STUDDED WINTER TYRES AND TRAFFIC SAFETY IN URBAN AND RURAL AREAS

Haraldur Sigthorsson

Linuhonnun Consulting Engineers
Sudurlandsbraut 4a
108 Reykjavik
Iceland

Tel: (354) 585 1500 / fax: (354) 585 1501
E-mail: haraldurs@lh.is

1. Abstract

The objective of this study is to estimate the safety benefits of studded tyres. The study was carried out in the periods 1983-1999 for Iceland's capital city, Reykjavik, and 1992-1999 for the country's rural areas and other municipalities. The accident databases contained information on all police-reported accidents, 35,848 for Reykjavik and 14,385 for other parts of the country.

A comparison was made between summer tyres and winter tyres (studded and non-studded). The database was split up into "perpetrators" (those making a mistake leading to an accident) and "victims" (those involved in an accident without causing it). The tyre types used by the victims were an indicator of the actual average use.

The use of summer tyres during the winter was obviously dangerous. This applied for both urban and rural areas alike. A straightforward comparison between perpetrators and victims in urban and rural areas seemed to show that studded tyres provided a considerable excess of safety. The circumstances were then split into dry and wet road surfaces, on the one hand, and ice and snow conditions, on the other. The group using studded tyres continued to show a similar excess of safety even though the equipment (the studs) should provide safety gains for ice and snow conditions only. This indicates that the drivers are safer and not the equipment.

However, there is a slight, unexplained difference, which could be related to the use of studded tyres. It is important to split the obvious safety gain from using studded tyres into a behavioural factor and an equipment factor. Studded tyres certainly provide more grip in icy and snowy conditions than non-studded tyres, but in good conditions, they may be even worse than non-studded tyres. The results shown here indicate that behaviour is a much greater factor than equipment, but a small proportion of the safety gain is nevertheless attributable to the equipment. While the behavioural factor is >20%, the equipment factor is <5% in urban areas. The same numbers are >30% and >10% for rural areas, respectively.

On the grounds of this safety study, ways should be sought to limit the use of studded winter tyres in the urban Reykjavik area. To maintain accessibility during winter, the rest of the country, entailing mainly rural areas, should not impose restrictions.

2. Introduction

The use of studded winter tyres in winter traffic imposes many problems on road authorities and the whole community. First, the studs tear down the asphalt, which means great maintenance costs, and second, the particles thrown into the air pose a danger to public health. The design of non-studded winter tyres has been improving over the years. In fact, the only advantage of using studded tyres is their much acclaimed safety benefit. This study investigates this matter using Icelandic accident data from urban and rural areas.

3. Methodology

The capital city study uses data for urban Reykjavik from 1983-1999, or a 17-year period. The rural study uses data from 1992-1999, or an eight-year period. The Reykjavik accident database was used for the period 1983-1991, and the Icelandic accident database for the period 1992-1999. Studded and non-studded winter tyres and summer tyres were compared. For cars to be included in this study, 3 or 4 of its tyres had to be of the same type. Worn tyres were included with the summer tyres. Therefore, cars with two tyres of the same type were not included here.

The database was split up into "perpetrators" (those, who make a mistake leading to an accident) and "victims" (those, who are involved in an accident without causing it) to see if there was difference between the two groups. This classification is done by the police and is, of course, reconsidered when the case goes to the insurance companies. Still, in the majority of cases, the police identify the responsible parties. There has been some concern about the methodology, for example, if the participants share the blame at later stages. According to the Icelandic insurance companies, blame is shared in less than 5% of the cases.

The method used for the calculations is as follows:

$$r = \frac{(\text{victim}_1 \times \text{perpetrator}_2)}{(\text{victim}_2 \times \text{perpetrator}_1)}$$

$$(1 - r) \times 100$$

Significance is checked for with Chi kvadrat statistics, e.g., on the 5% level.

Example of calculations: The evaluation of the weighted average in Table 1 was as follows. First, the columns for winter tyres are compared: 19.8/21.8 = 0.908, which means that these drivers are approximately 10% less safe than expected. Then, the columns for studded tyres are compared: 28.9/26.1 = 1.107, which means that these drivers are approximately 11% safer than expected. Then, the winter tyres and studded tyres are weighted together: 1.107/0.908 = 1.22, which, after subtracting 1 and multiplying by 100, gives 22% safer behaviour for drivers using studded tyres. It must be borne in mind that other methods for making this comparison are certainly possible and give similar results.

4. Urban analysis

Previous Icelandic researchers used data for Reykjavik from 1983-1988, or a six-year period. The same method was then used for the period of 1989–1995, or a seven-year period. The method was then used for the third time for the period 1996-1999, or a four-year period.

The former and latter periods are not entirely comparable. Only accidents reported by the police are included in the Icelandic accident database. As of 1 March 1988, it was no longer necessary to call the police when an accident happened. This meant the annual police

reporting rate dropped from approximately 3000 to approximately 2000 accidents . The lower reporting rate affected the sample size. 1988 is comparable to the preceding years, because it took time for people to realise the change and alter their behaviour.

In 1992, a different institution became responsible for the coding of accidents into the database. No major changes seem to be apparent, though, as the coding is entirely based on police reports, as previously. The police reporting rate of the classification of tyres seems to be dropping the last few years, which is a worry. However, it is clear that the information is missing mostly in very good weather during the summer months. In the first period, approximately 11% of the "perpetrator" records and 16% of those for "victims" have unknown road surfaces or types of tyres. The corresponding figures for the later periods are around 25%. This certainly reduces the significance of any findings for the later periods.

a) All accidents

The results are in three tables for the three periods of time. The tables include both the actual numbers and percentages.

	Perpetrators						Victims						Excess safety
1992-1999	Studded tyres		Non-studded winter tyres		Total		Studded tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%	count	%	count	%	%
Dry or wet	*2472*	*20.9*	*2260*	*19.1*	*11830*	*40.0*	*2428*	*22.5*	*1835*	*17.0*	*10792*	*39.5*	21
Ice or snow	*1522*	*43.6*	*1089*	*31.2*	*3491*	*74.8*	*1579*	*51.1*	*915*	*29.6*	*3090*	*80.7*	24
Average	*3999*	*26.1*	*3340*	*21.8*	*15321*	*47.9*	*4012*	*28.9*	*2749*	*19.8*	*13.882*	*48.7*	22

Table 1: The excess safety of studded tyres for 1983-1988 (all accidents).

	Perpetrators						Victims						Excess safety
1992-1999	Studded tyres		Non-studded winter tyres		Total		Studded tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%	count	%	count	%	%
Dry or wet	*1676*	*20.8*	*1547*	*19.2*	*8058*	*40.0*	*1802*	*22.9*	*1314*	*16.7*	*7871*	*39.6*	27
Ice or snow	*1464*	*48.9*	*1027*	*34.3*	*2994*	*83.2*	*1548*	*56.7*	*835*	*30.6*	*2730*	*87.3*	30
Average	*3139*	*28.4*	*2575*	*23.3*	*11052*	*51.7*	*3350*	*31.6*	*2152*	*20.3*	*10600*	*51.9*	28

Table 2: The excess safety of studded tyres for 1989-1995 (all accidents).

	Perpetrators						Victims						Excess safety
1996-1999	Studded tyres		Non-studded winter tyres		Total		Studded tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%	count	%	count	%	%
Dry or wet	*1322*	*18.13*	*1079*	*14.80*	*7293*	*32.92*	*1454*	*18.51*	*928*	*11.81*	*7855*	*30.32*	28
Ice or snow	*1046*	*47.94*	*651*	*29.84*	*2182*	*77.77*	*1171*	*53.11*	*546*	*24.76*	*2205*	*77.87*	33
Average	*2368*	*24.99*	*1730*	*18.26*	*9475*	*43.25*	*2625*	*26.09*	*1474*	*14.65*	*10060*	*40.75*	30

Table 3: The excess safety of studded tyres for 1996-1999 (all accidents).

The whole year is included, both winter and summer. The proportion of studded tyres or winter tyres is of course much higher during the winter than during the summer.

The results clearly differ for the three periods. For all periods, drivers using studded tyres drive more safely than drivers using winter tyres, and the difference is increasing. Still, it is very interesting that this applies for both dry and wet road surfaces as well as for icy and snowy conditions. Drivers using studded tyres thus drive more safely than other drivers do, according to this accident data, and the difference is increasing. The reason for this effect is not known.

It is argued here that the excess safety is due mainly to the behaviour of the drivers, and that the effect of the equipment is small. An indicator on the latter number could be the difference of the excess safety in good and poor road conditions (Table2: 30-27=3). The behavioral factor could be >20% and the equipment factor <5%, in this case of an urban area.

b) Injuries only

	Perpetrators						Victims						Excess safety
1992-1999	Studded tyres		Non-studded winter tyres		Total		Studded tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%	count	%	count	%	%
Dry or wet	*382*	*17.5*	*384*	*17.6*	*2183*	*35.1*	*307*	*20.0*	*278*	*18.1*	*1537*	*38.1*	11
Ice or snow	*257*	*49.5*	*167*	*32.2*	*519*	*81.7*	*190*	*54.0*	*106*	*30.1*	*352*	*84.1*	16
Average	*638*	*23.6*	*551*	*20.4*	*2702*	*44.0*	*499*	*26.4*	*383*	*20.3*	*1889*	*46.7*	12

Table 4: The excess safety of studded tyres for 1983-1995 (injury accidents only).

Looking at the table for injuries instead of all accidents (material damage included) changes the overall pattern somewhat. It must be kept in mind that the phenomenon is far from being significant and needs to be investigated further. Nevertheless, two findings seem to emerge:

Drivers using studded tyres are still considerably safer than drivers using non-studded winter tyres, but the difference is not as big as before. Now, the excess safety is 12%, compared with 20% to 30% for all accidents. One possible explanation of this is the behaviour of the drivers with studded tyres. They seem to be a safer group of people, but maybe they offset some of this quality by driving faster (false security). This, then, becomes apparent in the number of injuries, but not the number of all accidents. This could be related to speed, becoming ever more apparent as severity increases.

Comparing normal and slippery road surface conditions, the difference in excess safety for drivers using studded tyres is greater for accidents resulting in injuries than for all accidents. Simple subtraction gives 3 for all accidents in the two first periods and 5 in the latest, but for accidents with injuries, the number is 5. Perhaps the equipment is more efficient in preventing the severer accidents.

5. Rural analysis

The data for the rural analysis come from an eight year period, 1992-1999. This proved to be sufficient to get a picture of the situation in the towns and villages outside of the capital but insufficient for a judgement on the situation on highways and roads in rural areas.

The same method was used as before, and an example of the results can be seen in Tables 5,6, and 7. They contain data for the towns and villages outside of the capital area. The towns around Reykjavik (i.e., Kopavogur, Hafnarfjordur, Gardabaer, Mosfellsbaer and Seltjarnarnes) have been excluded as well, as Reykjavik.

a) Studded or non-studded

The usual comparison was made to establish the difference between studded and non-studded winter tyres. The results show very clearly that the drivers on studded tyres cause fewer accidents than those on non-studded tyres. Their excess safety ranges from 38% to 51%. However, this once again applies for both wet and dry condition and snow or ice conditions. The main difference here is the difference in the magnitude of the excess safety for those two conditions. The excess safety is much higher in difficult road surface condition. A clear equipment effect can be seen here. Expressed in a similar way as before, the behavioral factor is now very likely >30%, but the equipment factor is >10%.

	Perpetrators						Victims						Excess safety
1992-1999	Studded tyres		Non-studded winter tyres		Total		Studded tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%		%		%	%
Dry or wet	*310*	*10.72*	*203*	*7.02*	*2893*	*17.73*	*284*	*11.03*	*135*	*5.24*	*2574*	*16.28*	38
Snow or ice	*908*	*43.84*	*288*	*13.91*	*2071*	*57.75*	*925*	*49.36*	*194*	*10.35*	*1874*	*59.71*	51
Average	*1218*	*24.54*	*491*	*9.89*	*4964*	*34.43*	*1209*	*27.18*	*329*	*7.40*	*4448*	*34.58*	48

Table 5: The excess safety of studded tyres compared to non-studded for 1992-1999 (all accidents).

It has to be borne in mind that the numbers are very small in this case, and the difference between the good and bad road conditions is not quite significant.

b) Summer tyres

A special investigation was done on summer tyres and how they compared with winter tyres. Tables 6 and 7 show a part of the comparison. Studded tyres always showed considerable excess safety, compared with summer tyres, in both good and bad conditions. Non-studded tyres only showed excess safety, compared with summer tyres, in icy or snowy conditions; in dry or wet conditions, the outcome was exactly opposite. Note that a positive number means that the summer tyres are better and vice versa. This is an interesting finding and maybe not entirely unexpected as summer tyres have the shortest braking distances in dry conditions.

	Perpetrators						Victims						Excess safety
1992-1999	Studded tyres		Summer tyres		Total		Studded tyres		Summer tyres		Total		
	count	%	count	%	count	%		%		%		%	[%]
Dry or wet	*310*	*10.72*	*1076*	*37.19*	*2893*	*47.91*	*284*	*11.03*	*889*	*34.54*	*2574*	*45.57*	11
Snow or ice	*908*	*43.84*	*188*	*9.08*	*2071*	*52.92*	*925*	*49.36*	*119*	*6.35*	*1874*	*55.71*	61
Average	*1218*	*24.54*	*1264*	*25.46*	*4964*	*50.00*	*1209*	*27.18*	*1008*	*22.66*	*4448*	*49.84*	24

Table 6: The excess safety of studded tyres versus summer tyres for 1983-1988 (all accidents).

	Perpetrators						Victims						Excess safety
1992-1999	Summer tyres		Non-studded winter tyres		Total		Summer tyres		Non-studded winter tyres		Total		
	count	%	count	%	count	%	count	%	count	%	count	%	[%]
Dry or wet	*1076*	*37.19*	*203*	*7.02*	*2893*	*44.21*	*889*	*34.54*	*135*	*5.24*	*2574*	*39.78*	24
Snow or ice	*188*	*9.08*	*288*	*13.91*	*2071*	*22.98*	*119*	*6.35*	*194*	*10.35*	*1874*	*16.70*	-6
Average	*1264*	*25.46*	*491*	*9.89*	*4964*	*35.35*	*1008*	*22.66*	*329*	*7.40*	*4448*	*30.06*	19

Table 7: The excess safety of summer tyres vs. non-studded tyres for 1983-1988 (all accidents).

The latest conclusion indicates that the use of non-studded winter tyres all year round might be unfeasible. The use of summer tyres during winter is of course totally unacceptable.

6. Comparison of urban and rural areas

There is a clear difference between the results for an urban area (Tables 1, 2 and 3) and a rural area (Table 5). The excess safety of drivers using studded winter tyres ranges from 20 to 30% in the urban area, but from 40 to 50% in rural areas. Therefore, the drivers using studded tyres are even more aware and safer in rural areas than elsewhere. The difference between the excess safety in good and poor conditions is also greater in rural areas, indicating that the equipment factor plays a larger role there. The effect of the equipment could be >10% in rural areas and <5% in urban areas according to this. The data that the rural analysis is based on are not as comprehensive as the data used for the urban analysis. All the same, on the basis of these findings, decreasing the use of studded winter tyres in rural areas in Iceland could be dangerous and is clearly not advisable.

7. Other points of interest

The method used in this study assumes that the types of tyres of the traffic accident "victims" can be used as an indicator of the actual use of different tyre types in the city of Reykjavik. Another method relies on counts in car parks and on streets, and the third method is based on surveys made by listening to the noise from cars driving with studded tyres. These tallies all give similar results. The listening method only estimates the number of vehicles on studded tyres and cannot give results for other types of tyres. On the whole, it seems that the listening method systematically and significantly underestimates the number of vehicles with studded tyres. The method of using the victims' tyre types usually produces results in between counts and listening. The counts in car parks and on streets are not done regularly and are therefore not comparable for whole years or distributions throughout the year. The listening method has been used regularly since 1982 and gives a very thorough picture of the situation.

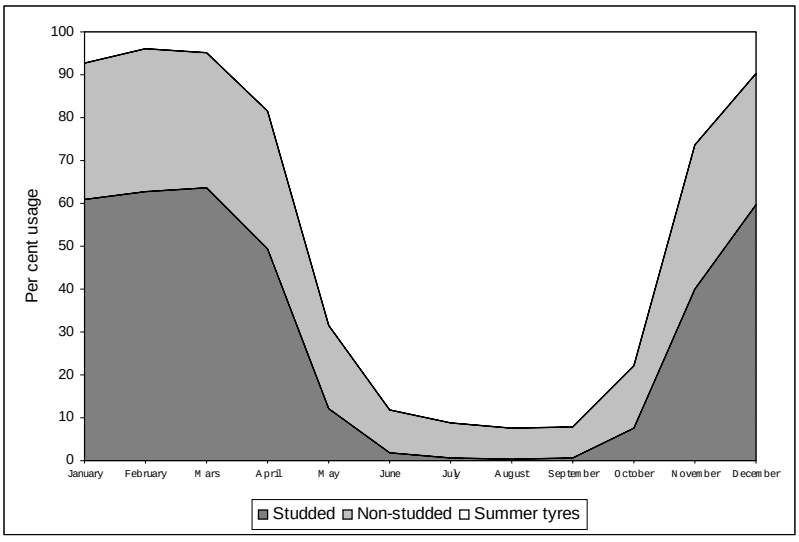

Figure 1: The distribution of tyre types in Reykjavik throughout the year.

The use of the same type of tyres on all four wheels is recommended to ensure uniformity when driving. All the same, some drivers choose to ignore this guideline for many reasons and mix different kinds of tyres on their car. According to the results from the victims' method, though, this is not very common. Table 8 shows a comparison of the use of counts carried out in 2001 and the victims method for 1983-1999. Note that this is an urban comparison. The use of 4 non-studded winter tyres seems to be less common than the use of 4 studded winter tyres. The victims' method also seems to overestimate the use of 4 tyres of same type and at the same time underestimate mixed tyre use. Mixed usage could also be increasing.

	Winter tyres in Reykjavik			
Tyres of same type	Non-studded [%]		Studded [%]	
	Victims' method 1983-1995	Counts 2001	Victims' method 1983-1995	Counts 2001
1 or 3	*3*	*10*	*2*	*8*
2	*12*	*17*	*7*	*11*
4	*85*	*73*	*91*	*81*

Table 8: The use of studded and non-studded winter tyres in Reykjavik.

An attempt was made to compare this statistic with counts on streets and in car parks. Clearly, the classification of a tyre as studded is subjective. A comparison between the three methods gave similar results for studded winter tyres. The counts in the year 2001 show that people stop using studded winter tyres in spring more abrubtly than the other methods indicate. Maybe this behaviour has changed with time. The comparison of the victims' method and counts for the summer tyres also gives similar results. The results for non-studded winter tyres differ from the counts to the victims' method again only for the month of May. The use of non-studded winter tyres continues through spring according to counts. This may be a growing trend as an ever increasing proportion of vehicles are jeeps on the same tyres all year.

	Studded winter tyres [%]			Non-studded winter tyres [%]		Summer tyres [%]	
	Victims' Method	Listening Method	Counts	Victims' Method	Counts	Victims' Method	Counts
Years Months	1983-1995	1983-1995	2001	1983-1995	2001	1983-1995	2001
February	*60.7*	*60.4*	*64.0*	*33.4*	*32.3*	*5.9*	*3.7*
March	*57.6*	*63.7*	*63.0*	*31.5*	*33.0*	*10.9*	*4.0*
April	*43.0*	*43.0*	*44.0*	*30.0*	*31.4*	*27.0*	*24.6*
May	*13.0*	*10.0*	*1.8*	*19.0*	*33.1*	*68.0*	*65.0*

Table 9: Comparison of methods to estimate the usage of different tyre types.

Some other findings from this study regarding the groups of drivers using studded or non-studded winter tyres are:

- The group using studded tyres seems to be a little older, on average, than the group using non-studded tyres.
- The excess safety for drivers using studded tyres is especially clear in rainy and/or dark conditions.
- The group using non-studded tyres seemed to be more frequently involved in injurious accidents, where a victim was not using seat belts.

This analysis and the statements above indicate that the group using studded tyres behave more safely in traffic than the group using non-studded tyres. Safe drivers drive according to conditions and are often experienced, use restraints and drive slowly when vision is poor.

8. Conclusions

The main results can be seen in the following tables. The group using studded tyres shows excess safety for both dry or wet conditions and ice and snow conditions. The excess safety is higher in the area outside Reykjavik. The excess safety in ice and snow conditions is higher than in dry or wet conditions. This difference is greater in the areas of Iceland outside Reykjavik. It can thus be concluded that both Reykjavik and the rest of the country show similar pictures of the situation, but both the behavioral factor and the equipment effect is higher outside of Reykjavik. The reason for this is not known, but did not come unexpectedly, because the use of studded tyres in rural areas is necessary during winter.

	Perpetrators		Victims		Excess safety of studded tyres
1983-1999	Studded tyres	Winter tyres	Studded tyres	Winter tyres	
Dry or wet	*5471*	*4886*	*5685*	*4077*	25
Ice or snow	*4032*	*2767*	*4298*	*2296*	28

Table 10: The excess safety of studded tyres in Reykjavik.

The data for Iceland, excluding Reykjavik, were split up further, but the expected difference between the rural and the urban parts did not show up, except for towns and villages outside the capital area. The results for Reykjavik seem to be changing with time, with both the behavioral factor and the equipment effect apparently increasing, but the reasons for this are not obvious.

	Perpetrators		Victims		Excess safety of studded tyres
1992-1999	Studded tyres	Winter tyres	Studded tyres	Winter tyres	
Dry or wet	*1009*	*734*	*959*	*532*	31
Ice or snow	*2246*	*989*	*2172*	*703*	36

Table 11: The excess safety of studded tyres in Iceland, excluding Reykjavik.

Drivers using studded winter tyres drive more safely than drivers using non-studded winter tyres. This applies for both dry and wet road surfaces and for icy and snowy conditions. This indicates that the drivers are safer and not the equipment. However, there is a slight, unaccounted-for difference. This could be related to the use of studded tyres. Looking at injuries instead of all accidents, the safer behaviour of the group using studded tyres decreases, but the still small potential effect of the studded tyres increases. Using summer tyres is dangerous during the winter but seems to increase safety, compared with non-studded winter tyres during summer.

It is important to split the obvious safety gain from using studded tyres into a behavioural factor and an equipment factor. Studded tyres certainly provide more grip in icy and snowy conditions than non-studded tyres and shorten braking distances, but in good conditions they can be even worse than non-studded winter tyres. The results here indicate that ***behaviour*** *is a much bigger factor, but a small portion of the safety gain is nevertheless attributable to the* ***equipment****. While the behavioural factor is >20%, the equipment factor is <5% in urban areas. The comparable figures for rural areas could be >30 % for the behavioral factor and >10% for the equipment factor. In rural areas the behavioural factor as well as the equipment factor seem to increase.*

9. Recommendations

Based on the findings of this safety study, ways should be sought to limit the use of studded winter tyres in the urban Reykjavik area. To maintain accessability during winter the rest of the country, mainly rural, should not impose restrictions.

Further research is needed. The actual difference in operating speeds between studded and non-studded tyre-equipped vehicles needs to be established. The differential in speed would allow one to estimate the relative increase in crash severity. Apart from those effects, an increase in the speed differential of the traffic alone contributes to collisions, as illustrated, e.g., by the impact of speed limit changes in the U.S., and has been shown in the literature as a U-shaped curve, with the lowest accident values close to the average speed. If taxing the use of studded winter tyres is decided on, as in Oslo, Norway, the effects have to be monitored accurately. The effects of studded tyre use on the severity of accidents should be investigated further. The situation on the rural highways in Iceland should be looked into more closely. It is also advisable to analyse the street surface conditions in Reykjavik during a winter or two to establish the actual time of ice and snow conditions.

The finding of this study explains why changes in studded tyre policy (a ban or an introduction) are not typically associated with significant changes in overall collision rates. This is because the "safer" drivers are rarely involved in collisions (as "Perpetrators" or "Victims"), regardless of whether or not they are allowed to equip their vehicles with studded tires. One thus realises (at best) the "technology benefit" alone.

10. Main references

Carlsson, Arne; Centrell, Per; Öberg, Gudrun: Studded tyres profitable in Swedish winter conditions, Nordic Road & Transport Research No 3, 1995.
Fosser, Stein: Pigg eller piggfritt gir samme risiko, Samferdsel nr. 10, Norge 1995.
Fosser, Stein: Studded or non-studded winter tyres: No significant difference in risk of accidents, Nordic Road & Transport Research No 1, 1996.
Fridström, Lasse: Safety Effect of Studded Tyres in Norwegian Cities, Nordic Road & Transport Research No 1, 2001.
Hiersche, et. al.: Zur Auswirkung der Spikesreifenverwendung auf den Verkehrsablauf, Straβenbau und Straβenverkehrstechnik Heft 170, Bundesminister für Verkehr 1974.
Ingason, Thorir: Studded tyres, salt and traffic safety, reference survey, The Building Research Institute of Iceland (Negldir hjólbarðar, salt og umferðaröryggi, heimildakönnun, Rannsóknarstofnun byggingariðnaðarins), Reykjavik, 1989.
Jóhannesson, Ásbjörn; Jónsson, Rögnvaldur: Use of studded tyres (Notkun negldra hjólbarða) 1976-1987, Mineral Committee, a collaboration of the State Road Authority, Building Research Institute of Iceland og Reykjavik Municipal Department for Road Construction and Maintenance, Reykjavik 1987.
Jóhannesson, Ásbjörn: Survey on the use of studded tyres in December 1997 (Könnun á notkun negldra hjólbarða í desember 1997).
Klement, Tom: Reykjavik study on studded tyres, comments and e-mails, Ministry of Transportation, Ontario Canada, spring 2000.
Sigfússon, Guðbjartur: Studded tyres and wear and tear on asphalt concrete, a lecture at the final conference of BUSL, 6 April 2001 (Negldir hjólbarðar og slit á malbiki, fyrirlestur á lokaráðstefnu BUSL, 6. apríl 2001).
Sigthorsson, Haraldur: Impact of studded tyres on traffic safety, unpublished notes for the Traffic Safety Department of the the Reykjavik Chief Municipal Engineer (Áhrif negldra hjólbarða á umferðaröryggi, óútgefnir minnispunktar fyrir Umferðardeild borgarverkfræðings), Reykjavik 1989.
Sigthorsson, Haraldur: Safety of studded tyres, report for the State Road Authority Research Fund (Öryggi negldra hjólbarða, greinargerð fyrir Rannsóknarsjóð Vegagerðarinnar), Reykjavik 2001.
Skarra, Nils: Piggdekk. Enten paabud eller forbud, Samferdsel nr. 2, Norge 1996.
Sætermo, Inger Anne; Fosser, Stein: Vinterdekk med eller uten pigger – betydning for traffikksikkerheten, TÖI rapport 310/1995, Oslo November 1995.
The Iceland Traffic Council (Umferðarráð): Accident Databank, queries and evaluations .
Traffic Safety Department of the the Reykjavik Chief Municipal Engineer (Umferðardeild borgarverkfræðings): Database and manual.
Öberg, Gudrun; Junghard, Ola; Wiklund, Mats.: En studie av methoder för att beräkna samband mellan dubbdäckanvändning och trafiksäkerhet, VTI meddelande nr 722, Linköping 1993.