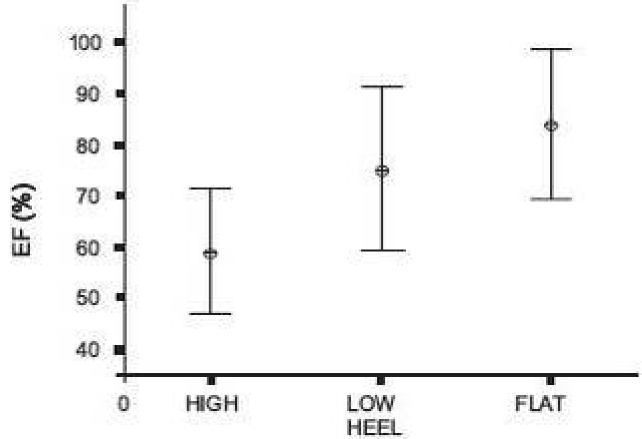


Figure 2 - Variation of ejection fraction (EF) in all three situations tested: bare foot, low heels and high heels in 15 young women (20-30 years)

Table 1 - Variation of ejection fraction (EF) in all three situations tested: bare foot, low heels and high heels

EF	1st quartile (P25)	Median (P50)	3rd quartile (P75)	Mean	SD
Bare foot	62.00	83.80	109.40	84.03	26.41
Low	61.20	72.30	92.60	75.11	28.63
High	40.40	57.10	75.50	59.08	21.67

EF = ejection fraction; SD = standard deviation.
Considering $p = 0.009$, there is significant difference between bare foot, low and high. According to Bonferroni *post hoc* test,[12] there is significant difference between bare foot and high, since bare foot had higher values than high heels ($p = 0.01$).

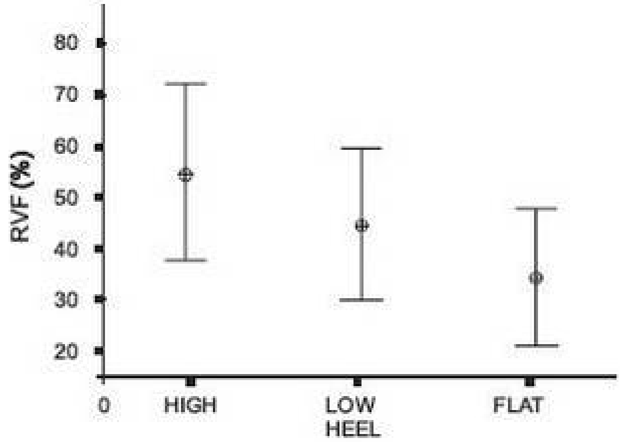


Figure 3 - Variation of residual volume fraction (RVF) in all three situations tested: bare foot, low heels and high heels in 15 young women (20-30 years)

Table 2 - Variation of residual volume fraction (RVF) in all three situations tested: bare foot, low heels and high heels

RVF	1st quartile (P25)	Median (P50)	3rd quartile (P75)	Mean	SD
Bare foot	21.60	25.30	38.90	34.76	25.47
Low	28.40	33.80	58.90	44.55	27.41
High	22.80	59.10	81.40	56.19	31.17

RVF = residual volume fraction; SD = standard deviation.
Considering p = 0.003*, there is significant difference between bare foot, low and high. According to Bonferroni *post hoc* test,[12] there is significant difference between bare foot and high, since bare foot had lower values than high heels (p = 0.01).

VFI behaved similarly in all three moments tested (Figure 4 and Table 3).

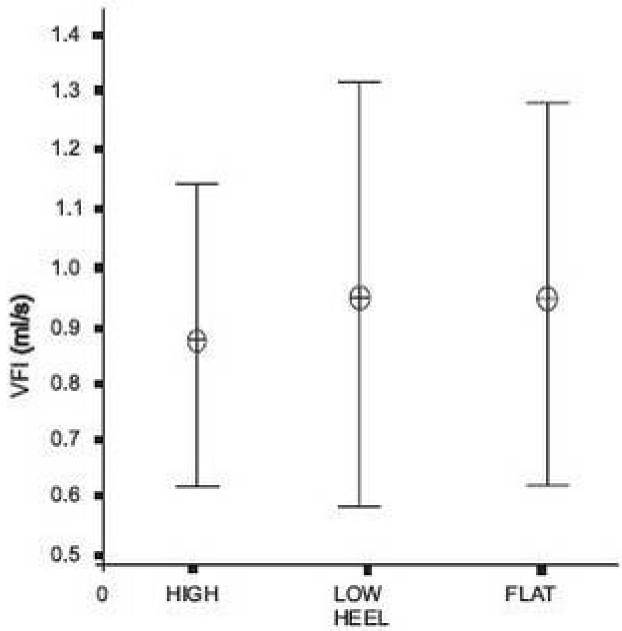


Figure 4 - Variation of venous filling index (VFI) in all the situations tested: bare foot, low heels and high heels in 15 young women (20-30 years)

Table 3 - Variation of venous filling index (VFI) in all the situations tested: bare foot, low heels and high heels

VFI	1st quartile (P25)	Median (P50)	3rd quartile (P75)	Mean	SD
Bare foot	0.44	0.81	1.28	0.95	0.59
Low	0.41	0.63	1.35	0.95	0.66
High	0.47	0.96	1.06	0.88	0.48

SD = standard deviation; VFI = venous filling index.
Considering p = 0.85, there is no significant difference between bare foot, low and high heels.

Discussion

APG is a method of great value in assessing the venous system of the lower limbs, allowing clinical and physiological correlations.[13] APG quantifies venous volume, superficial and deep venous reflux in mL/s, degree of venous obstruction and ejection capacity of calf muscle pump noninvasively, according to blood flow graphs obtained during the maneuvers.[14] According to Yang, in addition to that information, APG can reveal elements that help therapeutic management and assess the effect of the proposed treatment,[15] including by characterizing hemodynamic study during use of elastic compression.[16]

Assessment of calf muscle pump function according to age[17] and the effects of calf muscle strengthening in venous hemodynamics[18] have been observed using APG.

RVF expresses the combined effect of venous reflux and ejection fraction with rhythmic exercise. In addition, since it is a relevant indicator of outpatient venous pressure, it was one of the parameters chosen to assess the influence of different shoe heels in venous hemodynamics.[19]

The main mechanism of venous reflux in the lower limbs is blood ejection through muscle contraction. The "calf pump" is activated at each step, ejecting blood against gravity and, due to venous valve competence, there is no reflux.

Ankle mobility is an essential factor for an efficient performance of the calf pump. When tibial-tarsal ankylosis is installed, there is irreversible chronic venous insufficiency, because the gemellus-soleus pump function is cancelled.[20] Calf contraction during walking aims at elevating the body on tip toes, impelling it. Apparently, high heels limit this movement radically, reducing pump action. The higher the heels, the higher the intensity of this phenomenon.

The degree of ankle mobility in a normal individual is around 70º, 45º due to plantar flexion and 25º due to dorsal extension. After studying 32 limbs of 26 male adults, Back et al.[21] concluded that a limited degree of ankle mobility is a significant factor in venous ulcer index. Use of high heels is clearly not a definite change, but considering "exposure time," different impairment levels could occur.

In this study, there was no difference in VFI in the three moments (bare foot, 3.5-cm heels and 7-cm heels, respectively) tested, which shows that global valve competence of the venous system of lower limbs was preserved during the three stages of the experiment, a result that confirm the selection criteria of not having venous disease of any type in assessed women.

EF was reduced when volunteers were wearing high heels, which can be explained by a lower shortening of calf muscle fibers during muscle systole. Consequently, blood volume retained in the limb increases.

Increased RVF when wearing high heels (7 cm) found in this study is mainly due to higher blood residue that remains in the limb after EF fall, considering that RVF is obtained in muscle diastole and represents the sum of residual venous volume and arterial blood supply coming to the calf.

Despite the impossibility of confirming a significant difference between the medium-heel group (3.5 cm) and the other groups, there is a strong tendency to EF reduction and RVF increase in this group compared with the bare foot group. In further studies, using a larger population, such tendency is likely to be corroborated with statistical significance.

We conclude that high heels reduced calf muscle pump function and that its continuous use can cause a status of venous hypertension in lower limbs. That situation is an essential component in venous disease evolution from lower to higher clinical severity states.

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