SCIENTIFIC ARTICLE

Effect of Pregnancy and Obesity on Arch of Foot

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Objective: Endocrine changes occurring during pregnancy result in increased laxity of the ligaments of the foot. This may lead to gradual collapse of the foot arches. The aim of the study was to determine whether pregnancy and body mass index (BMI) had a role in affecting the foot arches at long term.

Methods: A collapsed arch results in widening of the feet, thus altering the foot size. The control group included nulliparous women, while the study group included women who had been pregnant at least once. The groups were stratified secondarily by obesity according to BMI. We reviewed over 1000 charts at the outpatient offices in a large Mid-Western city. The age, BMI, and shoe size in an athletic shoe were recorded.

Results: There were 40 subjects in the control group and 70 in the study group. 19/40 women in control and 46/70 in study group experienced a change in shoe size ($P = 0.06$). Of those affected, the non-obese control group experienced a 9.7% change in shoe size while the obese study group experienced a 15.5% change ($P < 0.05$).

Conclusion: There was neither a change in size between women who had been pregnant and the nulliparous, nor was there a difference between the obese and non-obese. However, there was a statically significant difference between those affected who were both non-obese and nulliparous and those who had been pregnant and who are obese. Individually, the effect of pregnancy and BMI are highly suggestive and clinically relevant.

Key words: Body mass index; Foot; Obesity; Pregnancy

Introduction

Pregnancy's effect on shoe size is a common topic of hearsay and anecdotes. However, to our knowledge there is no peer-reviewed study to date that has investigated the effect of pregnancy on a woman's arch. Arch collapse leads to valgus deformity and arthritic degeneration, which may predispose the patient to a number of surgeries including total ankle arthroplasty^{1,2}.

In the senior author's practice, the incidence of arch collapse is 9:1 among female to males. It is hypothesized that pregnancy plays an important role in this finding. Other research regarding women's shoe size centers around the size of her shoe as a predictor for birth weight, mode of delivery, and obstetrical pelvis diameter^{1,3,4}. It is known that arch collapse predisposes a patient to flat foot⁵. Hormonal changes in women may lead to loosening ligaments, and have been sug-

gested to cause an increase in ligamentous tears in female athletes of reproductive age^{6,7}. The increase in specific hormone levels, including Relxain, Progesterone, and Estradiol, which contribute to general ligamentous laxity, may also contribute to arch collapse during pregnancy^{8,9}. It is well known that pregnant and nulliparous women are exposed to different concentrations of hormones, as age, age at menarche, and age at first live birth are used in the GAIL breast cancer calculation¹⁰.

Jelen *et al.*¹¹ investigated change in the fall in arch as a result of pregnancy using a three-dimensional computer aided biomechanical study. The study measured the arch at the beginning of pregnancy, the end of pregnancy, and the end of puerperium. Results varied and were not significant, as the study only examined four individuals without a control. Alvarez *et al.*¹² ran a small cohort of pregnant women

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TABLE 1 Demographical comparison between the control group and study group

Item	Control (n = 40)	Study (n = 70)	P-value
Age	50.6 ± 1.0	54.6 ± 0.8	0.003
Hours on feet/day	7.1 ± 0.5	7.2 ± 0.4	0.94
Height (m)	1.67 ± 0.01	1.65 ± 0.8	0.23
Weight (kg)	86.4 ± 3.7	80.9 ± 2.3	0.19
Body mass index	30.8 ± 1.3	29.5 ± 0.8	0.37

measuring their feet at around 13 weeks, 35 weeks, and at 8 weeks after giving birth while a control of women who had never given birth were also measured twice. While changes in height and width were not significant, the volume of the feet increased significantly, 57.2 mm during pregnancy, and decreased only 8.42 mm after pregnancy. Alvarez *et al.* postulated that the increase in foot volume accounted for the complaints of shoes on account of pregnancy; however, actual shoe size was not recorded¹².

Further, obesity has also been shown to collapse the arch^{11,12}. In fact even in young children, obesity has been shown to cause flat feet^{13,14}. The primary objective of this study is to examine, in a retrospective case controlled study, if women's arch collapses as a result of pregnancy or obesity, over time, while controlling for age, endocrinological, metabolic, and other co-morbidities.

Materials and Methods

To assess the collapse the arch of the foot, a woman's change in shoe size over time will be used as the primary outcome variable. The size of a woman's shoe was recorded before first pregnancy, just after first pregnancy, just after last pregnancy, and current shoe size (at least 10 years since last pregnancy). In addition to shoe size in an athletic shoe, BMI and co-morbidities were recorded.

Criteria for inclusion consisted of women between 40 and 60 years old, who had given birth at least 10 years ago in the study group and women between 40 and 60 years old who had never given birth in the control group. While the criteria for exclusion were could not remember shoe size, diseases of lower extremities, hormonal disorders, neuropathy, type I diabetes, abortion, surgery on feet, flatfoot, postural edema, chronic swelling, and pregnancy within the last 10 years.

In the study pool, the size of a woman's shoe was recorded as aforementioned. While in the control pool, the size of a woman's shoe was recorded at the current size as well as their size at 18 years of age. To obtain this data the first author contacted the pool of subjects on the telephone. The subject, to the best of her memory, reported the size of their shoe at the specified intervals. The subject pool in both groups was drawn from an approved orthopedic practice at Spectrum Health. Any subject in the pool who presented with one of the exclusion criteria was not included in the study.

An alpha of 0.05 and a beta of 0.20 was implemented. As such at minimum, a sample size of 40 women in each group was necessary to determine if there was any change in shoe size between control and study, as the data were nominal. A *t*-test was used in all data except the nominal data, in which a χ^2 test was used.

Results

The average age between control (50.6 ± 1.0) and study (54.6 ± 0.8) ($P = 0.003$) was the only significant demographical difference between the two groups. Neither hours on feet per day (control 7.1 ± 0.5, study 7.2 ± 0.4; $P = 0.94$), height (control 1.67 ± 0.01 m, study 1.65 ± 0.8, $P = 0.23$), weight (control 86.4 ± 3.7 kg, study 80.9 ± 2.3; $P = 0.19$), nor BMI (control 30.8 ± 1.3, study 29.5 ± 0.8; $P = 0.37$) were statistically significant (Table 1). BMI was then stratified between non-obese (BMI < 30) and obese groups (BMI ≥ 30). There were 24 non-obese patients in the control group and 41 non-obese in the study group ($P = 0.5$). There were 16 obese patients in the control and 29 in the study group ($P = 0.45$).

In the control group 19/40 (47.5%) had a size change while 21/40 (52.5%) experienced no change in size, while in the study group 46/70 (65.7%) had a size change and 24/70 (34.3%) experienced no change in size ($P = 0.06$) (Fig. 1a). Assessing the amount of change of those affected, the control

Fig. 1 Graph showing the different composition and the percent change. (a) The number of women who experienced a shoe size change was compared between control and study groups. (b) Of the women who experienced a change in size in each of these groups, the percent change over time was calculated.

Fig. 2 Graph showing the different composition and the percent change. (a) The number of women who experienced a shoe size change was compared between non-obese (body mass index [BMI] < 30) and obese (BMI ≥ 30). (b) Of the women who experienced a shoe size change in each of these groups, the percent change over time was calculated.

group experienced an 11.2% increase ($n = 19$, ± 1.9) while the study group experienced a 13.2% increase ($n = 46$, ± 8.1) ($P = 0.14$) (Fig. 1b).

Of the non-obese group 35/65 (53.8%) experienced a change in size, while 30/45 (66.7%) experienced a change in size in the obese group ($P = 0.18$) (Fig. 2a). Of those affected the average size change in the non-obese was 10.7% ($n = 35$, ± 4.1) while the average change in size was 14.9% ($n = 30$, ± 10.7) ($P = 0.52$) (Fig. 2b).

Those affected by a change in size were then stratified according to both pregnancy and obesity. The control non-obese group experienced a 9.7% change in shoe size ($n = 11$, ± 1.1), the study non-obese experienced a 11.1% increase in size ($n = 24$, ± 0.9), the control obese group experienced a 13.2% change in size ($n = 8$, ± 4.2), and finally the study obese group experienced a 15.5% in size ($n = 22$, ± 2.2) ($P = 0.08$). (Fig. 3a). The difference between control non-obese (9.7%) and study obese (15.5%) was statistically significant ($P < 0.05$) (Fig. 3b).

Discussion

We sought to determine if pregnancy and obesity affects arch collapse. To do this, we examined the change in shoe size over time between nulliparous and women who had been pregnant as well as obese and non-obese women. With

the exception of age, there was no statistically significant difference in any of these groups (Table 1). While the nulliparous control was significantly younger than their pregnant counterparts (control 50.6 ± 1.0 versus study 54.6 ± 0.8 ; $P = 0.003$) this is not likely clinically significant.

Neither the difference in number of women with a size change nor the percent change between the nulliparous and control groups were statistically significant (Fig. 2). While only 47.5% of the nulliparous women experienced a change in shoe size, almost 66% of the women who had been pregnant experienced a change in shoe size ($P = 0.06$). This value, while not statistically significant, is certainly clinically relevant. It may likely prove statistically significant in a larger sample size. The control group consisted of 40 women, while the study group had 70 women. While these numbers provided sufficient power, a better populated study would likely reveal the clinically apparent collapse of arch in women who have given birth.

About half of all women will experience a change in shoe size. Almost 48% of nulliparous women have experienced an increase in shoe size and 54% of non-obese women had a size increase. Thus arch collapse may also be secondary to age. In fact, of women affected with a shoe size change between nulliparous and pregnant, the percent increase was not significant

Fig. 3 Graph showing the percent change in different groups. (a) Of the women that had a change in shoe size, dual stratification between control and study groups and obese and non-obese groups. (b) Comparison between nulliparous non-obese and pregnant obese patients proves statistically significant in the percentage of shoe size increase.

(control 11.2% and study 13.2%, $P = 0.14$) (Fig. 1b). In addition, although the pregnant group may have experienced a higher concentration of hormones in their lifetime, the control group would have also experienced significant exposure to these hormones, and thus these groups may have a similar risk for developing arch collapse over time. However, determining the arch collapse at each year would prove exceptionally difficult. Data would be subjectively unreliable and logistically impossible objectively.

As with the pregnancy stratification, obesity was not shown to be independently significant for arch collapse. Of the non-obese women 53.8% experienced a change in shoe size, while nearly 67% of the obese women had an increase in size ($P = 0.18$). Of those affected with a change in size, the non-obese experienced a 10.7% increase, while the obese experienced almost a 15% increase ($P = 0.52$). Although obesity was not shown to be an independent cause of arch collapse, these data are clinically relevant and possibly statistically significant in a more powerful study.

Combined pregnancy and obesity were shown to be statistically significant. While only 9.7% of nulliparous non-obese women experienced a change in size, 15.5% of obese women who had been pregnant had a change in size ($P < 0.05$).

This study had a few limitations, the most notable of which is the patient recall bias. The telephone survey required that women were able to remember their shoe sizes over 20 years ago. Although it would be difficult to obtain this data in another matter, the shoe sizes were reported subjective to the patient's memory. Also, obesity was determined by current BMI. However, this does not necessarily reflect a lifetime expo-

sure to obesity. In general, weight bearing X-ray films would be an ideal outcome variable in lieu of the shoe size, this would prove impossible to prospectively follow a group of both nulliparous and women who have given birth over decades.

We asked women the size of their athletic shoe; however, neither the width nor volume was recorded here, which may vary. An increase in width may potentially affect the size of shoe over time, but more likely would be secondary to temporary edematous changes during pregnancy. Alvarez *et al.*¹² documented an increase in volume during pregnancy but a subsequent decrease in the weeks following pregnancy. We also did not account for the number of pregnancies a woman had as long as she carried one child to term. It is possible that a woman having had multiple pregnancies would have a greater exposure to ligament-loosening hormones. It is conceivable that women having more pregnancies would have more exposure to such hormones, which may lead to greater changes in arch collapse and BMI; however, our study would not have been close to the power for such analysis.

Despite these limitations, short of embarking on an expensive prospective study over decades, this retrospective case controlled study using shoe size as the primary outcome variable is a novel approach to a common clinical problem. Here we demonstrated that the combination of pregnancy and obesity collapses the arch of the foot over time. These two factors may be independently affecting the arch; however, this could not be proven given the power of this study. Obese women who have been pregnant should be counseled regarding the possibility of a collapsed arch, potential arthritic degeneration, and the subsequent surgical implications.

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