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ESTIMATING THE TRAFFIC SAFETY EFFECT OF STUDED TIRES

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Abstract—Swedish accident and exposure data from December 1989 to February 1990 are used to estimate the risk of involvement in an accident on a slippery road when using studded tires compared with the risk when driving with summer tires. Two methods have been used, one involving both accident and exposure data, the other using only accident data. Both methods give similar estimates, indicating that studded tires reduce the risk of involvement in slippery road accidents by 20%–50%.

1. INTRODUCTION

Studded tires are used to improve road grip on surfaces made slippery by snow or ice. The positive effect of studded tires is primarily to be found in improved traffic safety. The improved road grip seems not to have been “used up” by faster driving. Both this and other positive effects should be compared against the negative effects of using studded tires, such as road wear.

In Sweden, the positive and negative effects have been discussed frequently in recent years. To further examine the effects of studded tires on traffic safety, an investigation was performed by the VTI during the winter of 1989–1990 with funding from the National Road Administration. This article describes the analytical methods used and summarizes the results obtained.

In this investigation we use the number of vehicles involved in traffic accidents (accident vehicles) as a measure of traffic safety. We try to estimate the relative accident risk, which is the ratio of the accident risk for vehicles with studded tires to the accident risk for vehicles with nonstudded tires.

To determine the effect of using studded tires on the total number of accident vehicles, we would also need to know total vehicle mileage distributed between slippery roads and nonslippery roads and between vehicles with studded tires and vehicles with nonstudded tires. However, this paper deals only with the estimation of the relative accident risk on slippery roads.

Section 2 describes two methods of estimating the relative accident risk on a slippery road. Both methods are based on the assumption that studded tires do not have any real effect on a nonslippery road, i.e. the relative accident risk on a nonslippery road is set at 1. In the first method, both data from accident vehicles and data from vehicles in traffic are used. This method gives approximately the same results as those of the second method where only accident vehicle data are used.

The data from the investigation are described briefly in Section 3. The data relate to three types of tires—studded tires, summer tires, and “other tires”. The last of these types comprises mainly nonstudded winter tires and friction tires. The number of vehicles with “other tires” are comparatively small, 5% of the total. In addition, as the investigation’s definition of “other tires” was unclear, only studded tires and summer tires are compared. Section 4 summarizes the results of the investigation.

2. METHODS OF ESTIMATING THE EFFECT OF STUDS

The first method is based on case control studies. This compares the relation between the number of studded and nonstudded vehicles among the accident vehicles (case) with the corresponding relation between the control vehicles (control). The control vehicles consist of vehicles in traffic. The relative accident risk, i.e. the object of the investigation, then is approximated by the odds ratio.

Let P_s be the risk of being involved in an accident for a studded tire user. The odds associated with this event is $P_s/(1 - P_s)$ (where $1 - P_s \approx 1$). The corresponding odds for nonstudded tire users is $P_n/(1 - P_n)$ where P_n is the accident risk for a nonstudded tire user. The odds ratio is the ratio of these two odds.

2.1. *Confounding variables*

In the analysis, it is necessary to pay attention to factors associated both with the accident risk and with the tire equipment. One such factor concerns young drivers with a high accident risk and who possibly also use studded tires to a lesser extent than the average motorist. A measured association between tire equipment and accident risk may then reflect the actual association between the driver's age and accident risk. Examples of possible confounding variables related to the driver are driver's age and sex, vehicle ownership (company/private car), and driving experience. Examples of variables linked to the vehicle are vehicle age, ABS (antilock braking system), and four-wheel drive.

In addition, there may be confounding variables linked to road conditions and driving conditions, such as road condition (slippery/nonslippery), type of location (urban/rural area), county, time of the day, and day of the week.

The standard way to overcome the problem of confounding variables is to use stratification. However, here we stratify only on county and date. We also separate the two road conditions. The other confounding variables are compensated for by the standardization procedure described in section 2.3.

2.2. *Analysis tools*

The odds ratio is estimated by logistic regression in the way described by Schlesselman (1982, Ch. 8) and with the Mantel-Haenszel method, also described by Schlesselman (1982, Ch. 7).

The difference between the estimates of the odds ratio with logistic regression and estimates of the odds ratio with the Mantel-Haenszel method using the same data seems to be negligible in the analyses reported here. The analyses have been carried out in SAS where both methods are available.

2.3. *Methods of analysis*

Assume that we have data on all important confounding variables for every accident vehicle and control vehicle. By introducing interaction terms in the logistic regression expression (see Schlesselman 1982, Ch. 8), we would be able to estimate not only an odds ratio that is common to all tables generated, but also different odds ratios relating, for example, to slippery roads and nonslippery roads, as well as differing between northern, central, and southern Sweden.

In this study, we have selected a simplified approach based on the assumption that on nonslippery roads there should be no effect of studded tires. This means that the relative accident risk, i.e. the ratio of the accident risk for vehicles with studded tires to the accident risk for vehicles with summer tires, on nonslippery roads is equal to 1. If the *measured* relative accident risk on nonslippery roads deviates from 1, the deviation will originate from the effects of confounding variables other than slippery/nonslippery roads (for example, drivers' age). By dividing the measured relative accident risk (the odds ratio) on a slippery road by the relative accident risk (the odds ratio) on a nonslippery road, we obtain a standardized measure of relative accident risk on a slippery road in which we have taken into account all other confounding variables.

The underlying assumption is that the influence of the confounding variables on the effect of studded tires is the same on nonslippery as on slippery roads. This is a simplification of reality, however. For example, the proportion of young drivers is probably higher at night when roads are more frequently slippery.

The proportion of studded tire users in Sweden varies greatly during the winter season. The proportion is highest in January and February and lowest at the beginning and end of the season. However, when road conditions are bad, drivers with nonstudded tires especially tend to leave their cars at home. Thus the proportion of vehicles with

studded tires can vary also from day to day. There is also a large variation between southern and northern Sweden regarding studded tire usage. We now assume that in a certain county during a certain day the proportion of vehicles with studded tires to vehicles with nonstudded tires among vehicles in traffic is constant. Therefore we utilise information on county and date for both accident and control vehicles, and stratify the data on county and date. We now seek an odds ratio common to all groups created by the stratification.

For each group, which comprises vehicles with common county and date, we have two 2×2 tables, one for nonslippery roads and one for slippery roads. Each table is divided into accident vehicles/control vehicles and studded tires/summer tires. The assumption of constant proportion of studded tire users (among vehicles in traffic) within the groups means that we can use the same control vehicles in both tables. Now the data can be analyzed in two ways.

The first method is to determine a common odds ratio O_{slippery} for the slippery road tables and a common odds ratio $O_{\text{nonslippery}}$ for the nonslippery road tables. We then divide O_{slippery} by $O_{\text{nonslippery}}$, and the standardized common odds ratio $O_{s/n}$ will be obtained as $O_{\text{slippery}}/O_{\text{nonslippery}}$.

The second method is to determine a standardized odds ratio directly for each group of vehicles with common county and date. Since the control vehicles are the same for the slippery road table and nonslippery road table of the group, they disappear in the standardization. The standardized odds ratio for the group is thus obtained from a 2×2 table of accident vehicles divided into studded tires/summer tires and accidents on slippery roads/accidents on nonslippery roads.

3. DESCRIPTION OF THE DATA

The data on accident vehicles were collected by the police, who noted the tire equipment on the cars in their accident reports. The reports also show the road surface condition at the time of the accident. The accident data covers all Swedish counties during December 1, 1989 to February 28, 1990. The accident data refer to public roads, which implies a predominantly rural environment.

The data on control vehicles were collected through a questionnaire survey carried out during the period January 10, 1990–February 9, 1990. The survey covers only 19 of the 24 Swedish counties. On each weekday during the period, a questionnaire was sent to a number of randomly selected vehicle owners. To those counties where snowfall was reported, a much larger number of questionnaires were sent out. The questionnaire contained questions on age, sex, and postal code of the vehicle owner and questions concerning the previous day's car driving, such as driving distance on rural roads and type of tire.

The original data comprise 15,000 accident vehicles and about 8,000 control vehicles.

In making an analysis covering control vehicles from the questionnaire survey, only the accident data coinciding in time with the questionnaire survey can be used. In both the accident data and the control data, there is a large measure of nonresponse in reporting the use of studded tires. The accident data that can be compared with the survey data is described by Table 1. In accident data the studded tire vehicles amount

Table 1. Number of passenger cars in analysis covering control vehicles from questionnaire survey

	Accident vehicles	Control vehicles
Studded tires	1,836	3,795
Summer tires	957	1,625
Other tires	139	396
Sum	2,932	5,816

Table 2. Number of passenger cars in analysis using only accident vehicles

	Slippery roads	Nonslippery roads
Studded tires	2,824	3,288
Summer tires	1,583	947
Other tires	239	156
Sum	4,646	4,391

to 65.7% and in survey data to 70.0%, disregarding "other vehicles". The stratification on county and date divides these vehicles into 19×30 groups, which will leave many groups empty or half empty. This problem is discussed in Section 4.2.2.

If the accident vehicles alone are used in the analysis, all accident data from the longer period, December 1, 1989 to February 28, 1990, can be used. The usable data on accident vehicles, divided between road surface condition and type of tire, are shown in Table 2. There are 64.1% vehicles with studded tires in slippery road accidents and 77.6% in nonslippery road accidents, disregarding "other tires".

The tire type "other tires" is not used in the estimates below.

4. ESTIMATING ODDS RATIOS

The estimates have been made using the Mantel-Haenszel method. The confidence intervals are test-based (see Schlesselman 1982, Ch. 7).

4.1. Estimates with questionnaire replies as control vehicles

We divide up the accidents according to the road surface conditions in the accident reports into "nonslippery roads" and "slippery roads". A stratification on county and date gives the following estimates:

$$O_{\text{slippery}} = 0.51(0.40 - 0.65),$$

$$O_{\text{nonslippery}} = 0.83(0.70 - 0.99).$$

The figures within brackets are the 95% individual confidence interval for the odds ratio. The designation O_{slippery} is to be read as "the relative risk of involvement in an accident on a slippery road when driving with studded tires, compared with driving summer tires", while $O_{\text{nonslippery}}$ is interpreted correspondingly.

The standardized odds ratio is thus estimated as $O_{s/n} = 0.51/0.83 = 0.61$. The odds ratio $O_{s/n}$ is interpreted as "the relative risk of involvement in an accident on a slippery road when driving with studded tires, compared to when driving summer tires, with influence of factors besides studded tire usage also taken into consideration".

4.1.1. Comment. In order to make a correct comparison between accident vehicles and control vehicles, we should really collect data on control vehicles on the road in connection with each accident. At present, we compare accident vehicles with control vehicles that have been in use in traffic without taking into account the fact that the control vehicles have different driving distances. If we experimentally weight each control vehicle with the previous day's driving distance on rural roads, we obtain $O_{s/n} = 0.57$. Evidently in this case, the different driving distances of the control vehicles have very little effect on the estimate of the odds ratio.

Another possible source of error is the nonresponse in the questionnaire survey, amounting to 36%. We have not studied whether there is any systematic nonresponse, which could bias the result.

4.2. Estimates without using questionnaire replies

This method uses data from the accident vehicles alone, so the factors of uncertainty associated with the questionnaire survey will have no influence. The vehicles involved in accidents on nonslippery roads are used as "control vehicles" and those involved in accidents on slippery roads are "accident vehicles". The data on accident vehicles from

the period December 1, 1989 to February 28, 1990, stratified on county and date give the following estimate of the standardized odds ratio:

$$O_{s/n} = 0.64(0.54 - 0.77).$$

This result indicates that studded tires with 95% probability reduce the accident odds by 23%–46%. If we instead use only accident vehicles from the same period as the questionnaire survey, the following estimate is obtained:

$$O_{s/n} = 0.50(0.37 - 0.68).$$

This value can be compared with the estimate 0.61 from Section 4.1 and with the estimate 0.57 from Section 4.1.1 where the control vehicles have been weighted with the previous day's driving distance on rural roads. The same accident data have been used in these three estimates. The differences could well be due to the randomness of the data.

4.2.2. *Comments on the stratification.* Using this method we stratify on 90 days and 24 counties and thus distribute the vehicles in Table 2 among $90 \times 24 = 2160$ groups. The vehicles in a group are divided into a 2×2 table. If one column or one row in a table is empty, this table contains no usable information. In fact, more than 80% of all tables are of this kind.

With a coarser division we will utilize information from a larger number of accident vehicles. But at the same time we are more likely to violate the assumption of constant ratio of studded to nonstudded vehicles among vehicles in traffic within each group. With a stratification on two-week periods and counties instead of date and counties, only 20% of the 144 created tables contain no usable information. In this case the standardized odds ratio is estimated to 0.69 (0.60 – 0.78).

5. CONCLUDING REMARKS

The results are in good agreement with an earlier Swedish study (Roosmark et al. 1976). This study used the number of traffic accidents as a measure of traffic safety. The studies also differ in that it compared the effect of studded tires on days with snowfall with the effect on days without snowfall. The estimated effect of studded tires on snowy days, compared to the effect on days without snowfall was 0.70 in southern Sweden and 0.71 in central Sweden. In northern Sweden the effect on snowy days was estimated to 0.81 and on days without snowfall 0.85.

There are several assumptions and approximations mentioned in this paper, and some not mentioned, which add some extra uncertainty to the estimation of the relative accident risk. There could, however, be little doubt of the positive traffic safety effect of studded tires. According to the result of this study, studded tires reduce the risk of involvement in a slippery road accident by 20% to 50%. It is also shown that this result could be obtained with a method that makes the tedious task of collecting control vehicles unneeded.

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