Does The Different Heel Heights of Foot Wear Affect Gait Parameters of Normal Pregnant Ladies?

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ABSTRACT

This study was conducted to determine the effect of different heel heights of foot wear on gait parameters of normal pregnant women. Sixty volunteer primigravidae women evaluated at their 24 weeks' gestation in motion analysis laboratory at the faculty of Physical Therapy to measure anterior pelvic tilting, pelvic rotation and planter flexors moment while wearing foot wear with different (flat, 1.5cms, 3cms. and 5cms.) heel heights and this procedure repeated at 28th, 32nd and 36th weeks' gestation.. Results showed a statistically significant decrease in anterior pelvic tilting, pelvic rotation and planter flexors moment while wearing foot wear with 1.5cms. and 3cms. heel heights in comparison with flat and 5cms. heel height which showed a statistically significant increase in anterior pelvic tilting and pelvic rotation and non significant difference in the planter flexors moment. Accordingly, medium heights (1.5 and 3cms) heels are advisable to be worn during pregnancy as it may have minimal impact on the pelvis, back and feet of the pregnant ladies.
Keywords: Pregnancy, Heel heights, Foot wear, Gait parameters, Pelvis, Planter flexor moment.

INTRODUCTION

Pregnancy results in a considerable compensation in the structure and function of the human body to allow normal development and parturition of the foetus. Many of these changes including weight gain, ligamentous laxity, alteration in biomechanics, structures of the spine and the whole pelvis undergoes several changes in preparation for a subsequent delivery[3].

As pregnancy progress there is natural tendency for anterior displacement of the trunk which may be counter balanced by increased activities of gastrocnemius and soleus muscles, extension of hip joints or posterior displacement of the upper trunk, including increase of the lumbosacral angle as well as, lumbar curvature and anterior displacement of the pelvis with simultaneous posterior displacement of the shoulders[7,13]. Also, due to instability and looseness of the joints, the pregnant woman attempts to keep her joints locked during locomotion and assumes the characteristics of the duck waddling gait at late pregnancy including wide base of support, external foot progression angle (toe out), and large pelvic obliquity range of motion[25].

However, even with the locking of the joints, there is still disturbing features of increased shearing stress applied on lumbosacral area. This is due to increased lumbar curve as well as, the shift of weight backward which increase the pressure on the back of lumbar vertebrae and jamming the posterior facet joints which manifested as joint pain, bony impingement as well as, capsule and nerve root irritation[16].

Contribute to the characteristic posture and gait associated with the pregnant female, these alterations, although transient, are believed to predispose to the development of postural complains such as back and hip pain, which have been found to be common in childbearing women and produce significant morbidity and loss of independence[4].

To ease back pain during pregnancy, some measures were advised by the American College of Obstetricians and Gynaecologists, these include wearing low heeled (but not flat) shoes with good arch support[22,24].

Flat shoes are not advised to be worn during pregnancy due to the increased physical strains caused by skeletal changes during pregnancy. Instead, pregnant ladies should wear comfortable heel heights of around an inch. This puts the spine muscles and joints in a better position to withstand the extra weight of the growing foetus[14].

A majority of cases of chronic low back pain may be caused by gait abnormalities which result in muscle over use and weakness of the lumbar discs, which trigger back injury and cause pain. So, examining gait style as a possible cause of chronic or acute recurrent LBP is essential. However, Dananberg and Guiliano (1999)[5], reported that shoe inserts appears to provide more effective back pain relief than standard therapies.

Hence, the pregnant woman needs to observe good feet health to prevent pain and discomfort. Since the body undergoes changes and acquire a new weight bearing stance, women should wear shoes with broad based heels that provide support and absorb shock. Additional body weight also calls for more support to prevent foot breakdown[1,21].

Gait is cyclic and can be characterized by the timing of foot contact with the ground. An entire sequence of function by one limb is identified as a gait cycle[1].

Gait is divided into a contact phase (stance phase) and a non contact phase (swing phase). One full gait cycle is the interval of time from heel strike of one foot to heel strike by the same foot at the next step. Each gait cycle has two basic components, stance phase and swing phase. Stance phase describes the duration of foot contact with the ground. Swing phase is the entire period during which the foot is in the air for the purpose of limb advancement. Swing phase can be further divided into three functional sub-phases (1) initial swing, (2) mid swing and (3) terminal swing, while stance phase can be divided into five sub-phases (1) initial contact, (2) loading response, (3) mid stance, (4) terminal stance and (5) pre-swing[11].

Aim of the study:

To evaluate the effect of different heel heights on gait parameters in normal pregnant ladies .So, it may act as a preventive measure to guard against low back pain during pregnancy which is a frequent common problem.

SUBJECTS, MATERIAL AND METHODS

Subjects

Sixty normal primigravidae ladies at their 24 weeks' gestation participated in this study. They were selected from the Obstetrics Outpatient Clinic at Kasr El-Eini University Hospital. Their ages ranged from 20 to 30 years old (26.15 ± 3.42), while their heights ranged from 150 to 169 cms (163.44 ± 3.69) and their weights ranged from 54.5 to 89 kgs (69.63 ± 7.82), 56 to 92 kgs (73.20 ± 6.54), 59 to 91 kgs (75.98 ± 7.43) & 59 to 92.5 kgs (76.55 ± 8.67) at 24, 28, 32 & 36 weeks' gestation respectively. Ladies with diabetes, pre-eclampsia, varicose veins, twins, polyhydramions, macrosomic foetues, musculoskeletal and neuromuscular disorders, deformities and / or previous surgery at their back and / or lower limbs were excluded from this study.

An informed consent form had been signed from each pregnant lady before starting the study.

Instrumentations:

1- Recording data sheet:All data and information of each pregnant lady participating in this study were recorded in a recording sheet .Weight- height scale was used to measure the height and weight of each pregnant lady.
2- Ultrasonographic machine was used before starting this study to detect and calculate the gestational age of each pregnant lady as well as to exclude cases of macrosomic foetues or those with congenital anomalies.
3- Qualysis gait analysis system was used to record and measure the gait parameters of each pregnant lady while wearing different heel heights of foot wear. It consists of the following units:
   a. ProReflex Motion Capture Unit (MCU) 120 : This unit is composed of a six cameras' system to expose reflective markers to infra-red light and detect the light reflected by the markers. 2-D image of the markers is obtained by each camera and the data of the six cameras are combined for calculating a 3-D position of the markers.
   b. A wand kit : Consists of two parts (L shape and T shape), was used for calibration of the system.
   c. Personal computer with Q-Trac and Q-gait software installed.
   d. Q-Trac and Q-gait software: Developed for analyzing the motion pattern as retrieved by ProReflex camera system to provide kinematics and kinetics data.
   e. Reflective Markers: 20 markers, silver in colour, 8cm^2 surface area, are adhered to the bony landmarks by using double face plaster.

Procedures

Each pregnant lady was instructed carefully about the evaluative procedures and she was advised to evacuate her bladder (as full bladder may disturb her walking pattern) and wear thin well fitted clothes before starting the measurement procedures in motion analysis laboratory at the Faculty of Physical Therapy.

Each lady taught a home routine (advice) about how to attain good posture through static abdominal exercises, posterior pelvic tilting and postural correction exercises.

System calibration: At the start, L-shape wand was placed in the middle of the walkway at the force plate form with the x-axis in the walkway direction And then, T-shape wand was moved in x, y and z direction so that, the wand markers were oriented in all three directions of the measurement volume. During this procedure, the operator moved around in the measurement volume to allow all cameras to view L-shape and T- shape of the wand during the calibration. Then the operator move the wand in the suggested area of measurement as much as possible so that, all cameras connected to the system can pick up the marker position in various locations, then four reference markers were placed at force plate corners to measure force plate position, The data was captured, tracked and then exported.

Application of markers

For each pregnant woman, 20 reflecting dots (markers) according to the system software were placed on special bony landmarks of her body two markers were placed on the tip of both acromions, one marker at the 12th thoracic vertebra and another one on the sacrum. Two markers were placed on both anterior superior iliac spines (ASIS), others on both greater trochanters, on the superior surface of the patellae on both sides, over the knee joint line on both sides, over the tibial tuberosities on both sides, over

both lateral malleolli, over the dorsum of both feet between bases of the second and third metatarsal bones and two markers one for each heel (posterior of calcanus) at the same horizontal plane as the toe marker.

When the pregnant lady passed the starting position, the Q Trac measurement was started and she was let to continue walking several meters beyond the volume to allow the Q Trac measurement to be completed and to prevent gait ending effect as slowing her walking speed.

The pregnant lady hit the force plate with one foot and the therapist made sure that she did not make any target on it. These previous procedures were done while the pregnant lady was wearing heel-less shoes then when wearing foot wears with different heel heights (1.5, 3 & 5cms).

At the end of capturing. These procedures were repeated again for each pregnant lady in this study at the 28^{th} , 32^{nd} & 36^{th} weeks' gestation. The data was processed and edited in Q Trac before it was used in the Q gait software for

- Tracking of the motion data (creating 3-D markers trajectories).
- Sorting of the 3-D according to the markers used in the measurement.
- Selecting of an appropriate part of the data and export of this selection.

Descriptive statistical analysis was used for the collected data to calculate mean, standard deviation (S.D.), and student t-test.

RESULTS

The results of this study were represented as follow:

1- Kinematic parameters as pelvic motion:
   - Anterior pelvic tilting.
   - Pelvic rotation.
2- Kinetic parameter as: Planter flexors moment.

Table (1): Anterior pelvic tilting at 24^{th}, 28^{th}, 32^{nd} & 36^{th} weeks' gestation with different heel heights.

		Heel heights			
		flat	1.5cms	3cms	5cms
t-value	24th	-	3.92	4. 64	-3. 38
	28th	-	4. 38	5. 60	-2.91
	32nd	-	2.12	4. 95	-6. 77
	36th	-	6.43	10.80	0.69
P-value	24th	-	0.001 H.S ↓	0.001 H.S ↓	0.003 H.S ↑
	28th	-	0.001 H.S ↓	0.001 H.S ↓	0.004 H.S ↑
	32nd	-	0.045 S ↓	0.001 H.S ↓	0.001 H.S ↑
	36th	-	0.001 H.S ↓	0.001 H.S ↓	0.54 N.S

The previous table shows that there were a statistically highly significant decrease in anterior pelvic tilting between the flat foot wear and both of 1.5 & 3 cms heel heights of foot wear throughout all times of measurements. While, on the contrary there were a statistically highly significant increase between the flat foot wear and 5cms heel heights of foot wear throughout all times of measurements. Fig. (1).

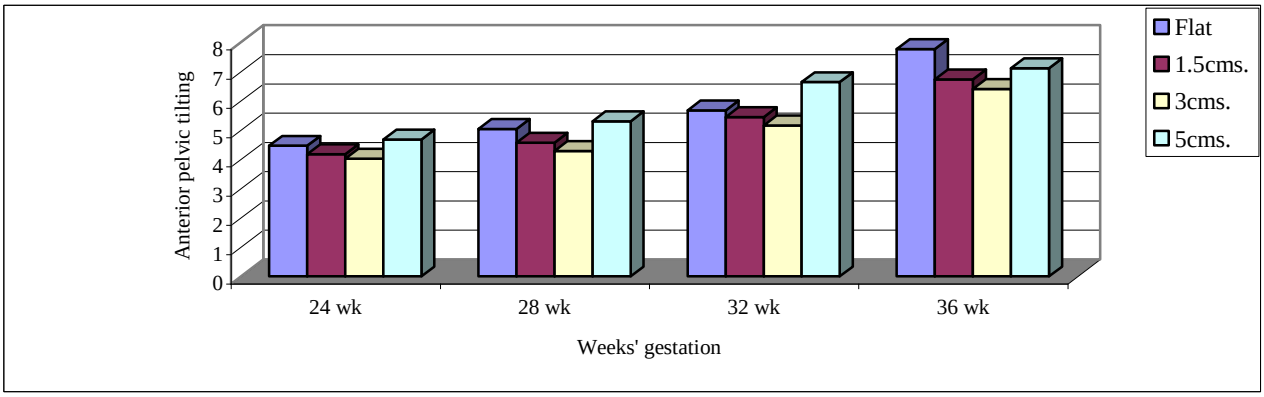

Fig. (1): The anterior pelvic tilting at 24th, 28th, 32nd, & 36th weeks' gestation with different heel height.

Table (2): The pelvic rotation at 24th, 28th, 32nd & 36th weeks' gestation with different heel heights.

		Heel heights			
		flat	1.5cms	3cms	5cms
t-value	24th	-	8. 22	6.94	-5. 08
	28th	-	5. 26	4. 84	-3.73
	32nd	-	2.02	5.97	-4.67
	36th	-	1.99	5. 33	-1. 44
P-value	24th	-	0.001 H.S ↓	0.001 H.S ↓	0.001 H.S ↑
	28th	-	0.001 H.S ↓	0.001 H.S ↓	0.002 H.S ↑
	32nd	-	0.040 H.S ↓	0.001 H.S ↓	0.001 H.S ↑
	36th	-	0.050 H.S ↓	0.001 H.S ↓	0.100 N.S

The previous table shows that there were a statistically highly significant decrease in pelvic rotation between the flat foot wear and both of 1.5 & 3 cms heel heights of foot wear throughout all times of measurements. While, on the contrary there were a statistically highly significant increase between the flat foot wear and 5 cms heel heights of foot wear throughout all times of measurements. Fig. (2).

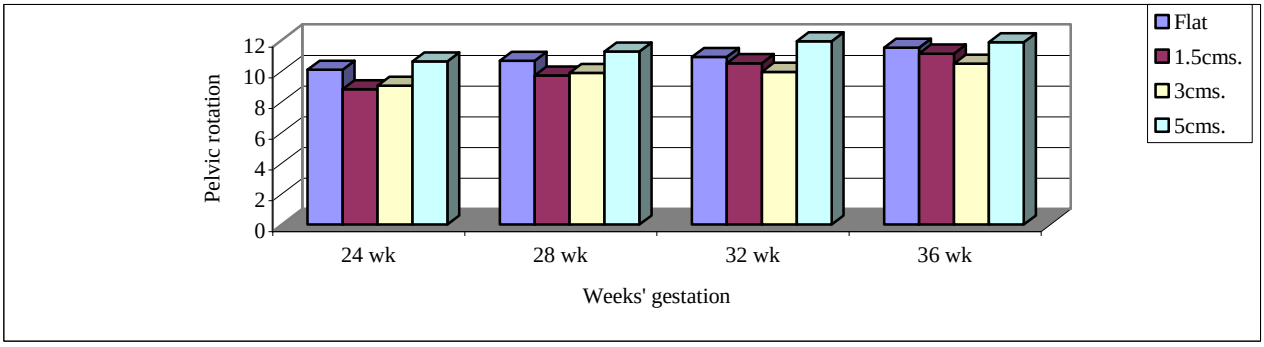

Fig. (2): The pelvic rotation at 24th, 28th, 32nd, & 36th weeks' gestation with different heel heights.

Table (3): The planter flexors moment at 24th, 28th, 32nd & 36th weeks' gestation with different heel heights.

		Heel heights			
		flat	1.5cms	3cms	5cms
T-value	24th	-	1. 69	0.74	1.16
	28th	-	2. 23	3.28	1.19
	32nd	-	4. 50	4.86	1.36
	36th	-	3. 80	3.86	0.805
P-value	24th	-	0.100 N.S	0.700 N.S	0.260 N.S
	28th	-	0.048 S ↓	0.003 H.S ↓	0.240 N.S
	32nd	-	0.001 H.S ↓	0.001 H.S ↓	0.170 N.S
	36th	-	0.001 H.S ↓	0.001 H.S ↓	0.400 N.S

The previous table shows that there were non significant differences in the planter flexors moment between different heel heights when the measurement was done at the 24th week gestation. While, there were a statistically highly significant decrease in planter flexors moment between the flat foot wear and both of 1.5 & 3cms heel heights of foot wear at the 28th, 32nd & 36th weeks' gestation. While, there was non significant difference between the flat foot wear and 5cms heel heights of foot wear throughout all times of measurements. Fig. (3).

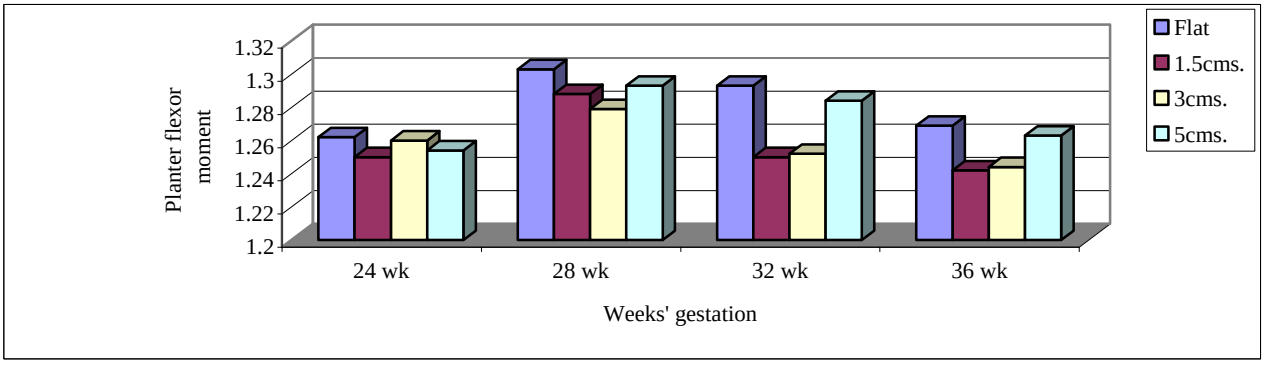

Fig. (3): The planter flexors moment at 24th, 28th, 32nd, &36th weeks' gestation with different heel heights.

DISCUSSION

The American College of Obstetricians and Gynecologists suggested that wearing low heeled (but not flat) shoes with good arch support is used to ease back pain during pregnancy. Also, advised the pregnant woman to avoid wearing shoes with elevated heels which accentuated lumbar lordosis and increased the shearing stress on the lower back and sacrum[26].

If the heel of a shoe is raised high enough to substantially alter the position of body segments, common sense suggests that some postural adaptations should occur to compensate these changes, but little researches had been done to confirm that especially during pregnancy.

This study was done to evaluate fifty volunteer primigravidas ladies at their 24th week' gestation while wearing foot wear with different heel heights (flat, 1.5 cms, 3 cms, & 5 cms) to measure the degree of change in anterior pelvic tilting, pelvic rotation and planter flexors moment. These procedures were repeated at their 28th, 32nd and 36th week' gestation to determine the effect of different heel heights of foot wear on gait parameters during pregnancy.

Anterior pelvic tilting

In the present study, the mean values of total anterior pelvic tilting decreased significantly when the participants were wearing foot wear with 1.5 & 3 cms heel heights in all times of measurements at 24th, 28th, 32nd, & 36th week gestation. While, the anterior pelvic tilting increased significantly when wearing 5 cms heel height of foot wear at 24th, 28th & 32nd weeks' gestation, with non significant difference between the flat and 5 cms heel height of foot wear at 36th week' gestation.

The decreased mean values of anterior pelvic tilting was observed when foot wear of 1.5 & 3 cms heel heights can be attributed to the movement of line of gravity (LOG) posteriorly nearly to its normal placement. This resulted in reduced lumbosacral angle and anterior pelvic tilting in comparison to the flat foot wear. While, wearing 5cms heel height of foot wear, there was exaggerated movement of LOG which resulted in increased lumbar lordosis, lumbosacral angle and anterior pelvic tilting.

Furthermore, Foti et al. (1997)[12] evaluated the walking of pregnant female (this resembling to the flat foot wear at this study), and they found a significant increase in the anterior pelvic tilting during pregnancy which may be explained by the increase in the

amount of body mass located in a lower abdomen which causes a forward rotating moment that tends to rotate the pelvis forward.

These results of the current study are in agreement with Murray and co-workers (1970)[17], who reported that 17 of 30 non pregnant females showed anterior pelvic tilting whereas 13 showed posterior pelvic tilting when wearing high heeled shoes as compared to low heeled shoes.

In addition, Bendix and his colleagues (1984)[2], also Opeila and colleagues (1988)[20], found a flattening of the lumbar spine and a tendency for the pelvis to roll backward in response to wearing high heeled shoes relative to barefoot.

Opeila (1990a)[18], investigated the kinematics of high-heel foot (ranged from 5 to 7 cms) gait with consideration for age and experience of wearer. He found that there were significant difference in the way of pelvis, trunk and upper trunk accommodated for foot wear to assist in absorbing the greater vertical lordosis of the trunk as younger ages had more anterior pelvic tilt, more posterior upper trunk and an increased lumbar lordosis.

On the other hand, the results obtained in this study were in disagreement with De Lateur and colleagues (1991)[6], who found no significant difference in the back, hip or pelvic tilt angles among subjects who were barefooted, wearing shoes with negative heels or high heels.

Also, Snow and Williams (1994)[23], investigated the effect of different heel heights (1.91, 3.81 & 7.62 cms) shoes on the three dimensional kinematics and they found no significant differences or trend found among heel heights for pelvic tilt, average lumbar curvature, or range of shoulders and pelvic rotation in the transverse plane.

Pelvic rotation

In the current study, the mean values of pelvic rotation decreased significantly while wearing foot wear with 1.5 & 3cms heel heights at 24th, 28th, 32nd, & 36th weeks' gestation. While, with the foot wear of 5cms heel height, the mean values of pelvic rotation increased significantly throughout all measurements.

The results obtained in this study can be explained as wearing medium heels (1.5 & 3 cms) effectively lengthens the lower limbs for the initial contact which optimizes the vertical displacement of COM (about 2.5cms). Also, this decreased displacement of COM resulting in decreased angular displacement which in turn leads to increased linear displacement and smoothness of gait.

Increasing pelvic rotation while wearing flat shoes during pregnancy can be explained by the postural changes that occur during this period of life. Normally the line of gravity falls approximately 4cms anterior to the first sacral segment, this would put it close to the axis of the hips around which pelvic rotation occurs[15]. During pregnancy, there is a tendency of the center of gravity to move forward (as a result of enlarged abdomen) away from the axis of the hips resulting in more pelvic rotation.

The increased pelvic rotation observed at heel height of 5cms was in accordance with Opeila (1990a), who found that experienced wearer of high heeled had exaggerated rotation of the pelvis.

Furthermore, Foti et al. (1997) investigated the biomechanical alteration in gait during pregnancy and found that there was a significant increase in hip abduction/adduction power due to increased body mass during pregnancy. Also, Eng and Winter (1995)[9], investigated the kinetic analysis of the lower limbs during walking on

normal 9 subjects and they found that the hip power phases were a result of the hip abductor muscles which controlling the pelvis, and a small absorption burst during weight acceptance was a result of external rotation which decelerated the forward rotation of the pelvis.

In contrast, Opeila (1990b)[19], who investigated the kinematics different heel heights ranged from 0-2 cms (as low heel) and from 5 to 7 cms (as high heel) on normal females and he added that pelvic rotation showed statistically non significant differences between different heel heights in both transverse and frontal planes. Also, he explained that the shorter stride length of high heeled gait causes illusion of the exaggerated rotation of the pelvis.

Planter flexors moment

In the present study, the mean values of planter flexors moment showed no significant changes between the different heel heights at the 24th week gestation. In the 28th, 32nd, & 36th weeks' gestation there was a highly significant decrease of planter flexors moment while, the participants wearing 1.5 & 3cms heel heights of foot wear. On the contrary, there was no significant difference between the flat and 5cms heel heights throughout all measurements as both have high planter flexors moment in comparison with 1.5 and 3 cms heel heights.

The results of this study showed an increased planter flexor moment during pregnancy while, the ladies were wearing flat shoes and this was attributed to the pregnancy progress. There was natural tendency for anterior displacement of the trunk which may be counter balanced by increased activities of gastrocnemius and soleus muscles. In medium heels (1.5 and 3cms) of foot wear, elevating heels to a position moving LOG more closer to the ankle joint, this generated planter flexors moment lower than the moment generated in the 5cms heel heights. Which elevated the heels into a position moving the LOG more anteriorly to the ankle joint. This needed more planter flexors moment to maintain body balance.

Furthermore, Eng and Winter (1995), stated that normally during walking the planter flexors eccentrically controlled the forward rotation of the leg over the foot (mid stance to terminal stance) and then, concentrically generated a rapid push off. Ebbeling et al. (1994)[8] found that during the support phase of the gait cycle, the body must attenuate the vertical forces as the foot makes contact with the ground, this is done by eccentric contraction of ankle dorsiflexors during ankle planter flexion and eccentric contraction of knee extensors during knee flexion.

Accordingly, the results of the current study were in agreement with Ebbeling et al. (1994) who investigated the effect of different heel heights (1.25 cms, 3.8 cms, 5.8 cms & 7.6 cms) on 15 females and found that the increased heel height placed the foot in a more planter flexed position at the initiation of support. At the two intermediate heel heights, the ankle reached moderately dorsiflexion while, at the highest heel height the ankle never attained a dorsiflexion, so, dorsiflexors were not able to act eccentrically to attenuate the vertical forces as much as normal during weight acceptance.

Also, Opeila (1990b), found that instability caused by increased planter flexion of the feet and smaller area of support with high heeled shoes (5 to 7 cms) was reflected in a cautious gait style, particularly in inexperienced wearer of high heeled shoes.

Snow and Williams (1994), showed that the soleus muscle was more powerfully contracted in high heels compared with low

heels. Maximum planter flexion was less in the low and medium heels (1.91 & 3.81 cms respectively) compared with the high heels (7.62 cms).

These results was in disagreement with Esenyel et al. (2003)[10], who found that walking in high heeled shoes causes a significant reduction in ankle planter flexor muscles moment, power and work occurred during the stance phase. This reduced planter flexor muscles moment resulted in a compensatory enhanced hip flexors that assisted in limb advancement during the stance to swing transition.

The results of this study revealed that foot wears with heel heights of 1.5 & 3cms are the most appropriate heel heights that can be worn during pregnancy as they are causing minimum change in the anterior pelvic tilting. While, the foot wears with 5cms heel height as well as the flat shoes are not advisable to be worn during pregnancy as they caused maximum change in the anterior pelvic tilting.

The results suggesting that medium heel heights between 1.5 cms and 3cms of foot wear is the most appropriate to be worn by the pregnant ladies as these medium heel heights have minimal impact on the pelvis, back and calf muscles. This in addition to antenatal classes must focusing on postural correction exercises, abdominal exercises and posterior pelvic tilting exercises which may help the pregnant ladies to pass through their pregnancies without or with minimal musculoskeletal discomfort.

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الملخص العربي

هل للتغير في ارتفاع كعب الحذاء تأثير على قياسات المشي لدى السيدات أثناء الحمل الطبيعي؟

أجريت هذه الدراسة لاختبار تأثير التغير في ارتفاع كعب الحذاء الذي ترتديه السيدة أثناء الحمل على قياسات المشي؛ وقد تم إجراء الدراسة على عدد ستين سيدة متطوعة تم تقييمهن أثناء الأسبوع الرابع والعشرين من الحمل عن طريق تحليل الحركة لقياس مدى ميل الحوض للإمام ومدى دورانه ، وكذلك عزم العضلات الباسطة للكاحل أثناء ارتدائهن لحذاء بدون كعب ثم بكعب ارتفاعه 1.5 سم ، 3 سم ، 5 سم . وقد تم إعادة التقييم لنفس السيدات في الأسبوع الثامن والعشرون والأسبوع الثاني والثلاثون والأسبوع السادس والثلاثون من الحمل. وقد أسفرت نتائج الدراسة عن وجود نقص ذو دلالة إحصائية في درجة ميل الحوض للإمام ودرجة دورانه ، وكذلك عزم العضلات الباسطة للكاحل أثناء ارتداء حذاء ارتفاع كعبه 1.5 سم ، 3 سم بالمقارنة بالحذاء بدون كعب أو بكعب ارتفاعه 5 سم مما يجعل من المناسب نصح السيدات الحوامل بعدم ارتداء الأحذية ذات الكعوب البالغة الانخفاض أو البالغة الارتفاع والاكتفاء بارتداء الأحذية ذات الكعوب متوسطة الارتفاع (1.5 سم ، 3 سم) حيث أنها الأنسب للسيدة أثناء الحمل .