# Research: Epidemiology

# Diabetes and risk of occupational injury: a cohort study

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## Abstract

**Aims**   To investigate if diabetes is associated with a higher risk of occupational (workplace or commuting) injury.

**Methods**   Medication data from the Finnish Prescription Register were used to identify diabetes cases in 2004 in a large employee cohort (the Finnish Public Sector study). These data were linked to injury records obtained from the Federation of Accident Insurance Institutions. A total of 1020 diabetes cases (median age 52 years, range 20 to 65 years; 66% women) and their 5234 age- and sex-matched controls were followed up until 2011. Sex-stratified Cox proportional hazards models, adjusting for age, occupational status, obesity and health behaviours, were applied. Because of the small number of men in the cohort, injury types and locations were only examined among women.

**Results**   During the median follow-up of 6.7 years, 25% of the participants with diabetes (*n*=252) and 20% of those without (*n*=1051) experienced an occupational injury. The association between diabetes and injury was stronger in women than men (*P*=0.048). Diabetes was associated with a higher risk of workplace (hazard ratio 1.37, 95% CI 1.11 to 1.69) and commuting (hazard ratio 1.36, 95% CI 1.03 to 1.79) injury in women. With regard to different injury types and locations, diabetes was associated with bone fractures, dislocations, sprains and strains, and injuries to upper and lower extremities. In men, there was an association between insulin-treated diabetes and commuting injury (hazard ratio 3.14, 95% CI 1.52 to 6.49).

**Conclusions**   Diabetes was associated with workplace and commuting injuries in women. Men with insulin-treated diabetes had a higher risk of commuting injuries.

*Diabet. Med.* 34, 1629–1636 (2017)

## Introduction

The prevalence of diabetes is rapidly increasing. The International Diabetes Federation has predicted that the number of people with diabetes globally will increase from 387 million in 2014 to 592 million by 2035 [1]. As the diagnosis of Type 2 diabetes mellitus is typically made in midlife, and in most developed countries working populations are ageing, the increasing diabetes rate is becoming a major challenge for occupational health.

Diabetes is associated with increased morbidity and mortality [2,3]. It has also been suggested that diabetes may increase the risk of occupational injury, but the evidence is limited [4,5]. A systematic review conducted in

2008 identified only two case–control studies and one large cross-sectional study on diabetes and occupational injury, and found a moderate positive association [4]. Another systematic review from the same year but on risk factors for work-related road traffic crashes resulting in injury, found two reasonable-quality studies that both reported an association between diabetes and increased risk of injury [5]. More recent studies have shown inconsistent results. In a 10-year follow-up study in manufacturing workers, diabetes was associated with an elevated risk of occupational injury [6], whereas, in the cross-sectional National Health Survey, no overall association between diabetes and occupational injury was found [7]. In a case–control study from the UK, diabetes medication was not associated with a higher risk of injury [8]. Many of these studies have been limited by self-reported data, cross-sectional design, or their focus on just one industry or occupation. No previous study has investigated occupational injury risks

> **What's new?**
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> • The present study is the first large prospective study to assess the association between diabetes and both workplace and commuting injuries in a diverse population of men and women, using objective measures and also differentiating by the type and anatomical site of injury.
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> • The results showed that diabetes is associated with workplace and commuting injuries in women. Men with insulin-treated diabetes had a higher risk of commuting injury.
>
> • The observed effect sizes were moderate and, with the rapid increase in diabetes cases, this translates to a significant population-attributable risk with large cost implications.

in employees with diabetes by the type or anatomical site of injury.

In the present study, we used a large occupational cohort to examine objectively measured diabetes as a predictor of subsequent recorded occupational injuries over a 7-year period. Furthermore, we investigated whether the associations were different in men and women, in terms of workplace and commuting injuries, and in relation to different types and anatomical sites of injuries.

## Participants and methods

### Study population

The data were derived from the Finnish Public Sector study, which is an ongoing prospective employee cohort study (N=151 901) [9]. The analytical sample was drawn from those who were employed by target organizations in 2004, had responded to the survey in 2004 or, in case of no response for 2004, in 2000–2002, and were alive and not retired at the start of the follow-up, 1 January 2005 (N= 60 549; 74% of all eligible employees). The survey data were linked to register data on diabetes medication. The record linkage was complete so there was no loss to follow-up (no drop-out). The analyses were based on a sample in which we included all employees with diabetes and randomly selected five age- and sex-matched controls for each case. All 1122 diabetes cases were individually matched with 5610 controls. After exclusion of those with a missing value for any of the covariates, 1020 employees with diabetes [median (range) age 52 (21–65) years; 66% women; 25% manual workers] and 5234 controls [median (range) age 52 (20–63) years; 67% women; 17% manual workers] remained for the analysis.

The study was approved by the Ethics Committee of Hospital District of Helsinki and Uusimaa. We followed the principles outlined in the Declaration of Helsinki.

### Ascertainment of diabetes

Finnish Prescription Register data were used to identify diabetes cases at the beginning of the follow-up. This register covers the prescription drugs purchases of all permanent residents in Finland.

The identification was based on purchased diabetes drugs (oral or insulin) and entitlements to special reimbursements for their costs. All people with Type 1 diabetes are eligible for special reimbursement (100% of the costs). Regarding Type 2 diabetes mellitus, a person's condition must meet explicit predefined criteria: diagnosis of diabetes (fasting plasma glucose level ≥7 mmol/l and need for long-term antidiabetes treatment) which has not been responsive to lifestyle intervention. We defined diabetes cases as those participants who had a valid entitlement to special reimbursement on 1 January 2005, or had purchases of diabetes drugs [Anatomical Therapeutic Chemical (ATC) code A10] in 2004. Of the 1020 participants with diabetes, 707 (69%) had Type 2 diabetes.

### Assessment of occupational injury

Occupational injury is an injury to the employee caused by an accident attributable to an unexpected, sudden external event at work or during commute. In Finland, where the present study was undertaken, occupational injuries are compensated through a statutory insurance system. For work done for the employer, the employer must purchase an obligatory accident insurance policy. In the event of an occupational injury, the employee needs to notify their employer or line manager who will then notify the relevant insurance company. Compensation of occupational injuries takes priority over other forms of statutory compensation and pensions, and, for example, medical treatment expenses are fully covered. In terms of compensation, commuting injuries are treated as occupational injuries. We obtained records on occupational injuries from the national register maintained by the Federation of Accident Insurance Institutions. We used national personal identification numbers (unique number assigned to all Finnish residents) to link the cohort members to these records.

The study outcome was the occurrence of the first recorded occupational injury (workplace injury or commuting injury) measured between 1 January 2005 and 31 December 2011. The median follow-up time was 6.7 years (range 3 to 2556 days).

Information of the type of workplace injury and the primary body part injured (anatomical site) was collected using the Federation of Accident Insurance Institutions classifications, merging the categories in cases in which numbers were small. The injury types identified were as follows: wounds and superficial injuries; bone fractures; dislocations, sprains and strains; concussions and internal injuries; and other or multiple injuries.

The categories of anatomical sites were: head; neck; back; torso and internal organs; upper extremities; lower extremities; and other parts, whole body and multiple sites.

### Covariates

Age, sex and occupational status, all measured at the beginning of the follow-up, were derived from employers' records [10]. As in previous studies in this cohort, occupational status was divided into three categories: manual; lower-grade non-manual; and higher-grade non-manual, according to the Classification of Occupations by Statistics Finland [11]. Health behaviour and body height and weight data were self-reported and were derived from survey responses in 2004 and for those with missing values for survey responses in 2004, from the 2000–2002 survey. Health behaviours assessed included: smoking; high alcohol intake, defined as ≥250 g of pure alcohol/week for men and ≥ 190 g of pure alcohol/week for women; and physical inactivity (<14 metabolic equivalent h/week) [12]. Self-reported height and weight were used to calculate BMI, which was split into three categories (normal weight BMI <25 kg/m$^2$; overweight ≥25 and <30 kg/m$^2$; and obese BMI ≥30 kg/m$^2$).

### Statistical analysis

The descriptive associations between covariates and occupational injury were analysed using the chi-squared test. Injury rates by covariate categories were calculated as injury rates per 1000 person-years (injuries/follow-up years* 1000). Cox proportional hazard models were used to examine the associations between diabetes and the onset of occupational injury. We calculated hazard ratios (HRs) and their 95% CIs for occupational injuries (overall, workplace and commuting injuries; and by specific injury types and anatomical sites), adjusting for covariates. In addition, we conducted two sets of further analyses comparing the following groups of people with diabetes to those with no diabetes: 1) participants with diabetes who had insulin treatment indicated by ATC code A10A but no glucose-lowering drugs indicated by ATC code A10B (n=183 women, n=63 men) and 2) participants with a long history (>10 years) of diabetes (n=218 women, n=96 men). Follow-up began from 1 January 2005 and ended at the first occurrence of the outcome, retirement or death, or on 31 December 2011, whichever came first. During the follow-up, 49 participants died and 1880 retired.

The interaction term between diabetes and logarithm of the follow-up period (P=0.369) was non-significant, suggesting that the proportional hazards assumption was not violated.

The association between diabetes and occupational injury depended on sex (test of interaction, P=0.048). We therefore stratified the main analyses by sex; however, because there

was a smaller number of men in the sample, analyses of injury types and locations were conducted only in women.

SAS statistical software, version 9.4, was used (SAS Institute, Inc., Cary, NC, USA).

## Results

Of the employees with diabetes, 25% (n=252) had an occupational injury during the follow-up, compared with 20% of controls (n=1051). Dislocations, sprains and strains (41% of the first injuries) were the most frequent type of injury, and upper (31%) and lower (30%) extremities were the most common injury locations. As Table 1 shows, in both women and men, occupational injuries were more common in lower non-manual and manual workers. In women, those who were obese and those with a low alcohol intake more often had an injury. In men, current smokers more often had an injury than non-smokers. In addition, in men the injuries were more common among those aged <50 years than among older workers In the multivariable model (which included adjustment for diabetes as well as for all covariates), the associations with age and occupational status remained statistically significant; with a higher risk of injury in those aged ≥50 years in women and those aged <50 years in men; and in lower non-manual and manual workers in both women and men (Table S1).

Table 2 shows that diabetes was associated with a higher risk of subsequent workplace and commuting injury in women. The fully adjusted HRs were 1.37 (95% CI 1.11 to 1.69) for workplace and 1.36 (95% CI 1.03 to 1.79) for commuting injury, respectively. Figure S1 shows the cumulative hazard curves for any occupational injury by diabetes status in women.

Table 2 further shows that there was no association between diabetes and workplace injury in men (HR 0.88, 95% CI 0.67 to 1.16). The HR for commuting injury trended in the same direction and was of the same magnitude as in women, but the association was not statistically significant (HR 1.33, 95% CI 0.76 to 2.33).

As shown in Table 3, the presence of diabetes increased the hazard of only certain types of occupational injuries in women. Diabetes was associated with a higher risk of bone fractures (HR 2.60, 95% CI 1.62 to 4.16) and dislocations, sprains and strains (HR 1.41, 95% CI 1.07 to 1.85), but not with wounds and superficial injuries, concussions and internal injuries, or other types or multiple injuries. In terms of anatomical sites, diabetes was associated with a higher risk of injuries to upper (HR 1.47; 95% CI 1.08 to 2.00) and lower (HR 1.83; 95% CI 1.37 to 2.44) extremities, but not with risk of injuries to head, neck, back, torso and internal organs, or multiple sites.

In addition, we compared those participants with diabetes who had insulin treatment with controls (Table 4). For women, the associations trended in the same direction as when all participants with diabetes were included (HR 1.25,

**Table 1** Characteristics of the participants in the Finnish Public Sector study (4175 women and 2079 men)

| Characteristic | Women (N=4175) | | | | Men (N=2079) | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | n (%) | Occupational injury during follow-up*, n (%) | P† | Injury rate/1000 person-years | n (%) | Occupational injury during follow-up, n (%) | P | Injury rate/1000 person-years |
| Age | | | 0.195 | | | | <0.0001 | |
| 20–49 years | 1912 (46) | 407 (21) | | | 638 (31) | 187 (29) | | |
| 50–65 years | 2263 (54) | 445 (20) | | | 1441 (69) | 264 (18) | | |
| Occupational status | | | <0.0001 | | | | <0.0001 | |
| Higher non-manual | 1142 (27) | 191 (18) | | 28.16 | 826 (40) | 82 (10) | | 17.60 |
| Lower non-manual | 2511 (60) | 509 (20) | | 33.63 | 612 (29) | 131 (21) | | 37.69 |
| Manual | 522 (13) | 152 (29) | | 54.33 | 641 (31) | 238 (37) | | 68.52 |
| Smoking | | | 0.286 | | | | 0.006 | |
| Never | 2829 (68) | 559 (20) | | 33.54 | 1054 (51) | 209 (20) | | 34.74 |
| Ex | 677 (16) | 151 (22) | | 36.55 | 558 (27) | 116 (21) | | 39.28 |
| Current | 669 (16) | 142 (21) | | 36.20 | 467 (22) | 126 (27) | | 47.77 |
| Physical inactivity | | | 0.148 | | | | 0.598 | |
| No | 3061 (73) | 608 (20) | | 32.94 | 1450 (70) | 310 (21) | | 37.38 |
| Yes | 1114 (27) | 244 (22) | | 38.97 | 629 (30) | 141 (22) | | 42.55 |
| BMI | | | 0.018 | | | | 0.959 | |
| Normal weight: BMI <25 kg/m$^2$ | 2151 (52) | 412 (19) | | 31.05 | 728 (35) | 156 (21) | | 37.64 |
| Overweight: BMI ≥25 and <30 kg/m$^2$ | 1351 (31) | 269 (20) | | 35.45 | 951 (46) | 209 (22) | | 38.85 |
| Obese: BMI ≥30 kg/m$^2$ | 709 (17) | 171 (24) | | 44.26 | 400 (19) | 86 (22) | | 41.28 |
| High alcohol intake‡ | | | <0.0134 | | | | 0.071 | |
| No | 3856 (92) | 804 (21) | | 35.21 | 1750 (84) | 392 (22) | | 40.15 |
| Yes | 319 (8) | 48 (15) | | 25.42 | 329 (16) | 59 (18) | | 32.01 |
| Diabetes | | | <0.0001 | | | | 0.795 | |
| No | 3497 (84) | 676 (19) | | 32.25 | 1737 (84) | 375 (22) | | 38.10 |
| Yes | 678 (16) | 176 (26) | | 46.84 | 342 (16) | 76 (22) | | 43.10 |

*In each category the number and percentage of the participants who had an injury during the follow-up, i.e. between 1 January 2005 and 31 December 2011.
†P values from chi-squared tests (two-tailed).
‡Defined as ≥ 190 g of pure alcohol/week for women and ≥ 250 g of pure alcohol/week for men.

95% CI 0.91 to 1.73 for any occupational injury); however, probably as a result of the small number of cases, the associations did not reach statistical significance. For men, the other associations were non-significant, as when investigating all participants with diabetes; however, unlike the finding for any diabetes, having insulin-treated diabetes was associated with a higher risk of commuting injury (HR 3.14, 95% CI 1.52 to 6.49).

In further analysis we investigated the associations between diabetes and injury in those who had a long history of diabetes (>10 years), compared with controls. The associations were very similar as in those analyses when all diabetes cases were included (Table S2).

## Discussion

We conducted a large cohort study with objective assessment of diabetes and occupational injuries and found that women employees with diabetes had a 36–37% higher risk of workplace and commuting injuries. Insulin-treated diabetes was associated with a 3.1-fold risk of commuting injuries in men. Our study supports the limited evidence available that diabetes may increase the risk of occupational injury [6,13].

The association between diabetes and injury has not been a universal finding; some studies have not indicated an increased risk [7,8,14,15]; however, many previous studies have important limitations: some used self-reported cross-sectional data [7,15], or investigated the association between diabetes and occupational injury only in men [14], or in one industry or occupation such as in farmers [14] or manufacturing employees [6]. Most of the studies did not report the results separately for men and women [6–8,15]. Furthermore, to the best of our knowledge, previous studies on diabetes and occupational injury have not separately examined workplace and commuting injuries. Large-scale prospective studies such as the present study, conducted in diverse employee populations, are rare.

**Table 2** Associations between diabetes and subsequent occupational injury in women and men: the Finnish Public Sector study, 2004–2011 (*N*=6254)

| | N/events | Rate/1000 person-years | Model 1* HR | Model 1* 95% CI | Model 2† HR | Model 2† 95% CI | Model 3‡ HR | Model 3‡ 95% CI |
|---|---|---|---|---|---|---|---|---|
| **Women** | | | | | | | | |
| Any occupational injury (workplace or commuting) | | | | | | | | |
| No diabetes | 3497/676 | 32.25 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 678/176 | 46.84 | 1.55 | 1.31 to 1.83 | 1.49 | 1.26 to 1.76 | 1.42 | 1.20 to 1.70 |
| Workplace injury | | | | | | | | |
| No diabetes | 3497/464 | 22.14 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 678/119 | 31.67 | 1.49 | 1.22 to 1.82 | 1.42 | 1.16 to 1.73 | 1.37 | 1.11 to 1.69 |
| Commuting injury | | | | | | | | |
| No diabetes | 3497/273 | 13.02 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 678/71 | 18.90 | 1.50 | 1.16 to 1.96 | 1.46 | 1.13 to 1.90 | 1.36 | 1.03 to 1.79 |
| **Men** | | | | | | | | |
| Any occupational injury (workplace or commuting) | | | | | | | | |
| No diabetes | 1737/375 | 38.10 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 342/76 | 43.10 | 1.12 | 0.87 to 1.43 | 0.94 | 0.73 to 1.20 | 0.95 | 0.75 to 1.23 |
| Workplace injury | | | | | | | | |
| No diabetes | 1737/326 | 33.12 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 342/64 | 36.30 | 1.07 | 0.82 to 1.40 | 0.88 | 0.68 to 1.16 | 0.88 | 0.67 to 1.16 |
| Commuting injury | | | | | | | | |
| No diabetes | 1737/71 | 7.21 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Diabetes | 342/16 | 9.07 | 1.25 | 0.73 to 2.16 | 1.19 | 0.69 to 2.05 | 1.33 | 0.76 to 2.33 |

HR, hazard ratio.
*Adjusted for age.
†Model 1 + occupational status.
‡Model 2 + smoking, physical inactivity, high alcohol intake, obesity.

**Table 3** Associations between diabetes and the type and anatomical site of subsequent occupational injury in women: the Finnish Public Sector study, 2004–2011 (*N*=4,175)

| Injury category | N events | Model 1* HR | Model 1* 95% CI | Model 2† HR | Model 2† 95% CI | Model 3‡ HR | Model 3‡ 95% CI |
|---|---|---|---|---|---|---|---|
| Type of injury | | | | | | | |
| Wounds and superficial injuries | 209 | 1.41 | 1.00 to 1.99 | 1.32 | 0.93 to 1.86 | 1.35 | 0.94 to 1.93 |
| Bone fractures | 91 | 2.67 | 1.71 to 4.17 | 2.67 | 1.71 to 4.18 | 2.60 | 1.62 to 4.16 |
| Dislocations, sprains and strains | 338 | 1.57 | 1.21 to 2.04 | 1.52 | 1.17 to 1.98 | 1.41 | 1.07 to 1.85 |
| Concussions and internal injuries | 172 | 1.30 | 0.88 to 1.92 | 1.26 | 0.85 to 1.86 | 1.15 | 0.77 to 1.73 |
| Other or multiple injuries | 39 | 1.09 | 0.46 to 2.60 | 1.04 | 0.44 to 2.50 | 1.02 | 0.41 to 2.52 |
| Anatomical site of injury | | | | | | | |
| Head | 89 | 0.75 | 0.39 to 1.45 | 0.72 | 0.37 to 1.39 | 0.62 | 0.32 to 1.22 |
| Neck | 26 | 1.06 | 0.37 to 3.08 | 1.04 | 0.36 to 3.03 | 1.29 | 0.44 to 3.83 |
| Back | 94 | 1.51 | 0.91 to 2.49 | 1.44 | 0.87 to 2.38 | 1.51 | 0.89 to 2.56 |
| Torso and internal organs | 33 | 1.32 | 0.55 to 3.20 | 1.25 | 0.51 to 3.02 | 1.19 | 0.47 to 2.98 |
| Upper extremities | 281 | 1.44 | 1.08 to 1.94 | 1.38 | 1.02 to 1.85 | 1.47 | 1.08 to 2.00 |
| Lower extremities | 257 | 2.27 | 1.73 to 2.98 | 2.20 | 1.67 to 2.89 | 1.83 | 1.37 to 2.44 |
| Other parts, whole body and multiple sites | 77 | 1.02 | 0.54 to 1.93 | 1.00 | 0.53 to 1.90 | 0.93 | 0.48 to 1.80 |

HR, hazard ratio.
Reference category: no diabetes.
*Adjusted for age.
†Model 1 + occupational status.
‡Model 2 + smoking, physical inactivity, high alcohol intake, obesity.

In addition, as far as we are aware, none of the previous studies examining the association between diabetes and occupational injury have measured different types and anatomical locations of injuries. The present study had sufficient power to examine this issue in women and showed that diabetes was associated with a higher risk of bone

Table 4 Associations between insulin-treated diabetes and subsequent occupational injury in women and men: the Finnish Public Sector study, 2004–2011 (N=3680)

| | N/events | Model 1* | | Model 2† | | Model 3‡ | |
|---|---|---|---|---|---|---|---|
| | | HR§ | 95% CI | HR | 95% CI | HR | 95% CI |
| **Women** | | | | | | | |
| Any occupational injury (workplace or commuting) | | | | | | | |
| No diabetes | 3497/676 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 183/41 | 1.23 | 0.89 to 1.70 | 1.24 | 0.90 to 1.71 | 1.25 | 0.91 to 1.73 |
| Workplace injury | | | | | | | |
| No diabetes | 3497/464 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 183/29 | 1.11 | 0.74 to 1.67 | 1.12 | 0.74 to 1.68 | 1.11 | 0.74 to 1.68 |
| Commuting injury | | | | | | | |
| No diabetes | 3497/273 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 183/18 | 1.32 | 0.81 to 2.14 | 1.33 | 0.82 to 2.15 | 1.34 | 0.82 to 2.18 |
| **Men** | | | | | | | |
| Any occupational injury (workplace or commuting) | | | | | | | |
| No diabetes | 1737/375 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 63/19 | 1.11 | 0.69 to 1.77 | 0.92 | 0.57 to 1.47 | 0.91 | 0.57 to 1.46 |
| Workplace injury | | | | | | | |
| No diabetes | 1737/326 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 63/11 | 0.70 | 0.38 to 1.28 | 0.57 | 0.31 to 1.04 | 0.56 | 0.30 to 1.03 |
| Commuting injury | | | | | | | |
| No diabetes | 1737/71 | 1.00 | reference | 1.00 | reference | 1.00 | reference |
| Insulin-treated diabetes | 63/9 | 3.18 | 1.54 to 6.55 | 3.03 | 1.47 to 6.27 | 3.14 | 1.52 to 6.49 |

HR, hazard ratio.
*Adjusted for age.
†Model 1 + occupational status.
‡Model 2 + smoking, physical inactivity, high alcohol intake, obesity.

fractures, dislocations, and sprains and strains, as well as injuries to upper and lower extremities.

The possible mechanisms explaining the association between diabetes and injury are mainly associated with the debilitating issues related to diabetes. These include signs and symptoms of hypoglycaemia, such as dizziness, shakiness, irritability, fatigue, lack of coordination and impaired consciousness, and diabetes complications, such as impaired vision, renal dysfunction and peripheral nerve sensory impairments [7,16,17]. We found that diabetes was associated with the types of injuries typically caused by falls, such as bone fractures, dislocations, sprains and strains. Previous studies have reported that falls become frequent because of visual impairment, retinopathy and neuropathy, which are known complications of Type 2 diabetes [18,19]. The finding that men with insulin-treated diabetes, but not those with non-insulin-treated diabetes, were at increased risk of commuting injuries is in agreement with this hypothesis because complications are more likely in the first group. Moreover, impaired bone quality may partially explain the higher risk of falls-related injuries [20].

Non-specific pathways, such as disease-induced fatigue, obesity, poor physical condition, distractions created by health concerns, and needs for routine care could also explain the relationship between diabetes as a chronic condition and occupational injury [6]. Pathways that are not specific to just diabetes seem plausible given the high prevalence of comorbidities among people with diabetes and the finding that several other chronic diseases such as asthma, depression and coronary heart disease have also been associated with a higher risk of occupational injury [6]. For example, obesity could underlie the association between diabetes and injury because it is a risk factor for both diabetes and injury [21,22]. Indeed, in an earlier study, obesity was associated with similar types and anatomical locations of occupational injuries to those with which diabetes was associated in the present study [23]. Nevertheless, our findings suggest that the association between diabetes and occupational injury in women is not explained by obesity because adjustment for obesity and health behaviours attenuated the association by only 7%.

In the present study, insulin-treated diabetes was associated with a higher risk of commuting injuries in men. This finding should be interpreted with caution because the number of men with insulin treatment was small (n=63). Men commute by car more often than women. Hypoglycaemia and other complications related to advanced diabetes can cause a deterioration in driving performance as a result of compromised psychomotor skills, poorer visuo-spatial functions, slower information-processing, decreased vigilance and poorer judgement [24]. Our finding is consistent with that of a previous study which reported the risk of motor vehicle crash-related injury to be almost twice as high in drivers with Type 1 diabetes as in drivers who do not have diabetes [25]. Furthermore, a previous study showed that

men were more likely than women to consider driving to be safe with hypoglycaemia [26].

The main strength of the present study is its methodological rigour. We used a large diverse employee cohort which was linked to high-quality national health and injury registers. We were reliably able to detect diabetes cases based on explicit predefined diagnostic criteria. By using the statutory national injury database we were able to determine injury cases based on medical evidence and to detect the exact timing of the injury. The use of high-resolution administrative data reduces the risk of misclassification bias. Major selection bias is unlikely as all cases and their randomly selected diabetes-free controls were from the same cohort, broadly representative of the Finnish public sector workforce. The matching procedure was successful, ensuring that cases and controls did not differ in terms of sex and age. A further strength was the ability to control for major behaviour-related potential confounders.

Some limitations also need to be considered. First, although misclassification among the cases was unlikely, it is possible that we were not able to detect all cases of diabetes because we obtained this information from administrative data on medically confirmed and recorded diagnosis, which does not include individuals with undiagnosed diabetes. Those employees with diabetes who were treated solely by lifestyle intervention were not included. If prediabetes and unrecorded diabetes were associated with an increased risk of occupational injury, inclusion of these cases in the control group could have attenuated the associations between diabetes and injury; however, the prevalence of prediabetes and undiagnosed diabetes among the controls would need to have been very high to cause a major bias. Second, selection is a source of bias in observational studies. The risks of occupational injury in employees with a chronic condition such as diabetes could be decreased as a result of their selective retention in less hazardous jobs that do not include shift work or need constant alertness [8], as well as selective job modifications for workers with diabetes [7]. Maintaining work ability can be more difficult in lower occupational status jobs with high physical demands and less job control [27]. If at all, such selection would bias the results towards null.

Third, it is possible that the most minor injuries that did not result in treatment, expenses or sickness absence were under-reported. Fourth, we did not have information on what means of transport the participants used for commuting. Fifth, the covariates were derived from baseline, but there could have been changes in these over the course of follow-up. Finally, because of the gender structure in the Finnish public sector, women were over-represented in the current sample and consequently the power to detect an association was lower for men, although case numbers were not necessarily low compared with other studies. More diverse samples, additionally representing the private sector

and male-dominated industries, are needed to confirm the generalizability of our findings.

In conclusion, the present large-scale prospective study showed that diabetes was associated with a 1.4-fold higher risk of workplace and commuting injuries in women. Women employees with diabetes were particularly vulnerable to bone fractures, dislocations, sprains and strains, and injuries to upper and lower extremities. In addition, insulin-treated diabetes was associated with a higher risk of commuting injury in men, although the small numbers warrant replication of this finding in further studies. The observed effect sizes were moderate and, with the rapid increase in diabetes cases, this translates into a significant population-attributable risk with large cost implications. Further studies are needed to confirm the findings in more diverse employee populations, including private sector workplaces and more male-dominated and manual work settings.

## Competing interests

None declared.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Figure S1**. Cumulative hazard for any occupational injury by diabetes in women.

**Table S1**. Associations between covariates and subsequent occupational injury in women and men: the Finnish Public sector study, 2004–2011 (4175 women and 2079 men).

**Table S2**. Associations between long-term diabetes and subsequent occupational injury in women and men: the Finnish Public Sector study, 2004–2011 (*N*=3715).