**Effect of Heeled Shoes on Joint Symptoms and Knee Osteoarthritis (OA) in Older Adults: a 5-year follow-up study**

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**Conflicts of Interest**: We declare that there are no conflicts of interest.

**Abstract**

**Objective:**

Our aims were to examine the effects of heeled shoes on incident knee OA and joint pain.

**Methods:**

We used longitudinal data from the Chingford 1000 Women Study (Chingford Study); a prospective cohort of women aged ≥50 years. Participants with musculoskeletal disorders and/or a history of knee-related injury/surgery were excluded. Participants were followed for up to 5-years for incident outcomes including; i) radiographic knee OA (RKOA) and ii) joint pain (feet, knees, hips and back). Footwear data including ever worn heels ≥2 inches and, daytime/evening hours (per week) spent wearing heeled shoes over five-decades (ages <20, 20-30, 30-40, >50 years) were available at Year 10 whilst knee radiographs and joint symptom data were also collected at Year 15. Cumulative time spent wearing heeled shoes was calculated for women reporting ever use of heeled shoes (≥2 inches). Multiple logistic regression was used to examine the relationship between exposures and outcomes (from years 10 to 15).

**Results:**

356 women were eligible at Year 10 with the median (IQR) age 60 (56 to 65) years. Compared to non-use, ever use of heeled shoes (≥2 inches) was not associated with incident RKOA (1.35, 95% CI 0.56 to 3.27). No association was observed between increasing cumulative time spent wearing heels and incident outcomes.

**Conclusion:**

Compared to the non-use of heeled shoes, ever use of heels (≥2 inches) was not associated with incident RKOA and incident joint symptoms, respectively. Further, increasing cumulative time spent wearing heels was not associated with any of our outcomes.

**Keywords:** osteoarthritis, pain, joint, heeled-shoes, incidence.

**Significance and Innovations**

* No association was observed between two heel-related exposures, ever use (yes/no) of heeled shoes (≥2 inches) and cumulative time spent wearing heeled shoes, and incident radiographic knee osteoarthritis (OA).
* No relationship was observed between heel-related exposures and incident knee, hip and foot pain, respectively. It is unlikely that ever use of heeled shoes is associated with incident back pain.
* Further studies are required to examine the involvement and effect of heeled shoes on the ankle joint.

**Introduction**

The effect of footwear as a modifiable factor for the prevention of joint symptoms and knee osteoarthritis (OA) appears to be important, however, there is insufficient and often conflicting evidence regarding its efficacy(1, 2). As part of routine clinical care, health professionals often attempt to modify footwear habits either as a primary intervention for lower-limb (e.g., feet, ankle) symptoms or a preventative measure in the development of lower-limb OA. Treatment recommendations for the non-surgical management for knee OA are, however, not consistent with some(3, 4), but not all(5), recommending ‘modified shoes’ as either part of core treatment or as an intervention further along the treatment algorithm.

As well as being a potentially important intervention strategy, footwear is often implicated in joint pathology. Abnormal knee loading has been associated with increased risk of knee OA(6), knee torque(7) and foot position and motion have been associated with knee load(8-10); footwear has significant effects on biomechanics(11). With a specific focus on heeled shoes, the wearing of heels can increase muscle activity(12) and increase knee flexion, plantar flexion, anterior pelvic tilt, and trunk extension(13). Together, these changes in kinematics can lead to adverse repetitive, dynamic loading leading to joint pain/OA in the lower and upper-limbs. These affects can be seen most prominently in the elderly, with footwear linked to the development of OA within the foot(14), knee(10, 15) and hip(16). In particular, older women are identified as often wearing incorrect fitting footwear and wearing of heels higher than 25mm that are associated with foot pathology(17), increased risk of falling(18) impairment in standing and leaning balance(19) and alterations in lower limb and back muscle activation(20).

Due to the relationship between footwear and joint pathology, footwear and heel height has been the subject of several investigations in relation to foot pain, with little attention on other joint sites, yet the evidence remains inconclusive. For instance, in a Brazilian-based study, 50% of women reported foot pain, but this was not associated with current high heeled shoe use(21). Previously in the UK, Dawson *et al*(14) reported that the prevalence of foot problems was 83% in a sample of 127 older women (aged 50-70) who had worn shoes with 1-inch heels regularly at some time. A surprising finding was that a number of foot problems were associated with wearing lower than average heels which challenges the belief that wearing high-heels is detrimental to foot health(14). Interestingly, whilst Dawson *et al*(14) reported that most older women had been exposed to high-heel shoes over many years, data from 3,378 members of the Framingham study, suggest that women who regularly wore high-heels in their past were more likely to experience foot pain in their later years(22). Additional studies are required, including the hip(23), to examine the effects of heeled shoes on incident joint symptoms not only of the feet but on other biomechanically involved sites.

There is now opportunity to retrospectively examine the associations between wearing heeled shoes, joint pain, and OA using data from the Chingford Study. It is anticipated that this may lead to greater understanding of this relationship when considering strategies to prevent joint pain in rheumatology-related foot health. Our aim was, therefore, to examine the effect of ever use of shoes with heels ≥2 inches and, in those with positive responses, to examine the effect of life-time cumulative wear on incident RKOA and incident joint pain in women aged ≥ 50 years using data from the Chingford Study.

**Methods & Materials**

**Study Sample**

This study was conducted retrospectively using data from the Chingford 1000 Women Study (Chingford Study); a prospective, population-based longitudinal cohort of 1003 women aged 45-64 years (mean: 54.2 years)(24). The women have been assessed annually and are representative of women from the UK population in terms of demographic characteristics(25).

For the current study, we used data acquired at Year 10 (9-years follow-up) and Year 15 (14-years follow-up). Participants were eligible for the primary analysis (i.e. incident RKOA) if they had no evidence of RKOA (Kellgren and Lawrence(26) (KL) grade ≥2) in both knees, were free of other musculoskeletal disease (i.e. rheumatoid arthritis) and had no history of knee injury requiring 1 weeks rest at Year 10. Further, participants with evidence of knee replacement at Year 10 and those who had a knee replacement during follow-up were excluded. For the incident joint symptoms analysis, participants were eligible if they had no joint pain at the respective site, were free of musculoskeletal disease (i.e. rheumatoid arthritis) and had no history of fracture at the respective site in the last 12 months. Knee-related fractures included fractures at the femur, tibia, fibular, foot-related fractures included fractures at the toe, metatarsal, and metatarsophalangeal (MTP) and back-related fractures included fractures at the vertebrae, ribs and clavicle. There were no reports of hip-related fractures in our study sample.

Weight-bearing anteroposterior (AP) view radiographs of the knee (left/right) for all participants were acquired at Years 10 and 15. Knee radiographs were graded on a 0-4 scale, across the whole knee joint, KL criteria(26). Radiographic OA of the whole knee OA was defined as a KL score of ≥2 (at a person-level).

At Year 10 and Year 15, participants were asked joint-specific, and where appropriate side-specific (left/right), joint pain questions for the knees, hips and feet, respectively. In addition, symptom questions for the back, comprising upper and lower regions, were also asked. Joint symptoms were assessed using the National Health and Nutrition Examination Survey (NHANES)(27). Specifically, participants were asked to report “any episodes of pain in past year?”. Women who responded positively to this question were asked to report the number of “days with pain in the last month?” with categories including i) 0, ii) 1-5, iii) 6-14 and iv) >15 days. Participants were classified at Year 10 as having current joint pain if the duration of pain was more than 15 days in the past month. Women reporting a value for days of pain in the past month though had a missing or zero entry for ‘any episodes of pain in past year’ were also included in analysis; there were few occurrences of this scenario. Pain for most days in the previous month has been shown to be the most appropriate outcome/exposure for the investigation of symptom development in OA research(28).

**Predictor variable**

At Year 10, all women were asked to complete a nurse-administered standardised questionnaire which included questions related to footwear. Specifically, participants were asked: “Ever worn shoes with heels 2 inches high or more?”. Women who responded positively to this question where then asked to complete the following questions: i) “Heel height worn?” (continuous), ii) “Number of daytime hours per week of wearing?” and iii) “Number of evening hours per week of wearing?” for each of the following age groups; <20 years, 20-30 years, 30-40 years, 40-50 years and >50 years. Women who had a negative response to ‘Ever use’ were not required to complete these fields. Women who reported positively to ‘ever worn shoes with heels 2 inches high or more’ and had a missing value for ‘heel height worn’ for a given decade, their missing responses for daytime and evening wear were assumed to be missing due to non-use in the given decade. All women who had a positive entry for ‘ever use’ and had missing entries for heel height at a given decade also had missing data on daytime and evening wear. We calculated the cumulative time spent wearing heeled shoes through summing daytime and evening hours across the five decades. Our two exposures included: i) ever worn heels ≥2 inches (yes/no) and in participants having worn heels, ii) cumulative time spent wearing heels across 5 decades.

**Outcome variables**

**Incident RKOA**

In those with no evidence of RKOA at baseline (Year 10) (KL<2 in both knees), incident RKOA was defined as the occurrence of KL≥2 in either/both knees during follow-up.

**Incident Joint Symptoms**

Incident joint symptoms were assessed for the knees, feet and hips and, the back respectively. In participants with no evidence of joint pain at the site investigated at Year 10, incident joint symptoms were defined as the occurrence of pain at follow-up (Year 15) (person-level). Participants were classified as having ‘current pain’ if they reported pain for most days in the previous month; in accordance with previous guidelines(28).

**Statistical analysis**

Descriptive statistics were tabulated with normally distributed variables presented as means and standard deviation (SD), and non-normally distributed variables presented as medians and interquartile range (IQR). Categorical variables were presented as counts and percentages. Data were analysed using STATA (version 15.1, StataCorp., College Station, TX, USA). To examine the relationship between our two heel-related exposures (i.e., ever use (yes/no) and, cumulative time spent wearing heels (continuous)) and incident outcomes, we used logistic regression modelling with: (i) incident RKOA; (ii) incident joint symptoms, (i.e., knee, foot, hip and back) as the respective outcomes. Results were presented as odds ratios (OR) with 95% confidence intervals (CIs) for crude and adjusted models. We simultaneously controlled for potential confounders using multiple logistic regression. Cumulative time spent wearing heels (hours) across five decades was categorised into quartiles due to the suspected non-linear effects on the outcomes.

 **Assessment of Covariates**

Covariates that were adjusted for included age and body mass index (BMI) calculated as (weight (kg) / height (m2)); as measured at Year 10. Additional covariates included previous occupation measured at Year 1; participants were asked to report their previous occupational job category (e.g., farming, sales) (see Supplementary 1). Categories were assigned to levels of workload (sedentary, light, light manual and heavy manual) in accordance with published methods(29). For the incident joint symptoms analyses, we further adjusted for baseline RKOA severity (i.e. KL score, left and right knees) and knee symptom status (person-level) as there is evidence to suggest that knee pain increases the risk of developing pain at sites outside the knee(30). We did not adjust for previous injury as this is likely on the causal pathway.

**Results**

Of 1003 study participants, 356 women were eligible and had heel-related footwear data at Year 10; see Figure 1.

**\*\*INSERT FIGURE 1 \*\***

Characteristics of the eligible study sample for the primary analysis, incident RKOA, are shown in Table 1. The median age was 60 years (range: 56 to 65) and BMI (mean, SD) was 25.8 (3.9). A total of 306 (86.0 %) women had positive responses to ever worn shoes with heels ≥2 inches and, of the sites assessed, back pain was most common occurring in 18.0% of participants. Of the 306 women reporting having ever worn heels ≥2 inches, 101 (33.0%) reported wearing heels across all 5 decades whilst 28 (9.2%) women reported wearing heels for one decade only. Further, the most worn heel type worn between the ages <20 to 30 years was stiletto and between the ages of 30 to >50 years, a court shoe.

A single study participant reported ‘no’ to having ever worn heeled shoes (≥2 inches) though had data on heel height, and daytime/evening wear across the decades and was subsequently included in all analyses. Further, an additional two participants had data on daytime/evening wear though had missing data for heel height at a particular decade; these participants were also included in all analyses. Further, in the fifth decade (>50 yrs), one participant reported heel height as ‘2-4’ on a continuous scale (inches) and so was relabelled as 3 inches. All study participants with positive responses to having ever worn heeled shoes (≥2 inches) reported at least 1 hour a week of wearing time during at least one of the five decades.

**\*\*INSERT TABLE 1\*\***

In participants with no evidence of RKOA, women reporting ever use of heeled shoes (≥2 inches) was not statistically significantly associated with incident knee OA compared to non-use in multivariate analysis (1.35, 95% CI 0.56 to 3.27); see Table 2. In women reporting ever use of heeled shoes, increasing cumulative time spent wearing heels was not statistically significantly associated with incident RKOA in multivariate analysis.

**\*\*INSERT TABLE 2\*\***

Compared to women reporting non-use of shoes with heels ≥2 inches, ever was not associated with incident knee pain (0.96, 95% CI 0.49 to 1.92), foot pain (0.80, 95% CI 0.37 to 1.73) and hip pain (1.61, 95% CI 0.64 to 4.05), respectively; see Table 3. However, in multivariate analysis, the relationship between ever use of shoes with heels ≥2 inches and incident back pain was of borderline statistical significance, in a protective direction, based on conventional standards (0.49, 95% CI 0.24 to 1.00).

**\*\*INSERT TABLE 3\*\***

Similarly to the univariate analysis, after adjusting for age, BMI, previous occupation and RKOA severity, there was no statistically significant association between cumulative time spent wearing heels and incident knee pain; see Table 4. Specifically, compared to the lowest quartile, no association was observed for the second (0.61, 95% CI 0.26 to 1.48), third (0.96, 95% CI 0.41 to 2.25) and fourth quartile (0.41, 95% CI 0.16 to 1.04). Similarly, no associations were observed between increasing quartiles and incident foot, hip and back pain respectively.

**\*\*INSERT TABLE 4\*\***

**Discussion**

We examined whether ever use of shoes with heels ≥2 inches and, cumulative time spent wearing heeled shoes, were associated with incident RKOA and joint symptoms, respectively. No relationship was observed between both of our heel exposures and incident RKOA and, incident knee, hip and foot pain, respectively. A statistically significant negative relationship was observed between ever use ofshoes with heels ≥2 and incident back pain though this was likely a consequence of un-measured, residual confounding and type 1 error.

Wearing of high-heeled shoes has been shown to increase forces across the patellofemoral joint, lead to greater compressive force at the medial compartment and increase knee flexion and varus moments(10, 31) which may predispose to later degenerative joint changes. However, there are few data describing the relationship between high-heels and knee OA and, previous studies investigating the effects of high-heels on risk of knee OA have revealed varying results(2, 31-34). Consequently, the clinical message regarding the use of such footwear is unclear. Typically, lower extremity muscle strengthening is recommended to help decrease knee loading in high-heel users.

In a recent systematic review and meta-analysis, Nguyen *et al*. reported that of 203 participants across 14 studies, high-heels were associated with increased knee flexion moment, flexion angle and varus moment thus the authors concluded that high heels likely increase susceptibility to knee OA(31). This review, however, highlights a need for prospective evaluation and the use of large, observational data to examine this relationship. In a separate case-control study, McWilliams *et al*. reported that the persistent wear of high heeled shoes between the ages of 21-50 years was associated with a decreased risk of knee OA in univariate analysis (OR: 0.55, 95% CI 0.33 to 0.90) though after adjustment for age, BMI, occupation and previous injury, no association was observed(35). Our study goes beyond this to examine the relationship between two heel-related exposures (i.e., ever worn (yes/no) and cumulative time spent wearing heels) and incident knee OA using a large, prospective dataset.

After adjustment for potential confounders, no association between ever use of shoes with heels ≥2 inches and cumulative time spent wearing heeled shoes, and incident knee OA was observed. This is agreement with previous data. For instance, Dawson *et al* reported, using a case-control design of 111 women waiting for knee replacement, that the ever use of high heeled shoes (2-3 inches) were associated with reduced risk of symptomatic knee OA, although none of these findings were statistically significant(32). Similarly, in a separate case-control study, McWilliams *et al* reported that persistent users of heels during early adulthood was not associated with risk of knee OA though in univariate analysis, the findings pointed towards a negative association between persistent users of high/narrow womens’ heels and lower-limb OA(33). A possible explanation for a negative relationship between regular use of heeled shoes and risk of knee OA could be that these women are from a reduced risk group; i.e., have a lower BMI and/or are exposed to fewer occupational risk factors (e.g., lifting/carrying goods).

In the current study, we observed a statistically significant negative association between ever use of shoes with heels ≥2 and incident back pain after adjustment for participant demographics and other structural/symptom endpoints. The extent to which a participants’ posture and spinal position is modified by shoes with heels during dynamic activities is highly contested. There is evidence to suggest that lumbar lordosis, an exaggerated inward curve of the spine, is associated with lower back pain(36) and shoe heels may(37) or may not(38, 39) decrease lumbar lordosis. Further, there is conflicting evidence on whether shoe heels affect pelvis and trunk movement during gait within different female populations(40-42). Although there is acknowledgement that compensation occurs during gait, this is unique for each individual when wearing heels at different heights(40, 42) and whether this places a person at higher risk of developing future complications is unknown. Couple this with the natural ageing process, where it is known that balance declines and changes in gait occur that can affect a person's stability, muscular strength and functional mobility(43) it would be hard to determine from this data set alone the true association of heel height and back pain. Back pain encompasses physical, emotional, and psychological risk factors(44, 45). In our analysis we undertook several comparisons, and it is possible this observed finding may be due to type 1 error. When examining the relationship between cumulative time spent wearing heels and incident back pain, no relationship was observed (see Table 4). Given that no such association was observed when using the more sensitive exposure of cumulative time spent wearing heels, we are confident that the use of heeled shoes (≥2 inches) is unlikely to be associated with incident back pain. Further studies are, however, needed to confirm these findings.

There are many strengths to this study. We utilised data from a large, observational dataset of women that had well-characterised data on footwear. To our knowledge, this is the first study to examine the effect of two heel-related exposures on incident RKOA and incident joint pain.

There are several potential limitations to this study. Firstly, we were unable to examine the presence of hip, foot or spinal OA at Year 10 as x-rays for such joints/regions were not acquired as part of the study protocol. Subsequently, when examining the relationship between heel exposures and incident joint pain, we were unable to control for OA status; except for RKOA status. An additional limitation was that we were unable to account of heel wear during the ages of 50 to ≥60 years. Median age at Year 10 was 60 years (range: 56 to 65), and we had data for ages 20 to >50 years. Subsequently, we were unable to account for possible heel use during the early years of study participation in the Chingford Study. This, however, is unlikely to affect our findings as the average time spent wearing heels decreased with age. More so, we were unable to assess the validity of the shoe-related predictors. It is likely that our findings were subject to recall bias, as the exposures were recalled over 5 decades. Further work is required to confirm our findings. In addition, future studies should aim to examine the relationship between changes in footwear and risk of knee OA and joint symptom development. Whilst we adjusted for previous occupational status, there is likely to be residual confounding as age at start of occupation and occupational duration were not reported. Therefore, we cannot confirm whether adjustment for previous occupational status overlapped with the decades of 20 to >50 years. Also, the absence of previous injury data, beyond joint fracture, and knee surgery meant that these variables could not be adjusted for within our analyses. Therefore, we cannot exclude the potential effects of such factors on our models. Lastly, we did not include women who had a total knee replacement during follow-up as incident knee OA cases.

**Conclusions**

In the current study, compared to women who had never worn heeled shoes (≥2 inches), use of heeled shoes was not associated with incident RKOA and, incident knee, hip and foot joint symptoms. Whilst a statistically significant relationship was observed between ever use of heeled shoes and incident back pain, this was likely a result of type 1 error and un-measured, residual confounding. Lastly, in those reporting having worn heeled shoes, increasing time spent wearing heels was not associated with any of our outcomes. These data challenge the belief that wearing heeled shoes is detrimental to foot health though further study is required to confirm the involvement and effects of heeled shoes on the ankle joint.

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**Conflict of Interest Disclosures:**

TAP, CD, TDS, DJH and CB declare no conflicts of interest. NA has received honorariums from Novartis, Alliance for Better Health, and Lilly; held advisory board positions (which involved receipt of fees) at Merck, Merck Sharp and Dohme, Roche, Novartis, Smith and Nephew, Q-MED, Nicox, Servier, GlaxoSmithKline, Schering-Plough, Pfizer, and Rottapharm; and received consortium research grants from Alliance for Better Bone Health, Amgen, Novartis, Merck Sharp and Dohme, Servier, Eli Lilly, and GlaxoSmithKline; he has no other relationships or activities that could appear to have influenced the submitted work.

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**Author Contributions:**

Conception and Design: TAP, CD and CB. Analysis and interpretation of data: TAP, CD, CB and NA. Drafting Article: TAP. Critical revision of article: all authors. Final Approval: all authors. No other disclosures relevant to this article were reported.

**Availability of data and materials:**

All data generated and analysed in this study are available upon reasonable request. Access to data generated in this report should be sent to the corresponding author at thomas.perry@ndorms.ox.ac.uk.

**Patient and Public Involvement (PPI):**

We did not include PPI in this study.

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