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Influence of Different Shoe Heel Heights on Dynamic Balance in Different Age Groups of Females

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Abstract:*Many women wear high heeled shoes (HHS) on a daily basis to increase the femininity. Wearing HHS increases the height of the center of gravity and takes the line of gravity away from the center of the base of support. This may result in the loss of body balance. This study was conducted to investigate the effect of different shoe heel heights on dynamic balance in different age groups of females.*
Methods:*Repeated measure design was conducted. Sixty female subjects aged from 16 to 45 years were assigned according to their ages into three equal groups: Group (A) consisted of 20 female subjects; their ages ranged from 16 to 20 years with mean age (18.70 ±1.17) years. Group (B) consisted of 20 female subjects; their ages ranged from 21 to 35 years with mean age (25.25 ±4.63) years. Group (C) consisted of 20 female subjects; their ages ranged from 36 to 45 years with mean age (40.45 ±3.67) years. Biodex Balance System was used to assess dynamic balance (Overall Dynamic Stability Index (ODSI), Anterior / posterior stability Index (APSI) and Medial / lateral stability Index (MLSI)), while these subjects were wearing shoes of different heel heights (0cm (flat), 3cm and 5cm) in different trials.*
Results: *Showed that there was no significant difference (P > 0.05) in dynamic balance including (ODSI, APSI and MLSI) of the Biodex among different shoe heel heights (0, 3 and 5 cm) within groups (A, B and C). While there was a significant (P<0.05) difference between group (A, B and C) in all dependent variables (ODSI, APSI and MLSI) at each shoe heel height (0, 3 and 5 cm).*
Conclusion: *It may be concluded that there was no significant effect of different shoe heel heights (0, 3 and 5 cm) on dynamic balance. While there is a significant effect of age on dynamic balance at different shoe heel height (0, 3 and 5 cm).*
Keywords- *Heel heights, Balance, Age groups.*

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I. Introduction

Many women wear high heeled shoes (HHS) on a daily basis to increase the femininity and attractiveness, making these shoes remain popular despite the negative effects surrounding HHS [1]. Wearing HHS increases the height of the center of gravity (COG) and takes the line of gravity away from the center of the base of support (BOS). This may result in loss of body balance [2]. High heeled shoes generally cause qualitativelyconsistent changes in the neuromechanics of walking. Thesechanges are widespread, affecting structures from the toes to thespine, and mostly disadvantageous in terms of movement economy or increased risk of tissue damage [3].

Current statistics show that there are approximately 13,042,000 fatal falls throughout the population of the United States in year 2010 and a lack of balance control against perturbation is believed to be one of the biggest contributors to such accident [4].In a prospective study, It was found that 45% of all falls over a twelve month follow-up occurred with “unhelpful footwear”, mostly as slippers or other shoes without a firm heel-hold. These findings indicate that footwear or heel-hold issupposed to have influence on postural control during walking[5].

On the other hand,Lord and Bashford [6].found thathigh-heel shoes contributed to balance hazards in older women. This indicated a certain influence of footwear on balance. Jung et al. [7].found that wearing high heels can cause problems in the musculoskeletal system, body unbalance, and postural abnormality, leading to negative effects on movement over time. In recent years, it was reported thatmost functional shoes value convenience and functionality while HHS give more importance to the design of the shoes. Thus, the effects of heel height during walking were evaluated by analyzing the distribution of foot pressure, and kinematic changes in the lower extremity. However, the reason why HHScauses musculoskeletal and postural abnormalities was not discovered. Researcher prospectively examined risk factors associated with falls in 100 subjects and identified inadequate footwear as a major contributing factor. Out of 22 falls, 10 occurred while participants were wearing either heavy boots or boots with cutaway heels, slip-on shoes, or slippers. Also, it was found that a history of HHS wearing in women was a predisposing factor for falling [8].

Although studies relate the use of high-heeled shoes withpostural changes in adult women, there is need for a better understandingof the influence of different shoe heel heights on human dynamic balance in different age groups of female subjects using the Biodex balance system (BBS), as little is known about its impacts at these ages.

II. Materials and Methods

This study was conducted during period from February 2015 to October 2015 in balance laboratory at Faculty of Physical Therapy, Cairo University to investigate the effect of different shoe heel heights on dynamic balance in different age groups of females.

2.1 Study Design: Repeated measure design

2.2 Study Location:Carried out on females in balance laboratory at Faculty of Physical Therapy.

2.3 Study Duration: from February 2015 to October 2015

2.4 Sample size:60 healthy female subjects

2.5 Subjects & selection method: All subjects were recruited from students and workers of Faculty of Physical Therapy, Cairo University.

2.6 Inclusion criteria:

1. Healthy female subjects who are not habitual high heel wearers have participated in this study.
2. Their ages ranged from 16 to 45 years old.
3. Body Mass Index (BMI) ranged from 18.5 to 25 Kg/m².

2.7 Exclusion criteria:

1- Female subjects who are habitual high heel wearers who had worn shoes with a minimum heel height of 5 cm at least 40 hours per week for a minimum of 2 years [9].
2- History of lower limb injuries.
3- Chronic ankle or knee problems.
4- Auditory and visual problems.
5- If they had any orthopedic, vestibular, cognitive or neurological deficits affecting balance.
6- Over-weight and obese subjects.

2.8 Procedure methodology

All participants signed a written consent. They were assigned into three equal groups according to their age.Group (A):It included 20 female subjects; their ages ranged from 16 to 20 years .Group (B):It included 20 female subjects; their ages ranged from 21 to 35 years .Group (C):It included 20 female subjects; their ages ranged from 36 to 45 years [10].The Biodex balance system (BBS) was used to assess dynamic balance (ODSI, APSI and MLSI)[11], while these subjects wearing shoes of different heel heights (0cm (flat), 3cm and 5cm) in different trials.

Instrumentations

A. BiodexBalance System

The Biodex balance system(Biodex Stability Balance SystemModel 945-300 made in New York)is unique dynamic postural control assessment and training system. It is used to assess the subject's ability to maintain dynamic postural stability on an unstable tilting platform; a cursor, which represents the center of the platform, has to be maintained in the center of the bull's-eye on a visual feedback screen. A chosen level of platform instability is usually tested for 20 or30 sec. while the test person tries to keep the platform in the level position[12].

B. Shoe Characteristics

Standard shoes were especially manufactured in the Factory of Orthoses and Prostheses of the Faculty of Physical Therapy, Cairo University. Shoes were comfortable to wear and were designed to fit women in sizes ranging from size 37 to 41. There were shoes of three different heel heights (0cm (flat), 3cm, and 5cm) [13].All subjects were wearing socks and a 5-mm thick inner sole enabled half size adjustment if required. The principal investigator laced the shoes to verify with the subject that both the left and right shoe laces were secured with a similar level of tension [14].

Procedures

Initially, the purpose of the study and procedure of evaluation were explained to each participant. Each participant signed written approval consent.

Centering Steps

The aim of centering process is to position the COG over the point of the vertical group reaction force. Centering was achieved through the following steps:

Asking the subject to stand on both feet while grasping the handrail.The subject was then instructed to achieve a centered position on a slightly unstable platform by shifting her feet position until it is easy to keep the cursor (which represents the center of the platform) centered on the screen grid while standing in a comfortable, upright position. The subject‘s heel coordinates were measured from the center of the back of the heel, while her foot angle was determined by finding a parallel line on the platform to the center line of the foot**.** Once the participant was in a comfortable standing position, the foot placement of the participant subsequently remained constant throughout the test. After introducing feet angles and heels coordinates into the Biodex System the test began.This test was performed to test the subject’s ability to control the platform angle of tilt. All subjects were given an explanatory session before the evaluation procedure to be aware about the different test steps of Biodex System [15]. Each subject was asked to stand on the center of the locked platform of the BBS with two–leg stance wearing the shoes of 0cm heel height [13]. Support rails and biofeedback display were adjusted for each subject to ensure comfort and safety. The display was adjusted so that the subjects could look straight at it [16]. Test duration: all subjects were tested for 30 seconds [17].

As the platform advances to an unstable state, the subject was instructed to focus on the visual feedback screen directly in front of him (while standing with both arms at the side of the body without grasping hand rails) and attempt to maintain the cursor in the middle of the bull’s eye on the screen[12].At the end of each test a printout report was obtained. This report included information as regard to:

1. Overall dynamic stability Index: Represents the subject’s ability to control their balance in all directions. High values represent that subjects have difficulty.
2. Anterior / posterior stability Index: Represents the subject‘s ability to control their balance in front to back directions. High values represent that subjects have difficulty.
3. Medial / lateral stability Index: Represents the subject‘s ability to control their balance from side to side. High values represent that subjects have difficulty .Then the previous steps were repeated while wearing the shoes of 3 cm heel height and finally while wearing the shoes of 5 cm heel height .Between each footwear condition the subjects were seated, allowing them to rest to prevent fatigue and for the principal investigator to assist in fitting the next pair of shoes [13].

2.9 Statistical analysis

The SPSS (version 17; SPSS Inc., Chicago, Illinois, USA) statistical software package was used for statistical analyses. All data are expressed as mean and SD. The level of significance was set at *P* value less than 0.05. Data were first analyzed using the Kolmogorov-Smirnov test to identify anormal distribution. Two way analysis of variance (ANOVA) was used to assess dynamic postural balance before and after wearing shoesand to study significant difference within and between groups (A, B and C).

III. Results

A comparison of the demographic data of 60 participants in three groups revealed no significant differences between the three groups as regardsmean height, weight and body mass index (Table 1).But there wasstatistically significant difference (P<0.05) between groups A, B and C in mean subjects’ ages(Table 1).

Table (1): Demographic data of subjects in groups A, B and C.

Items	Age (year)	Body Weight (kg)	Height (cm)	BMI (kg/m^2)
Group A Mean ± SD	18.70 ±1.17	57.03 ±7.39	161.25 ±6.17	21.81 ±2.11
Group B Mean ± SD	25.25 ±4.63	59.80 ±6.68	161.07 ±5.65	23.07 ±1.77
Group C Mean ± SD	40.45 ±3.67	60.34 ±5.89	163.85 ±7.06	22.71 ±0.79
F-value	205.43	2.03	1.21	1.03
P-value	0.0001	0.073	0.306	0.245
Significance (P<0.05)	**S**	**NS**	**NS**	**NS**

SD: standard deviation Cm: centimeter BMI: body mass index P-value: probability value

S: significant Kg: kilogramNS: nonsignificant Kg/m²: kilogram per square meter

1. Overall Dynamic Stability Index at Different Shoe Heel Heights within Groups.

From table (2), there were no significant differences in dynamic balance (ODSI) among different shoe heel heights (0 (flat), 3 and 5 cm) within group (A,B and C) as P-value > 0.05.

Table (2): Overall dynamic stability index at different shoe heel heights within groups (A, B and C).

Items	Overall Dynamic Stability Index		
	Group A Mean ± SD	Group B Mean ± SD	Group C Mean ± SD
0 cm	1.32 ±0.55	1.46 ±0.51	2.27 ±0.83
3 cm	1.48 ±0.29	1.46 ±0.37	2.33 ±1.00
5 cm	1.42 ±0.33	1.37 ±0.26	2.07 ±0.63
F-value	0.733	0.300	0.534
P-value	0.485	0.742	0.589
Significance (P<0.05)	**NS**	**NS**	**NS**

SD: standard deviation Cm: centimeter P-value: probability value NS: nonsignificant

2- Overall Dynamic Stability Index at Different Shoe Heel Heights between Groups (A, B and C).

As observed in table (3) ,There was a significant difference in dynamic balance (ODSI, MLSI and APSI) between groups (A, B and C) at (0, 3 and 5 cm) shoe heel height as P-value< 0.05.

Table (3): Overall dynamic stability index at different shoe heel heights between groups (A, B and C).

Items	Overall Dynamic Stability Index		
	0 cm	3 cm	5 cm
Group A Mean ±SD	1.32 ±0.55	1.47 ±0.29	1.42 ±0.33
Group B Mean ±SD	1.46 ±0.51	1.46 ±0.37	1.37 ±0.26
Group C Mean ±SD	2.27 ±0.83	2.33 ±1.00	2.07 ±0.63
F-value	12.42	12.00	15.60
P-value	0.0001	0.0001	0.0001
Significance (P<0.05)	**S**	**S**	**S**

SD: standard deviation Cm: centimeter P-value: probability value S: significant

2. Anteroposterior stability index at Different Shoe Heel Heights within Groups.

As observed in table (4),there were no significant differences in dynamic balance (APSI) among different shoe heel heights (0 (flat), 3 and 5 cm) within group (A, B and C) as P-value > 0.05.

Table (4): Anterior / posterior stability index at different shoe heel heights within groups (A, B and C).

Items	Anterior / Posterior Stability Index		
	Group A Mean ±SD	Group B Mean ±SD	Group C Mean ±SD
0 cm	0.99 ±0.40	1.09 ±0.46	1.78 ±0.60
3 cm	1.13 ±0.40	1.18 ±0.45	1.73 ±0.71
5 cm	0.99 ±0.37	1.00 ±0.26	1.60 ±0.50
F-value	0.779	0.988	0.438
P-value	0.464	0.379	0.648
Significance (P<0.05)	**NS**	**NS**	**NS**

SD: standard diviation Cm: centimeter P-value: probability value NS: nonsignificant

5 - Anterior / Posterior Stability Index at Different Shoe Heel Heights between Groups (A, B and C).

As observed in table (5) ,There was a significant difference in dynamic balance (ODSI, MLSI and APSI) between groups (A, B and C) at (0, 3 and 5 cm) shoe heel height as P-value< 0.05.

Table (5): Anterior / posterior stability index at different shoe heel heights between groups (A, B and C)

Items	Anterior / Posterior Stability Index		
	0 cm	**3 cm**	**5 cm**
Group A Mean ±SD	0.99 ±0.40	1.13 ±0.40	0.99 ±0.37
Group B Mean ±SD	1.09 ±0.46	1.18 ±0.45	1.00 ±0.26
Group C Mean ±SD	1.78 ±0.60	1.73 ±0.71	1.60 ±0.50
F-value	14.75	7.62	15.67
P-value	0.0001	0.001	0.0001
Significance (P<0.05)	**S**	**S**	**S**

SD: standard diviation Cm: centimeter P-value: probability value S: significant

6- Medial / Lateral Stability Index at Different Shoe Heel Heights within Groups

As observed in table (6),there were no significant differences in dynamic balance (MLSI) among different shoe heel heights (0 (flat), 3 and 5 cm) within group (A,B and C) as P-value > 0.05.

Table (6): Medial / lateral stability index at different shoe heel heights within groups (A, B and C).

Items	Medial / Lateral Stability Index		
	Group A Mean ± SD	**Group B Mean ± SD**	**Group C Mean ± SD**
0 cm	1.07 ±0.41	1.10 ±0.42	1.61 ±0.67
3 cm	1.09 ±0.30	1.04 ±0.16	1.72 ±0.77
5 cm	1.11 ±0.34	1.07 ±0.28	1.47 ±0.51
F-value	0.064	0.183	0.717
P-value	0.939	0.833	0.492
Significance (P<0.05)	**NS**	**NS**	**NS**

SD: standard diviation Cm: centimeter P-value: probability value NS: nonsignificant

7- Medial / Lateral Stability Index at Different Shoe Heel Heights between Groups (A, B and C)

As observed in table (7) ,There was a significant difference in dynamic balance (ODSI, MLSI and APSI) between groups (A, B and C) at (0, 3 and 5 cm) shoe heel height as P-value< 0.05.

Table (7): Medial / lateral stability index at different shoe heel heights between groups (A, B and C).

Items	Medial / Lateral Stability Index		
	0 cm	**3 cm**	**5 cm**
Group A Mean ± SD	1.07 ±0.41	1.09 ±0.30	1.11 ±0.34
Group B Mean ± SD	1.10 ±0.42	1.04 ±0.16	1.07 ±0.28
Group C Mean ± SD	1.61 ±0.67	1.72 ±0.77	1.47 ±0.51
F-value	6.88	11.78	6.07
P-value	0.002	0.0001	0.004
Significance (P<0.05)	**S**	**S**	**S**

SD: standard diviation Cm: centimeter P-value: probability value S: significant

IV. Discussion

Our clinical study was carried out to determine the effect of different shoe heel heights on dynamic balance in different age groups of females.

Findings of this study indicated that, there was no significant difference in ODSI, APSI and MLSI of dynamic balance at different shoe heel height within groups (A, B and C) as P-value was > 0.05.

In an attempt to explain the previous results, Cowley and his colleagues [18]reported that the design of HHS is highly variable, ranging from platform to stiletto or tapered heel. It was demonstrated that postural stability in wearers of HHS is improved by increasing the area of the base of the heel. And they indicated that to improve stability of the high-heel wearer, the center of the heel should be medial, by 2 to 4 mm, to the midline of the shoe. Moreover they demonstrated that stance phase time in high-heeled gait increased when compared to low-heeled gait. Furthermore, the subjects in high-heels walked more slowly, had shorter strides and longer stance time than when in low heels, while cadence remained unchanged**.**

Furthermore, these findings were consistent with Lindemann and his colleagues [5]who indicated that there seems to be a range of acceptable footwear regarding static and dynamic balance as long as the heel height is below a critical value. A heel height of up to a critical height seems to be not sufficient for producing balance hazards.

Another study stated that heel elevation induces more effort from lower limb muscles but results in worse human balance regardless of the wearing experience, especially starting at 7cm heel height. Calf muscles play primary roles and the vastuslateralis and tibialis anterior muscles play secondary roles in maintaining standing balance when wearing HHS. Experienced wearers do not show significantly better overall balance performances, even though they have better excursions and directional control in the forward and back directions [1,19].

Also, results of the current work disagreed with Menant and his colleagues [14] who stated that a shoe with an elevated heel of medium height (4.5 cm) significantly increased postural sway and impaired overall performance in tests of balance when compared to a standard shoe. Several mechanisms are postulated to explain the detrimental effect of elevated heel on balance. Firstly, heel elevation shifts the total body center of mass anteriorly, modifying posture and plantar pressure distribution. In addition, shoes with higher heel may lead to lateral instability as they present a smaller critical tipping angle compared to lower heel shoes.

Also, in contrast to our results,Hapsarietal.[1]Found that the increased heel height shifted the force and peak pressure from the rear foot and mid foot regions to the forefoot (including toes) region, and the COP location moved forward and to the medial side of the foot. Human stability limits were worsened significantly, especially when the heel height reached 7cm. The contrast may be due to the shoe design used in the present study which was with wide BOS and not beveled heels, so this design could produce less balance hazards, while Hapsari and his colleagues used women's dress shoes with stiletto heel that has smaller BOS and greater bevel angle that could cause greater balance challenge.

Findings of this study indicated that, there was a significant difference in ODSI, APSI and MLSI of dynamic balance at different shoe heel height between groups (A, B and C) as P-value was < 0.05. Results also revealed significant reduction in dynamic balance (ODSI, APSI and MLSI) in group (C) more than group (A and B).

The results of the current study come in agreement with Tencer and his colleagues [20] who conducted a 2-year prospective investigation of falls in which they matched older people who fell (n = 327) with people with similar demographics who did not fall. The researchers found that 61% of the falls occurred outdoors and that shoes with heels greater than 2.5 cm increased the risk 77 of falls compared with athletic or canvas shoes. They also noted that heel elevation is associated with an increased risk of falling in older people.

Normal ageing is associated with decreased ability to maintain postural stability in standing and when responding to unexpected perturbations [21].Age and sex interactions appear to lead to different trunk and pelvis kinematics during gait. When wearing shoes with high heels, older women show a flattened lumbar lordosis while younger women display increased trunk lordosis [14].

Also, several studies have reported significant increases in forefoot loading during high-heeled gait, with especially greater pressures in the medial forefoot. Such increased pressures might contribute to the development of plantar calluses. In fact, these foot problems have been associated with wearing shoes with heels higher than 2.5 cm in older women [22, 23, 24].

In terms of the risks accompanying improper balance control,Baloh et al. [25] stated that age-related changes in the somatosensory system reflect a drop in the proprioceptive function with aging, a reduced vibration sense at the ankles and changes in joint sensation. Aging is often accompanied by balance disorders or age-related pathologies. Since small balance impairment is a consequence of natural aging process, several authors showed that body sway increases with age [26].

However, depending on the type and characteristics ofthe high-heeled shoes there can be a sum of factors that maycontribute to the biomechanical imbalance of the ankle andpredispose to compensatory postural dysfunctions.Some studies categorized the size of the heels as low, medium, or high without reference of the measurement considered. Another difficulty in assessing heel height was that there is no consensus in the literature regarding the size of the heels, frequency of use, and minimum time of use that can lead to postural changes and musculoskeletal disorders. Thus, further research should be conducted, because knowledge of the effect of the use of high-heeled shoes on dynamic balance becomes imperative for professionals in order to identify early disturbances caused by this habit and to help in the prevention and guidance on the most appropriate treatment. Furthermore, it allows the guidance in changing behavior and making the correct and safest choice in relation to the type of footwear suitable for this population [11,27].

Study Recommendations

Further research should be carried out with a larger sample size, using shoes with higher heel heights at a different level of stability rather than level 8 to achieve better understanding of effect of different shoe heel heights on dynamic balancein different age groups of females.

V. Conclusion

According to the findings of this study, it was concluded that there was no significant effect of different shoe heel heights (0 (flat), 3 and 5 cm)on dynamic balance at stability level 8, while there was a significant effect of age on dynamic balance at different shoe heel heights (0 (flat), 3 and 5 cm). These effects should be considered when clinicians manage young and middle-aged females and should give care to the dynamic balancein order to identify early disturbances caused by this habit and to help in the prevention of complications for these subjects with regard to balance disturbance.

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