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Risk of pedestrian falls in Oslo, Norway: Relation to age, gender and walking surface condition

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ABSTRACT

The risk of pedestrian falls in Oslo, Norway, is analysed. Injury data were collected during 2016 by the municipal emergency medical clinic. A total of 6309 injured pedestrians were recorded. 6109 were injured in falls in which no other road user was involved. The risk of falling per million kilometres walked varies by age, gender and surface condition. Women have a higher risk than men. Risk has a J-shaped variation with age for both genders, being highest among the oldest. The presence of snow or ice on the walking surface is associated with more than a doubling of risk. There are few comparable previous studies of the risk of pedestrian falls. However, to the extent comparisons can be made, pedestrian risk of injury by falling is higher in Oslo than in other cities or countries. The preventability of falls is discussed.

1. Introduction

A road accident is usually defined as an accident in which a vehicle in motion is involved. Vehicles include motor vehicles and bicycles. If a pedestrian falls and is injured, this does not count as a road accident. Many studies, reviewed by Schepers et al. (2017), have found that pedestrian injury in falls is far more frequent than pedestrian injury in road accidents, i.e. accidents in which the pedestrian is struck by a vehicle. As an example, a Swedish study (Öberg, 2011) found that 20,943 pedestrians were injured in falls and 3853 in road accidents. Data collected by the medical emergency clinic in Oslo in 2016 (Melhuus et al., 2017) showed that 6109 pedestrians were injured when falling and 200 were injured when struck by a vehicle. Indeed, the number of pedestrians injured when falling in the city of Oslo exceeded the total number of injured road users in police reported injury accidents in all of Norway in 2016, which was 5539. Since pedestrian falls are not defined as road accidents (Methorst et al., 2017), and data are not routinely collected about them, they have been labelled a hidden problem (Oxley et al., 2018).

The objective of this paper is to describe the risk of pedestrian injury in falls in the city of Oslo, based on data collected in 2016. Unlike most previous papers dealing with pedestrian falls, risk is stated as the number of falls per kilometre walked. Most previous studies, see the review by Schepers et al. (2017), did not contain any data on exposure to risk or estimated risk using population as indicator of exposure. This paper studies variation in the risk of falling with respect to age, gender and walking surface condition. Of particular concern is how snow or ice influences the risk of falling. Previous studies (Möller et al., 1991, Öberg et al., 1996, Öberg, 2011) have found that snow or ice on the walking surface is associated with a large increase in the risk of falling. Before presenting the data and estimates of risk, previous studies whose results can be compared to this study will be reviewed.

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2. Previous studies

The focus of this paper is to determine the level of risk faced by pedestrians and analyse variation in risk with respect to age, gender, and walking surface condition. As noted above, most studies of pedestrian falls have not tried to quantify risk. The review focuses on studies quantifying risk, including studies using population as the denominator when estimating risk.

Ragnøy (1985) studied risk of falling during winter in Oslo. He found that risk increased from 0.6 injuries per 1000 inhabitants in the 1–15 age group to 4.8 injuries per 1000 inhabitants in the 50–66 age group. In higher age groups, risk declined to 4.3 injuries per 1000 inhabitants (67–79) and 2.5 injuries per 1000 inhabitants (80 or more). Average risk was 2.7 injuries per 1000 inhabitants.

Möller et al. (1991) studied variation in the risk of pedestrian falls and of single bicycle accidents during winter according to surface condition. During three winters in Gothenburg, relative risk on snow or ice was 5–5.5 times the risk on a bare surface. In the city of Skellefteå, located further north, risk during three winters on snow or ice was between 7.5 and 11 times higher than on a bare surface.

Guldvoget al. (1992) estimated that 31,973 pedestrians were injured in falls in Norway in 1990, based on data collected at four hospitals. The rate of falls per 1000 inhabitants was 8.3 among women and 6.7 among men. The rate of falls was highest among women aged 65–74, at 14.3 injuries per 1000 women. For women, the rate of falls was lowest in the 25–34 years age group; for men it was lowest in the 45–54 years age group.

Öberg et al. (1996) estimated the risk of pedestrian falls in three cities in Sweden. Based on average risk in the three cities, risk was found to increase monotonically as the share of walking surface covered by snow or ice increased. Senior citizens (aged 66 or above) had a higher risk of injury than those aged between 16 and 65.

Björnstig et al. (1997) studied the risk of pedestrian falls in winter in the city of Umeå, Sweden. The data covered the period from November through April. Mean injury rate was 3.5 per 1000 inhabitants. Women had a higher injury rate than men (4.2 versus 2.8 per 1000). Injury rate had a complex relationship to age. Young people had a high injury rate. Injury rate declined until the age of 40–49 for women and 50–59 for men, after which it again increased. Women aged 60–69 had the highest injury rate; older women had a lower injury rate. Among men, injury rate peaked at the age of 70–79.

Methorst (2010) reported that the rate of pedestrian falls in the Netherlands between 2003 and 2007 was 3.07 per 1000 inhabitants. He also quoted a study estimating the number of pedestrians injured when falling in Europe to about 1.6 million per year.

Öberg (2011) found that there were more than 4 times as many falls in January (the month with the highest number) as in May (the month with lowest number of falls). Since neither the size of the population nor the amount of walking varies this much during the year, it is clear that the risk of falling is higher in winter than in summer. More than half of all falls were on snow or ice in January, February, March, November and December.

Mindell et al. (2012) studied pedestrian risk of falls resulting in hospital admission in Great Britain in 2007–2009. Risk was stated as the number of falls resulting in hospital admission per million kilometres walked. Mean rates were 1.68 for men and 1.80 for women. The rate of falls increased by age for both genders and was highest for women aged 70 or above, at 13.92 falls leading to hospitalisation per million kilometres walked.

Duckham et al. (2013) studied the risk of outdoor falls for older men and women in Boston, Massachusetts. Study participants were 70 years or older and reported detailed information about their fitness and the amount they walked. On average, men walked nearly 50% longer per week than women. Women had (adjusted for confounding) 15% higher risk of outdoor falls than men. On snow or ice, women had 34% higher risk than men.

Li et al. (2014) studied the relation between various indicators of the amount of walking and the risk of outdoor falls among older adults in Boston. One of the indicators of walking can be converted to kilometres walked per week. It was found that the incidence of falls did not increase in proportion to kilometres walked. Those who walked the longest distance per week had the lowest risk of falling per kilometre walked. Comparable data for Oslo are not available.

Schyllander (2014) estimated the total number of pedestrian falls leading to injury in Sweden to about 27,000 per year. By combining his data with population data, injury risk by age and gender can be estimated. Injury risk per 1000 inhabitants was found to increase from childhood (age 0–9) to adolescence (age 10–18 years), then decline until a minimum was reached at age 30–39 for both genders. At higher ages, risk increased monotonically among men, but reached a peak at age 80–89 among women, after which it declined. Mean risk was about 55% higher among women than among men.

Eriksson and Sörensen (2015) matched weather data to data on pedestrian falls in four Swedish cities, showing that the number of falls increased in adverse winter weather. They also estimated the risk of falling per kilometre walked in winter in the cities of Umeå, Stockholm, Gothenburg and Malmö. Risk was highest in Umeå and lowest in Malmö. There was a positive dose-response relationship between the percentage of days in winter having at least one hour of snowfall and the risk of falling per kilometre walked.

Methorst et al. (2017) stated the estimated annual number of pedestrian falls in the Netherlands, Switzerland and Austria. By combining this with population figures for the three countries, annual population risk of falls was estimated. The risk of pedestrians was estimated to be 2.57 per 1000 inhabitants in the Netherlands, 6.97 per 1000 inhabitants in Switzerland and 3.88 per 1000 inhabitants in Austria. The variation in risk between the countries is quite large, but reasons for this are unknown.

Oxley et al. (2018) studied the risk of falling while walking in Victoria, Australia. Injury data were taken from hospital records and police reports. Walking distance was estimated by relying on a travel behaviour survey. Injury risk per kilometre walked increased monotonically with age. Injury risk was 20 times higher in the age group of 85 or older than in the age group 1–14 years of age.

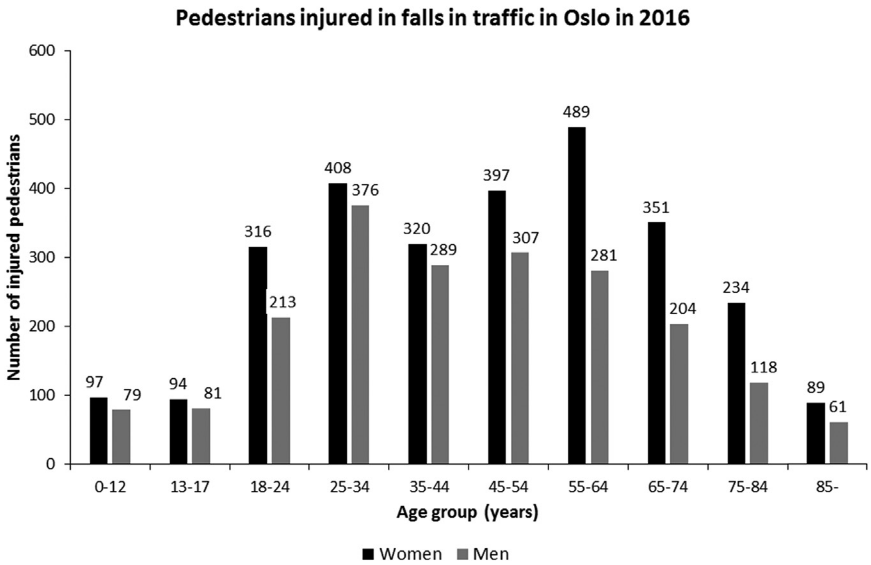

Fig. 1. Pedestrians injured in falls in traffic in Oslo in 2016.

3. Data sources and estimation of risk

The medical emergency clinic in Oslo recorded injuries sustained by pedestrians during 2016. The clinic is an outpatient facility. Most injury victims travel there on their own and are discharged the same day following treatment. In 2016, a total of 6309 injured pedestrians were recorded, of which 6109 were injured when falling. Not all of these falls occurred in traffic. The following location codes were treated as traffic: road, pedestrian crossing, sidewalk, public transport stop and path for walking or cycling. Injuries were excluded if the location was coded as: staircase, house, school or preschool, park, parking area or Opera house roof.

Walking surface condition was coded as follows: dry, wet, dry snow, wet snow, ice and ice covered by snow. The following age groups were used when estimating risk: 13–17, 18–24, 25–34, 35–44, 45–54, 55–64, 65–74 and 75 and older. The age group below 13 is not included in the travel behaviour survey, which is used for calculating exposure in this study. Risk was estimated separately for men and women. Fig. 1 shows the number of injured pedestrians by age and gender. For completeness, the age group 0–12 has been included.

In total, 4804 pedestrians were included. Women outnumbered men in all age groups. The total number of injured women was 2795 (58.2%). The total number of injured men was 2009 (41.8%).

To estimate exposure, the national household travel survey made in 2013–14 was applied (Hjorthol et al., 2014). While these are not the same years as the data on injuries, it is unlikely that walking has changed much between 2014 and 2016. Kilometres walked was estimated for each gender and age group, by multiplying mean daily walking distance by the number of days in the month and mean population size. Mean population size reflects the population in the middle of the year. Population will be slightly smaller at start of the year and slightly larger at the end of the year, but the difference is very small. Pedestrian trips are known to be underreported in travel behaviour surveys (Sammer et al., 2018). It is, however, the shortest trips that are not reported. Distance walked is therefore more completely reported than the number of trips.

To give an example of the estimation of risk, mean daily walking distance for women aged 25–34 in February 2016 was 1.0019 km. Million kilometres walked in February was estimated as:

$$\text{Million kilometres walked} = (1.0019 \cdot 29 \cdot 71,013)/1,000,000 = 2.381$$

There were 29 days in February 2016, as it was a leap year. Mean annual population in the group was 71,013. There were 47 female pedestrians aged 25–34 registered as injured in February 2016. Risk was estimated as injuries divided by exposure:

$$\text{Risk} = 47/2.381 = 19.74 \text{ injuries per million kilometres walked.}$$

Estimates of risk are uncertain. There is uncertainty in both numerator and denominator. Uncertainty is stated as the standard error of each estimate of risk. If it is assumed that random variation in the number of injuries is Poisson-distributed, the standard error of a given number of injuries N equals the square root of the number. Thus:

$$\text{Standard error of number of injuries (N)} = \sqrt{N}$$

Estimates of standard error of exposure is produced by the statistical software used to process travel behaviour data. Thus, for the mean daily walking distance used in the example above, standard error was 0.38151. The relative standard error of an estimate of risk was estimated as:

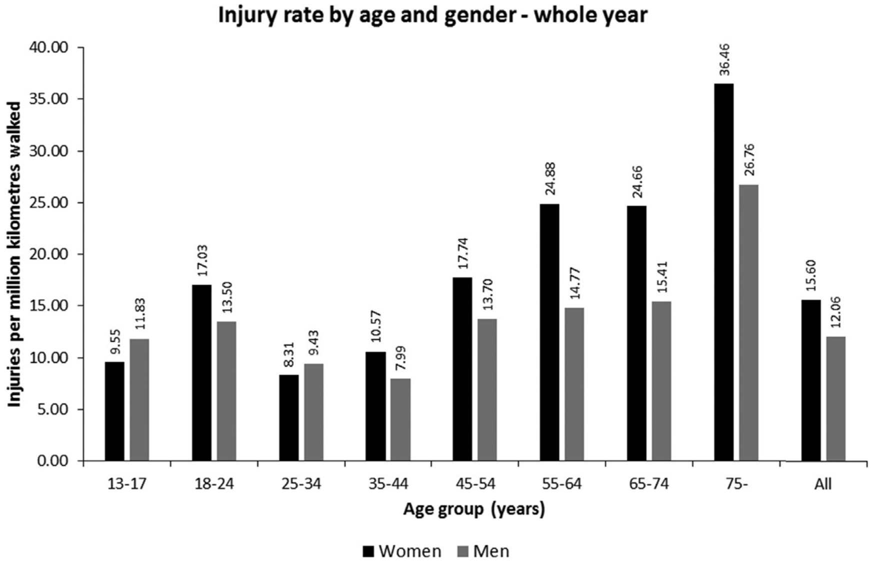

Fig. 2. Injury rate by age and gender – whole year.

$$\text{Relative standard error of estimate of risk} = \sqrt{\left(\frac{S_e}{e}\right)^2 + \left(\frac{S_n}{n}\right)^2}$$

In this formula, e denotes exposure, and n denotes number of injured pedestrians. Relative standard error expresses standard error as a proportion of the estimated value. Thus, for women aged 25–34 in February 2016, standard error becomes:

$$\text{Relative standard error of risk (19.74)} = \sqrt{\left(\frac{0.38151}{1.0019}\right)^2 + \left(\frac{6.856}{47}\right)^2} = 0.408$$

Standard error was 40.8% of the estimate of risk (19.74 ± 8.05). When presenting estimates of risk, focus will be on the main pattern of risk and not on the standard error of each estimate.

4. Risk of injury when falling

Fig. 2 shows the number of injured pedestrians per million kilometres walked by age and gender. The estimates of risk apply to the whole year.

Below the age of 45, there is no consistent difference in risk of injury when falling between men and women. In all age groups above 45 years, women have a higher risk than men. If the lowest age group is disregarded, the variation in risk of injury by age has a J-shape for both genders. Average risk is higher for women than for men. The risk of injury when falling is extremely high. As a comparison, the risk of injury to car occupants, adjusted for incomplete reporting (Bjørnskau, 2018), is about 0.14 injuries per million person kilometres of travel. Pedestrian risk is roughly 90–110 times higher than this.

Surface conditions associated with winter, i.e. dry snow, wet snow, ice or ice covered by snow were found only in the months of November, December, January, February and March. The year was therefore divided into summer and winter, with summer comprising the months from April to October (both included) and winter comprising the five months mentioned above. The risk of injury when falling was estimated for summer and winter and winter without surfaces covered by snow or ice. The latter estimate was obtained by subtracting all falls on winter surfaces from the total, leaving only falls not occurring on snow or ice. It should be noted that walking cannot be partitioned by surface condition. Hence the estimates of risk for winter without winter surface are probably a bit too low, as not all walking will have been on winter surfaces, even in months when, say, 70–80% of falls were on a winter surface. The difference between the estimates of risk including all falls and the estimates only including those not on winter surfaces nevertheless illustrates the huge contribution winter surfaces makes to risk in winter. Separate estimates were developed for men and women. Fig. 3 shows injury rates for women by age and season.

Average injury rate in winter is more than twice as high as in summer. The variation in injury rate by age is similar for summer and winter. Injury rate during winter is higher than during summer in all age groups. Injury rate in winter with walking surface as summer is lower than in summer in almost all age groups. This is surprising, considering the fact that winter is associated with other risk factors than a slippery walking surface, such as darkness, low temperatures and possibly glare from the sun being lower on the sky than in summer. Estimates suggest that if walking surface conditions were the same in winter as in summer, risk would be lower in winter than in summer.

This suggests that there is behavioural adaptation among pedestrians in winter. They walk more cautiously than in summer. Examples of more cautious behaviour include: walking in daylight only, walking slower, paying more attention to the surface,

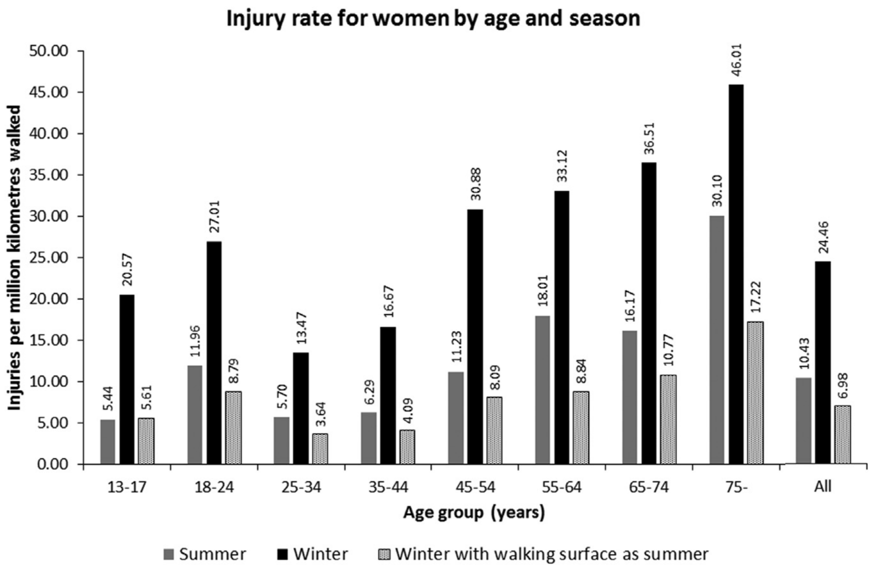

Fig. 3. Injury rate for women by age and season.

wearing shoes with better friction, wearing detachable anti-slip devices, using walking sticks for support or choosing different routes. Very little is known about these forms of behavioural adaptation, but all of them are likely to occur. Still, behavioural adaptation does not prevent the risk of falling from increasing dramatically when there is snow or ice on the surface.

Fig. 4 shows injury rates for men by age and season.

The pattern is very similar to that found for women. Risk increases substantially when the surface is covered by snow or ice. The increase in risk of getting injured when falling in winter is, however, slightly smaller among men than among women. This can be seen from Fig. 5, which shows relative injury rate in winter by age and gender.

A tendency can be seen among women for the increase in risk during winter to decline with age. Relative risk is 3.78 in the 13–17 age group and 1.53 in the 75 or older age group. Among men, the variation between age groups in relative risk is more erratic. Reasons for this interaction between age and gender with respect to relative risk are not known, but one may speculate that older women more extensively adapt their behaviour to walking surface conditions than older men do, including by abstaining from walking when it is slippery.

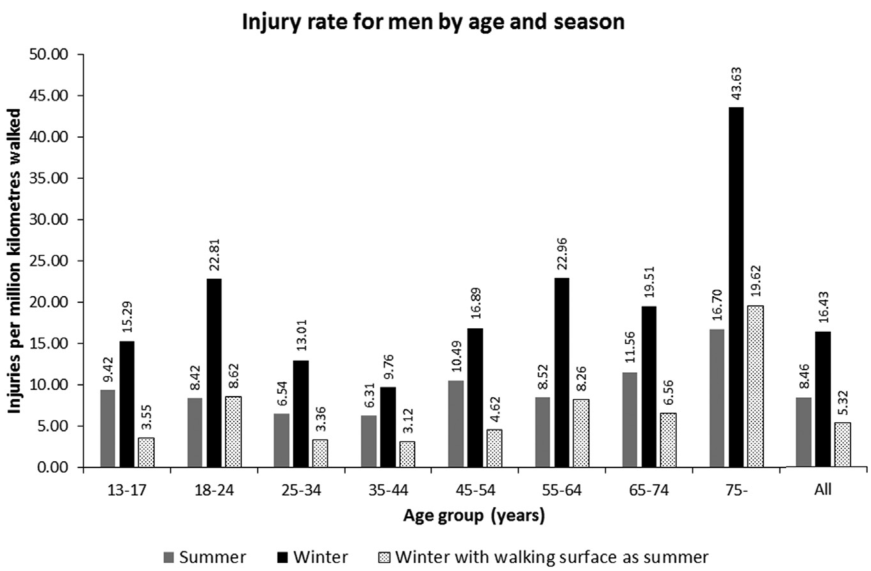

Fig. 4. Injury rate for men be age and season.

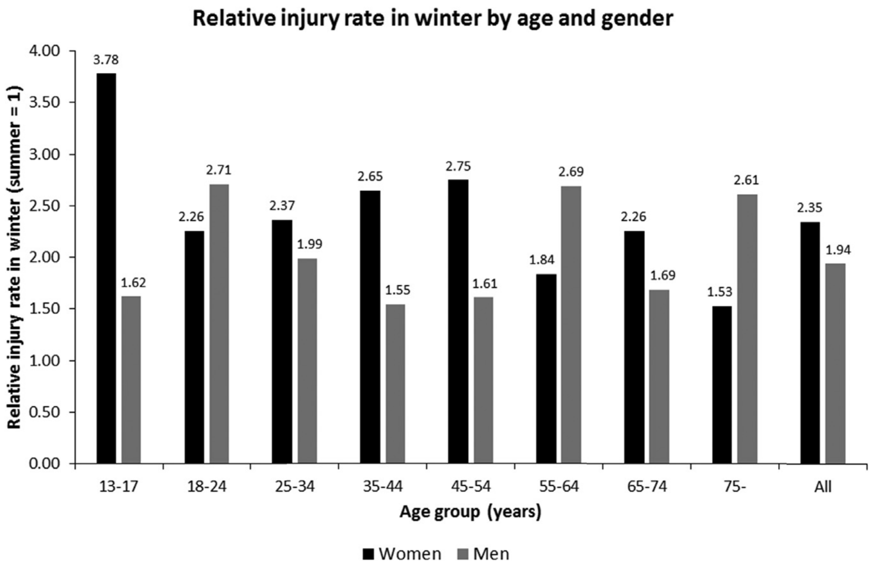

Fig. 5. Relative injury rate in winter by age and gender.

5. The preventability of falls

If winter surface conditions (dry snow, wet snow, ice, ice covered by snow) did not occur, estimates of risk presented above suggest that risk in winter would be at least as low as in summer. It does not seem plausible that risk would be lower in winter than in summer, as nearly all the estimates of risk indicated. This result is probably due to more cautious pedestrian behaviour in winter. If eliminating winter surfaces eliminated the need for this extra caution, one might expect a rebound in behavioural adaptation, meaning that extra caution would no longer be exercised to the same extent as now.

It is clearly not realistic to eliminate winter surface conditions. Even if winter maintenance was increased, it would inevitably have some delay. Snow or ice cannot be removed from all roads instantaneously. There would still be places where snow or ice remained on the road before any maintenance service could deal with it. How does the risk of pedestrian falls depend on the extent to which walking surfaces have winter conditions?

While walking cannot be partitioned according to surface conditions, it is possible to study whether the increase in risk is associated with the share of falls that take place on winter surface conditions. Fig. 6 shows this relationship for women.

Relative risk (risk in winter divided by risk in summer) increases as the share of falls occurring on winter surface conditions increases. One might have expected the opposite pattern if there was a learning effect. Surely, pedestrians get more training in

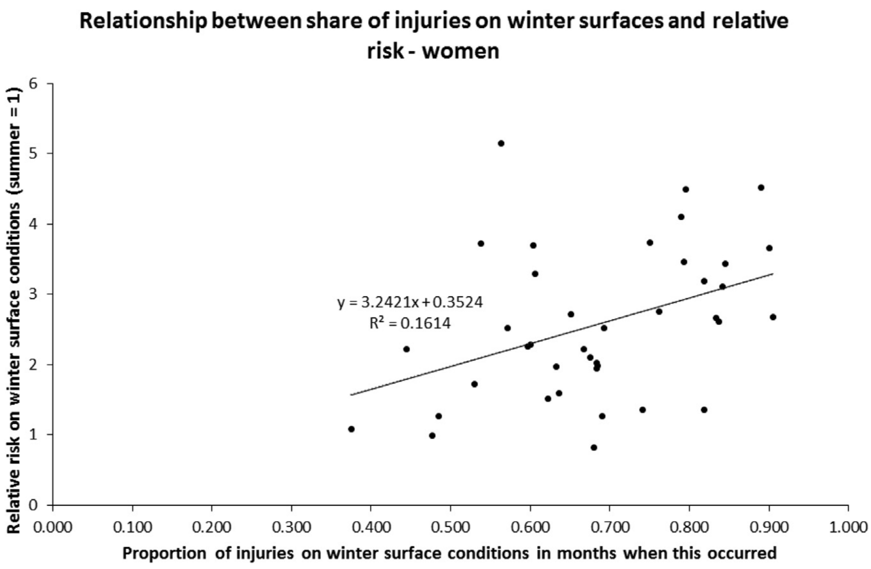

Fig. 6. Relationship between share of injuries on winter surfaces and relative risk – women.

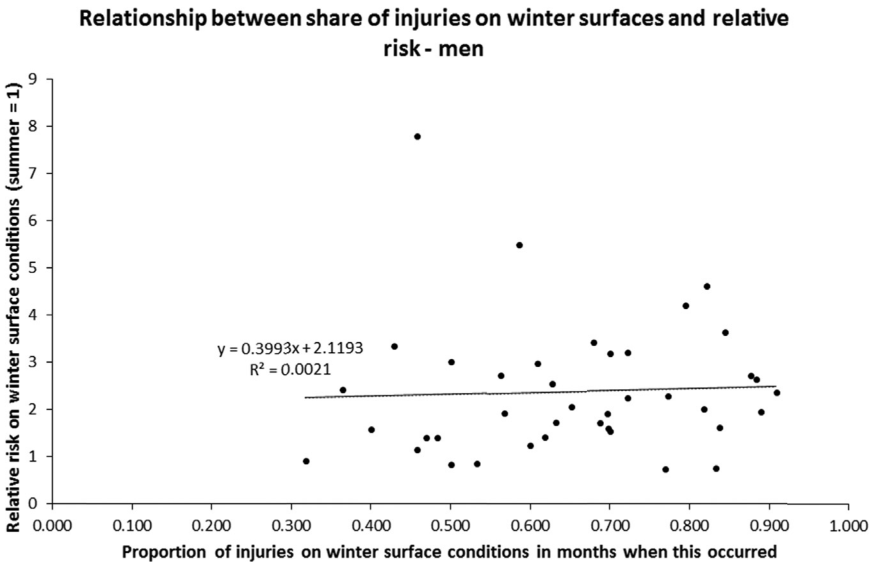

Fig. 7. Relationship between share of injuries on winter surfaces and relative risk – men.

walking on winter surface conditions the more common such conditions are. Fig. 6 shows, however, that the more prevalent winter surfaces are, the higher is the risk associated with them. The regression equation in Fig. 6 suggests that if winter surface conditions were eliminated, risk would be lower than in summer ($3.421 \cdot 0 + 0.3524 = 0 + 0.3524 = 0.3524$, or 65% lower risk than in summer).

On the average, the proportion of injuries to women in winter occurring on winter surface conditions is 0.713. An older Swedish study (Möller et al., 1991) suggests that by increasing winter maintenance, one may reduce the occurrence of winter surface conditions by up to 50%. This means that the proportion of injuries on winter surfaces among women would be reduced to 0.356. Applying the regression equation in Fig. 6, a reduction of the proportion of injuries on winter surfaces from 0.713 to 0.356 implies a reduction of relative risk of about 43%.

The relationship between the share of injuries occurring on winter surface conditions and relative risk for men is shown in Fig. 7. The relationship differs from that found for women.

Among men, there is no relationship between the share of injuries occurring on winter surface conditions and relative risk. Thus, reducing the prevalence of winter surface conditions would apparently not reduce relative risk in winter among men.

It is obviously not possible to interpret the relationships in Figs. 6 and 7 as causal relationships that predict what would happen if winter maintenance was improved. These relationships are static statistical relationships only and do not account for the behavioural adaptations to changes in surface conditions that might be expected to occur if winter surface conditions became less common or less slippery. It is nevertheless possible to use the relationships in Figs. 6 and 7 to estimate a potential reduction of pedestrian injury if winter surface conditions became less common.

For women, the potential for reducing risk was estimated by assuming, as noted above, a 50% reduction in the occurrence of winter surfaces, and a reduction of relative risk of 43% on the remaining 50% of winter surfaces. The amount of walking was assumed not to change. Under these assumptions, the potential for reducing the number of injuries to women, using women aged 25–34 as illustration, was estimated as follows:

1. There were 186 injuries in summer. This number remains unchanged.
2. The occurrence of winter surfaces is reduced by 50%. This means that exposure in winter, now 16.475 million walking kilometres, is reduced by 50%. The remaining 50% will have the same injury risk as in summer, 5.70 injuries per million kilometres walked. Thus, the expected number of injuries is $16.475/2 \cdot 5.70 = 46.9$, rounded to 47.
3. Current risk is 13.47 injuries per million walking kilometres in winter and 5.70 injuries per million walking kilometres in summer. The difference in risk ($13.47 - 5.70 = 7.77$) is reduced to 0.565 of its current value. Risk on winter surfaces then becomes 10.09 per million walking kilometres. The expected number of injuries on winter surfaces becomes $16.475/2 \cdot 10.09 = 83.1$, rounded to 83.
4. The total expected number of injuries is $186 + 47 + 83 = 316$. The current number of injuries is 408. Estimates were done for each age group and summed for all age groups. A potential reduction of the number of injuries of about 23% was found.

For men, it was assumed that exposure on winter surfaces could be reduced by 50%, but no change in relative risk was assumed. Thus, their expected number of injuries was summer injuries, plus half of winter walking at the current risk in summer, plus half of winter walking at the current risk in winter. Under these assumptions, a potential reduction of the number of injuries (whole year) of 15% was estimated.

These estimates should be interpreted as the maximum possible reduction of injuries, as they do not account for possible behavioural adaptation in the form of more walking or less cautious behaviour.

Anti-slip footwear can reduce the risk of falling. According to Berggård and Johansson (2010), the risk of falling per kilometre walked was 36% lower for pedestrians wearing anti-slip devices than for those not doing so. However, those who wore anti-slip devices walked 54% longer than those who did not wear anti-slip devices. Thus, the risk per person of falling was identical in the two groups.

6. Comparison and discussion

The literature review in Section 2 included studies whose results could be compared to the present study. Ragnøy (1985) found a risk (October–March) of 2.7 per 1000 inhabitants. The corresponding estimate in this study is 4.8 per 1000 inhabitants. Ragnøy indicates that the reporting of injuries in his study was incomplete, but even adjusting for this, the risk found in the present study was higher than in his study. Across age groups, risk in his study varied by a factor of 7.9 (4.79/0.61 = 7.9). In the present study the range of variation in risk (falls per 1000 inhabitants) by age (winter only) was 8.4 (10.1/1.2) among women and 8.8 (9.7/1.1) among men, which is in the same order of magnitude as found by Ragnøy.

Möller et al. (1991) estimated relative risk on winter surfaces of between 5 and 11. The increase in risk (per kilometre walked) during winter found in this study is smaller, at most 3.78 (women aged 13–17). Öberg et al. (1996) show that relative risk increases substantially when the share of injuries on winter surfaces increases. Table 1 shows estimates of relative risk based on Table 8.13 in the report by Öberg et al. (1996).

According to Öberg et al., the risk of falling increases substantially when the share of falls occurring on winter surface increases from 0 (summer) to 50, 75 or 90%. For older citizens the risk is 44 times higher when 90% of falls are on a winter surface than the risk in summer for adults aged 16–65. The corresponding variation in risk found in this study (with slightly different age groups: 18–64 and 65+) is much smaller. The overall pattern is the same, but the range of variation in risk (about 4.6) is an order of magnitude (a factor of 10) smaller than in Öberg et al. (1996).

Population risk as estimated by Guldvog et al. (1992) for Norway for 1990 can be compared to population risk for the city of Oslo for 2016. Risk is stated as falls per 1000 inhabitants for the whole year by age and gender. Table 2 shows the comparison.

The overall pattern is very similar, indicating that variation in risk by age and gender is stable over time. In Oslo in 2016, women had higher risk than men in all age groups. For Norway in 1990, women had lower risk than men below the age of 35, higher than men above this age. The mean level of risk was almost the same in Oslo in 2016 as in Norway in 1990 for both genders.

Björnstig et al. (1997) studied variation in risk of falling in winter (November–April) by age and gender. Risk was stated as fall injuries per 1000 inhabitants. Table 3 shows their results compared to corresponding estimates in the present study. Age groups are not identical, but comparable.

All estimates of risk apply to the period from November to April. The general pattern is very similar. Both studies show that risk increases from childhood and in adolescence and early adulthood. Then risk decreases, before it starts increasing again at about the age of 50. In the oldest age groups, Björnstig et al. (1997) found a decrease in risk. In both studies, women had a higher risk than men. Overall risk was 37% higher in Oslo in 2016 than in Umeå in 1993–94. The range of the highest to lowest risk in Umeå (9.7–0.7 = 13.9) was larger than in Oslo (10.1–1.1 = 9.2).

Öberg (2011) found that injuries were more numerous in winter than in summer. The ratio of the month with the highest number of injuries (January) to the month with the lowest number of injuries (May) was 3253/781 = 4.2. In Oslo, the corresponding ratio was (January/July) 676/209 = 3.2. Variation in the number of injuries between months was smaller in Oslo than in Sweden.

Mindell et al. (2012) provide statistics on the number of pedestrians hospitalised as a result of falls and the number of kilometres walked. The rate of hospitalisations per million kilometres walked was 1.80 among women and 1.68 among men. The data collected in Oslo in 2016 did not identify hospitalisations, but injury severity was stated according to the Abbreviated Injury Scale (AIS). If injuries classified as AIS 3 or more severe are regarded as comparable to injuries resulting in hospitalisation, rates per million kilometres walked can be estimated. The rates were 1.82 per million kilometres walked among women – almost identical to the risk reported by Mindell et al. (1.80) – and 0.88 per million kilometres walked among men, which is lower than the risk reported by Mindell et al. (1.68).

The studies of Guldvog et al. (1992), Schyllander (2014), Methorst et al. (2017) and Oxley et al. (2018) permit a comparison of the overall population risk of pedestrian falls (falls per 1000 inhabitants per year) in Norway, Sweden, the Netherlands, Switzerland, Austria, and Victoria as well as the city of Oslo. The results are shown in Fig. 8. Norway and Oslo appear to have a higher population risk of injury than any of the other countries or cities included in the comparison.

Duckham et al. (2013) found a higher risk for women than for men (in Boston, Massachusetts). The risk ratio, adjusted for confounding, was 1.15 for all outdoor falls and 1.34 for falls on snow or ice. In Oslo, the overall risk ratio (women/men) was 1.29. On snow or ice, it was 1.49. Gender differences in risk were therefore a little larger in Oslo than in Boston, but in both cities risk on snow or ice increased more for women than for men.

Eriksson and Sörensen (2015) estimated the risk of injury at a severity of MAIS 2+ per kilometre of walking in four cities in Sweden. Corresponding estimates have been developed for Oslo. Fig. 9 compares risk in Oslo to risk in the four Swedish cities.

In the Swedish cities, a dose-response pattern is seen in the risk of injury: the more days with snow, the higher the risk. Women had higher risk than men in all four cities. In the city of Oslo, risk was higher than in all the Swedish cities. Exact data on the number of days in Oslo that had snowfall for more than one hour have not been found, but a rough estimate, based data from the eKlima website (maintained by met.no, the Norwegian Institute of Meteorology), is about 25%. This share may seem low compared to the

Table 1
Relative risk by surface condition according to Öberg et al. (1996) and present study.

Age group	Estimates of relative risk according to Öberg et al. (1996)				Estimates of relative risk in the present study			
	Summer	Winter (50)	Winter (75)	Winter (90)	Summer	Winter (50)	Winter (75)	Winter (90)
Adults (16–65; 18–64)	1.0	3.0	8.3	9.2	1.0	1.3	2.1	2.8
Older citizens (66-; 65-)	7.0	12.3	37.2	44.2	2.0	4.0	3.1	4.6
		About 50% of falls on winter surface	About 75% of falls on winter surface	About 90% of falls on winter surface		About 50% of falls on winter surface	About 75% of falls on winter surface	About 90% of falls on winter surface

Table 2
Population risk in Norway in 1990 and Oslo in 2016.

	Injuries per 1000 inhabitants (Guldvog et al.1992)				Injuries per 1000 inhabitants (this study)		
Age group	**Women**	**Men**	**Total**	**Age group**	**Women**	**Men**	**Total**
10–14	7.3	7.9	7.6	13–17	6.5	5.4	5.9
15–24	8.5	10.2	9.3	18–24	10.3	7.6	9.0
25–34	3.9	6.0	5.0	25–34	5.7	5.4	5.6
35–44	5.4	4.7	5.1	35–44	6.4	5.2	5.8
45–54	8.1	4.6	6.3	45–54	10.0	7.1	8.5
55–64	12.4	5.8	9.2	55–64	15.4	8.9	12.2
65–74	14.3	6.3	10.7	65–74	14.4	9.0	11.8
75-	12.9	10.4	12.0	75-	15.2	14.0	14.8
Total	8.3	6.7	7.5	Total	8.4	6.1	7.3

Table 3
Population risk in Umeå (Björnstig et al., 1997) and Oslo.

	Injuries per 1000 inhabitants (Björnstig et al., 1997)				Injuries per 1000 inhabitants (this study)		
Age group	**Women**	**Men**	**Total**	**Age group**	**Women**	**Men**	**Total**
0–9	0.7	0.9	0.8	0–12	1.2	1.1	1.2
10–19	4.6	1.7	3.2	13–17	4.1	3.4	3.7
20–29	2.2	3.2	2.7	18–24	6.2	5.1	5.6
30–39	2.9	2.5	2.7	25–34	3.5	3.7	3.6
40–49	2.6	2.3	2.5	35–44	4.6	3.4	4.0
50–59	8.2	2.2	5.2	45–54	6.6	4.8	5.7
60–69	9.7	5.5	7.7	55–64	10.1	6.4	8.2
70–79	9.3	6.4	8.0	65–74	9.8	6.3	8.1
80–89	3.3	4.3	3.6	75-	9.0	9.7	9.3
Total	4.2	2.8	3.5	Total	5.4	4.1	4.8

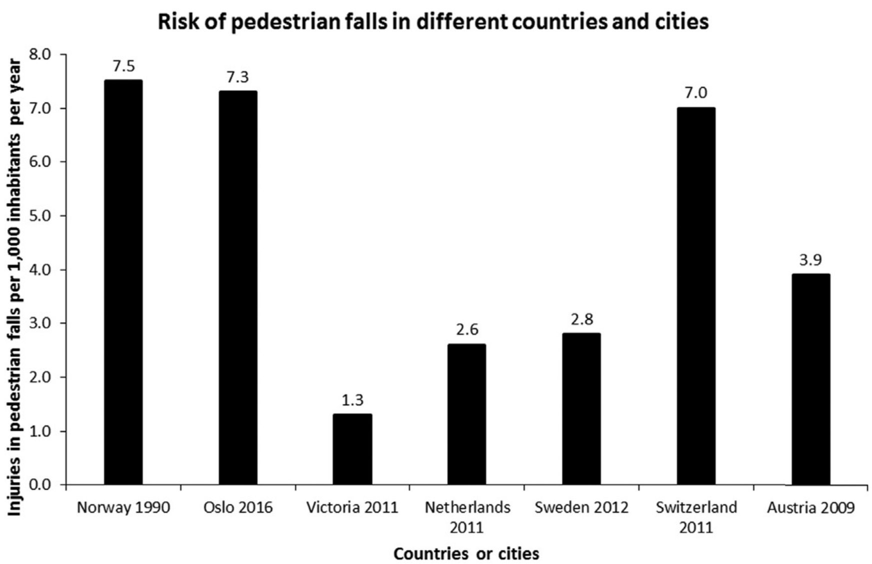

Fig. 8. Risk of pedestrian falls in different countries and cities.

Swedish cities, but the data for the Swedish cities include the severe winters of 2009–10 and 2010–11, whereas the winters of 2015–16 (of which the months January, February and March were included in the data) and 2016–2017 (November, December 2016) were not particularly severe in Oslo.

The final comparison that can be made between Oslo and other locations is based on the study by Oxley et al. (2018) for Victoria, Australia. It is probably not too inaccurate to assume that their estimates of risk reflect summer conditions. The relevant comparison is therefore with risk in summer in Oslo. Injuries per million kilometres walked in Victoria and Oslo in summer are shown in Table 4.

The risk of injury is higher in Oslo than in Victoria below the age of 75. Above the age of 75, the risk of injury is lower in Oslo. The

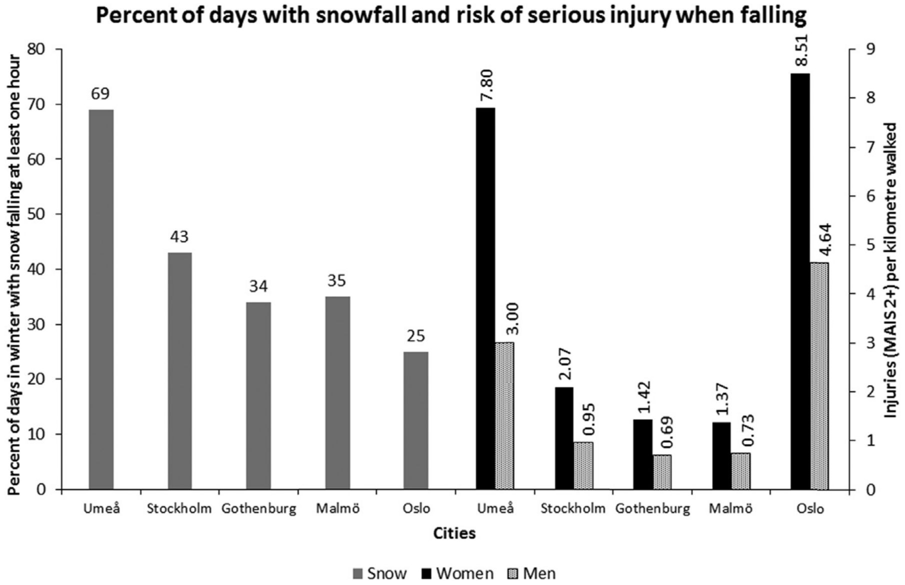

Fig. 9. Percent of days with snowfall and risk of serious injury when falling.

Table 4
Risk of falling per million kilometres walked in Victoria (Oxley et al., 2018) and Oslo.

	Injuries per million kilometres walked in Victoria and Oslo (by gender in Oslo)			
Age groups	Victoria	Women	Men	Both
15–34	5	7	7	7
35–64	5	11	8	10
65–74	9	16	12	14
75-	41	30	17	24

variation in injury risk by age is smaller in Oslo than in Victoria.

Overall, these comparisons show that the risk of injury associated with pedestrian falls is very high in Oslo, higher than in Sweden and in Victoria, Australia. Some comparisons indicate that there is less variation in risk by age and gender in Oslo than in other locations. The main pattern in the variation of risk by age and gender is, however, the same in all data sets. Women, in particular older women, have the highest risk. Risk increases substantially during winter. These main patterns are found in all data sets and are likely to reflect a very general pattern.

Comparisons of risk by gender normally find that women have lower risk than men. Pedestrian falls show the opposite tendency. This is probably not because women as pedestrians behave less cautiously than men, e.g. by walking when drunk, by not paying attention to the walking surface, etc. In Oslo, 3% of women wore anti-slip devices, compared to only 1% of men (this variable had a high percentage of missing data). On the other hand, 6% of women wore high-heeled shoes versus only 0.4% of men.

Older women are more prone to loss of bone density and strength than men. Thus, when they fall, they may more often sustain a fracture than a man of the same age. This may perhaps explain some of the higher injury risk among older women than among older men. There are small differences in walking distance per day between men and women. It is therefore not likely that the gender differences in injury risk can be explained by the "safety-in-distance" tendency found by Li et al. (2014).

7. Conclusions

The main results of the study presented in this paper can be summarised as follows:

1. Pedestrians in the city of Oslo, Norway run an extremely high risk of getting injured when falling. The risk is 90–110 times higher than the injury risk to car occupants.
2. Risk varies by age and gender. It is higher for women than for men. Risk decreases from childhood to adolescence and early adulthood, but then increases by age for both genders.
3. Risk increases substantially in winter. The increase in risk during winter is greater for women than for men.
4. The main pattern in the variation in risk by age, gender and walking surface condition found in this study agrees with the findings of other studies.

5. Comparisons of pedestrian risk in Oslo to pedestrian risk found in other studies indicate a higher level of risk in Oslo than in other locations.

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Conflict of interest

None.

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References

Berggård, G., Johansson, C., 2010. Pedestrians in wintertime – effects of using anti-slip devices. Accid. Anal. Prev. 42, 1199–1204.
Bjørnskau, T., 2018. Flere trafikkskader av nullvekstmålet? Effekter av å flytte framtidige reiser fra bil til andre transportmidler (Rapport 1631). Transportøkonomisk institutt, Oslo.
Björnstig, U., Björnstig, J., Dahlgren, A., 1997. Slipping on ice and snow – elderly women and young men are typical victims. Accid. Anal. Prev. 29, 211–215.
Duckham, R.L., Procter-Gray, E., Hannan, M.T., Leveille, S.G., Lipsitz, L.A., Li, W., 2013. Sex differences in circumstances and consequences of outdoor and indoor falls in older adults in the MOBILIZE Boston cohort study. BMC Geriatr. 33 (13), 133.
Eriksson, J., Sörensen, G., 2015. Vintervädrets betydelse för att fotgängare skadas i singelolyckor (VTI rapport 868). Väg- och Transportforskningsinstitutet, Linköping.
Guldvog, B., Thorgersen, A., Ueland, Ø., 1992. Ulykker, vold og selvpåført skade (Rapport 1/92). Statens Institutt for Folkehelse, Seksjon for forebyggende og helsefremmende arbeid, Oslo.
Hjorthol, R., Engebretsen, Ø., Uteng, T.P., 2014. Den nasjonale reisevaneundersøkelsen 2013/14 (Nøkkelrapport. Rapport 1383). Transportøkonomisk institutt, Oslo.
Li, W., Procter-Gray, E., Lipsitz, L.A., Leveille, S.G., Hackman, H., Biondolillo, M., Hannan, M.T., 2014. Utilitarian walking, neighborhood environment, and risk of outdoor falls among older adults. Am. J. Public Health 104, e30–e37.
Melhuus, K., Siverts, H., Enger, M., Schmidt, M., 2017. Snøen som falt i fjor. Fotgjengerskader i Oslo 2016 Oslo skadelegevakt. Statens vegvesen, Oslo Universitetssykehus, Helsedirektoratet, Oslo.
Methorst, R., 2010. Evaluation of the Pedestrian's Performance and Aatisfaction. Chapter B.5.9. 149-180 in Pedestrian Quality Needs, PQN Final Report, Part B5 Documentation. Report of COST 358 Pedestrians' Quality Needs, Brussels.
Methorst, R., Schepers, P., Christie, N., Dijst, M., Risser, R., Sauter, D., van Wee, B., 2017. 'Pedestrian falls' as necessary addition to the current definition of traffic crashes for improved public health policies. J. Transp. Health 6, 10–12.
Mindell, J.S., Leslie, D., Wardlaw, M., 2012. Exposure-based, 'like-for-like' assessment of road safety by travel mode using routine health data. PLoS One 7 (12), e50606.
Möller, S., Wallman, C.G., Gregersen, N.P., 1991. Vinterväghållning i tätort – trafiksäkerhet och framkomlighet (Huvurapport). TFB & VTI forskning/research, Stockholm, pp. 2 (1991).
Oxley, J., O'Hern, S., Burtt, D., Rossiter, B., 2018. Falling while walking: a hidden contributor to pedestrian injury. Accid. Anal. Prev. 114, 77–82.
Ragnøy, A., 1985. Gangtrafikk på vinterføre i Oslo. Kan vegvedlikeholdet hjelpe? (Rapport). Transportøkonomisk institutt, Oslo.
Sammer, G., Gruber, C., Roeschel, G., Tomschy, R., Herry, M., 2018. The dilemma of systematic underreporting of travel behaviour when conducting travel diary surveys – a meta-analysis and methodological considerations to solve the problem. Transp. Res. Procedia 32, 649–658.
Schepers, P., den Brinker, B., Methorst, R., Helbich, M., 2017. Pedestrian falls: a review of the literature and future research directions. J. Saf. Res. 62, 227–234.
Schyllander, J., 2014. Fotgängarolyckor. Statistik och analys (Publikation MSB 744). Myndigheten för samhällsskydd och beredskap, Karlstad.
Öberg, G., Nilsson, G., Velin, H., Berntman, M., Brundell-Freij, K., Hydén, C., Ståhl, A., 1996. Fotgängares och cyklisters singelolyckor (VTI meddelande 799). Väg- och transportforskningsinstitutet, Linköping.
Öberg, G., 2011. Skadade fotgängare. Fokus på drift och underhåll vid analys av sjukvårdsregistrerade skadade i STRADA (VTI rapport 705). Väg- och Transportforskningsinstitutet, Linköping.