



Seasonal variation in risk perception and travel behaviour among cyclists in a Norwegian urban area



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ABSTRACT

The main purpose of the article is to examine the association between risk perception and cyclists' decision as to whether to cycle during the different seasons of the year. The study on which the article is based included worry as a feeling that emerges as a result of an individual's cognitive assessment of risk, attitudes toward traffic rules, risk tolerance and safety priority. The study was based on a questionnaire survey carried out among cyclists from Trondheim Municipality in Norway ($n = 291$) during spring 2017. The results revealed seasonal differences in perceived risk and that risk perception was an important predictor of both the decision as to whether to cycle and the frequency of cycling during wintertime. The same results were not found for cycling during the other seasons of the year. Additionally, an association was found between risk perception and worry. The respondents were more worried when cycling in winter conditions compared with cycling in summer conditions, and worry was a strong predictor of travel mode behaviour. The authors found that when the respondents' perception of risk was very low, they were not worried and hence their behaviour was not affected. Perceived risk and worry were only associated with cycling behaviour during wintertime. These findings may be used as a guide in measures implemented to increase the number of cyclists during winter and in communications to the public about the risks linked to cycling.

1. Introduction

In order to reduce transport-related CO₂ emissions, the Norwegian Government has set as a target for the largest cities that all future growth in individual travel should be accommodated by walking, cycling, and public transport, and thus there should not be growth in car traffic. Achieving this target calls for a variety of measures and enhanced knowledge about road users' preferences and choices in order to establish long-term changes in mode use. When choosing a mode of transport, road users take several factors into consideration, and risk perception may be one of these factors. In Norway, the share of cycling is significantly higher in summer than in winter, which leads to the following questions: Could road users' risk perception be part of the explanation for the phenomenon? Do cyclists perceive cycling as riskier during winter? Are they more worried about cycling in winter? This article presents the results of a study of cyclists' risk perceptions of cycling during summer and winter among cyclists living in Trondheim, one of the largest cities of Norway.

After an overview of cycling in Norway, we address some challenges related to winter cycling, and cyclists' accident risk. In addition, we present theories of risk perception, worry and risk tolerance, both in

general and with respect to cycling in particular. Finally, at the end of the introduction part of the article, we presents the full scope of the study.

1.1. Cycling in Norway

According to the results of the National Travel Survey carried out in Norway for the period 2013–2014 (Hjorthol et al., 2014), 75% of the population aged 13 years or older owned a bicycle. However, only 5% of all daily trips were made with bicycles. The share of cycling trips was higher among young persons aged 13–17 years compared with other age groups, 12% and 4% respectively. Also, persons with higher university education were more likely to cycle, accounted for 6% daily trips by bicycle. The gender differences were small, 4% for women and 5% for men. However, cycling trips for men were on average longer than cycling trips made by women: while the average cycling trip length was 4.1 km and lasted 17 min, the average trip for women was 3.2 km/16 min compared with 4.9 km/19 min for men. The highest shares of cycling trips were school trips (10%) and commuting trips (7%). The share of cycling trips also showed geographical variations: in general, the share of cycling trips increased with density-populated

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areas. In Trondheim, the city in which the present study took place, the overall share of cycling was 9%.

A number of policies have been recommended to reach the main goal of the Government's National Cycling Strategy (managed by the Norwegian Public Roads Administration), and they stated that cycling should constitute 8% of all daily trips by 2023. Among the policies, special emphasis has been placed on the provision of a coherent network of cycle paths, the development of main road networks for cyclists, and safe routes to school (Statens vegvesen, 2012). Trondheim has set the ambitious target of becoming the best city for cycling in Norway, with the priority given to building new infrastructure for cyclists in the city. Since 2014, more than 30 km of new dedicated infrastructure for bicycles has been built, as well as a high number of parking facilities for bicycles in the city centre (Miljøpakken, 2016).

Cycling during the winter season is a specific challenge in Norway due to adverse climate conditions, with snow, slippery roads, and darkness. In Trondheim, the temperature during wintertime (December–February) is on average minus 2.5 °Celsius. During December and January, the sun rises at 10:00 and sets at around 15:00. During spring and autumn too, the temperatures often fall below zero. The seasonal variations are reflected in the use of bicycles for daily travel. During the summer months, 7% of daily trips in Norway are cycling trips compared with only 2% during the winter months. Local travel surveys conducted in Trondheim have revealed cycling shares ranging from 3% to 13% across the seasons (Miljøpakken, 2018). Previous studies have found that high-standard road clearance operations in winter positively affect people's decision to cycle (Svorstøl et al., 2017). In Trondheim, the removal of snow and ice are given high priority on the main road network for the benefit of cyclists. No more than 1 cm of snow is allowed to accumulate before removal, as the strategy is to provide clear surfaces all year round (Miljøpakken, 2014).

Both international and Norwegian studies of road safety with respect to cycling have recently been reviewed by Høye (2017). The review indicates that the youngest and the oldest cyclists, as well as male cyclists are at higher risk than other cyclist groups. Winter conditions with snow and ice-covered surfaces were found to increase the accident risk. The studies are ambiguous with regard to whether winter conditions lead to accidents that are more severe (Doherty et al., 2000; Melhuus et al., 2015; Rolfsman et al., 2012). Although the number of bicycle accidents has decreased in the last decades in Norway, when estimates of underreported accidents are included, the accident risk for cycling (number of injuries and fatalities per km travelled) is estimated as 20–25 times as high compared with travelling by car (Bjørnskau, 2015).

1.2. Risk perception, risk tolerance, and the feeling of worry

The psychometric paradigm has dominated the field of risk perception research over the recent decades (Sjöberg et al., 2004). The approach is characterized by the use of psychometric scaling methods to measure how characteristics of risk sources relate to perceptions of risk (Breakwell, 2007; Fischhoff et al., 1978; Slovic, 1992). In their classic study, Fischhoff et al. (1978) used psychometric procedures to elicit quantitative judgements of perceived risk. To measure perceived risk, their respondents were asked to consider the risk of dying as a consequence of 30 different activities or technologies (e.g. smoking, bicycles, motor vehicles, and nuclear power). Additionally, nine different dimensions were measured for the same activities or technologies. The first one was whether people faced the risk source voluntary. The second dimension was whether death was effected immediately or delayed. The third dimension was whether the risk level was known by the person. The fourth dimension was about the chronic versus the catastrophic potential of the risk – whether the activities or technologies kill one person at a time (chronic) or a large number at once (catastrophic). The fifth dimension was whether the risk evoke great dread or if it is seen as common. The sixth dimension of the risk was the

severity of the consequences of risk-taking (i.e. the likelihood that the consequences will be fatal). The seventh question concerned to the extent to which the risk is known in science (measured by asking respondents to rank whether the risk level was known precisely or not known to science). The eighth characteristic was about the level of control (the respondents were asked to rank their perceived level of control if they were exposed to the risks). The last dimension concerned the newness of the risk (the respondents were asked to rank whether they considered the risks as novel or familiar). Fischhoff et al. (1978) found that perceived risk correlated only with the severity of the consequences and dread, and not with any of the other dimensions. However, in accordance with recommendations by Breakwell (2007), studies carried out during recent years have used assessments of probability and judgments of the severity of consequences as indicators of perceived risk (Moen and Rundmo, 2006; Nordfjaern et al., 2014a; Roche-Cerasi et al., 2013; Rundmo and Moen, 2006). Consequently, perception of risk can be measured by the two factors 'assessments of probability' and 'judgments of the severity of consequences' of an accident occurring when performing an activity. According to Sjöberg et al. (2004), risk perception can be defined as people's cognitive assessment of risk along these two dimensions.

Backer-Grondahl et al. (2009) considered the feeling of worry as an ecological measure of risk perception. However, the inclusion of feelings in the concept of risk perception is not in accordance other studies. Thus, in the present article, risk perception is defined as a purely cognitive assessment of probabilities and judgement of severity of consequences of a particular adverse event (Rundmo, 2002; Sjöberg, 1998).

Risk tolerance is another important aspect of how individuals relate to risk. Individuals may differ in their thresholds for the level of risk they find acceptable. The original impetus for the psychometric paradigm came from Starr (1969), in his effort to answer the question 'How safe is safe enough?' He measured the level of risk that individuals found acceptable for different activities, and found that activities that were voluntary and perceived as beneficial were tolerated more than other activities. In a later study conducted by Fischhoff et al. (1978), respondents were asked to judge the acceptable level of risk associated with different activities or technologies, and the authors found that risk was less tolerated when the activities were associated with dread. They also found that higher risk levels were tolerated for voluntary activities with well-known and immediate consequences.

The terms 'acceptance' and 'tolerance' are often used synonymously. However, Sjöberg (1999) argues that risk tolerance and risk acceptance are two separate concepts. Risks are less likely to be accepted, and more likely to be tolerated. One may be aware of a certain risk and choose to tolerate it, even if one does not accept it. In the present study, we investigated risk tolerance among cyclists.

Cognitive models have dominated risk perception and decision-making research, but recently affective processes have received increased attention (Breakwell, 2007). The risk-as-feeling approach highlights the role of anticipatory and anticipated emotions for risk perception (Loewenstein et al., 2001). Anticipatory emotions are immediate visceral reactions to risk, such as worry, fear, anxiety, and dread, whereas anticipated emotions are emotions that the individual expects to have as a consequence of a decision. There are two types of anticipatory emotions: integral emotions and incidental emotions. Integral emotions are caused by the decision problem itself, whereas incidental emotions are caused by other factors, such as mood (Loewenstein and Lerner, 2003). In this article, worry is considered as an anticipatory emotion and integral to the decision problem, which implies that worry is defined as a feeling that emerges as a reaction to the individual's cognitive assessment of risk. Accordingly, the aim of this article is to examine the association between perceived risk and anticipatory feeling of worry about cycling.

Risk perception and worry are primarily of interest because they may relate to people's behavioural choices. According to the risk-as-feeling approach, behaviour is influenced by the interplay between

cognitive evaluations of risk and feelings. Further, emotions often produce behavioural responses that differ from the individual's cognitive assessment of the best course of action. When divergence occurs, it appears that behaviour is driven by emotional reaction, not by cognitive assessment (Loewenstein et al., 2001). Loewenstein et al. (2001) argue that in contrast to cognitive evaluations, anticipatory emotions such as worry and fear are largely insensitive to changes in probabilities. As an illustration, they refer to different experiments in which subjects were given information about probability estimates for winning a lottery, receiving an electric shock, or investing money. The experiments showed that changes in probability estimates did not influence the emotional state of the research subjects. The effect is known as the certainty effect, and it supports the risk-as-feeling hypothesis, which suggests that when making behavioural choices, people will be less affected by changes in probabilities of negative outcome, the more the consequences themselves evoke anticipatory emotions such as worry or fear.

Contrary to the findings of Loewenstein et al. (2001); Baron et al. (2000) found that worry was largely affected by probability judgements, especially among lay persons, and that their participants' desire for action largely was determined by worry and probability judgements. They used a questionnaire with a list of 32 different risks, each of them defined in terms of a cause and an outcome (e.g. injury or death from an automobile accident). For each risk, the respondent was asked (among other questions) to give probability estimates, to estimate the badness of the outcome, the number of persons affected, and how much he or she worried about the risk. A similar approach was adopted in the present study, and investigated the role of worry in addition to assessing probabilities and the severity of the consequences of an accident when cycling.

1.3. Risk perception, risk tolerance, and the feeling of worry among cyclists

The study of risk perception among cyclists has received little attention to date (Chaurand and Delhomme, 2013). Much of the research in this field has been conducted to aid engineers and planners in designing and improving infrastructure for cyclists. In most of these studies, cyclists were asked to rate their overall risk perception of a route described by video clips, simulations, or surveys. Manton et al. (2016) used mental mapping to study cyclists' risk perception. The respondents were asked to draw their regular route with different colours according to their perception of safety and risk. All the studies of risk perception among cyclists have in common to focus on perceptions on either the road infrastructure or the traffic (Lawson et al., 2013). Some researchers have investigated cyclists' risk perceptions relating to specific roads (Llorca et al., 2017), crossings, and roundabouts (Moller and Hels, 2008).

According to our knowledge, no studies to date have solely investigated risk perception among cyclists from a psychometric approach. However, previous studies have examined risk perception related to different travel modes. Moen and Rundmo (2006) and Oltedal and Rundmo (2007) included cycling as well as other travel modes when investigating risk perception. The respondents' perceived probability of being involved in an accident was found to be higher when cycling compared with when using other travel modes. However, the severity of the consequences of a bicycle accident was judged as lower. Another interesting finding was that the respondents reported they were more worried about experiencing an accident when cycling, compared with when travelling with other modes of transport.

Studies on risk perception are however difficult to compare due to the different ways used to measure the perceived risk. According to Cristea and Delhomme (2016), some studies measured only the probability of involvement in an accident, not the perceived consequences if an accident were to occur. Frings et al. (2012) and Moller and Hels (2008) asked their respondents to evaluate risk without asking about the probability or consequence of risk. Backer-Grondahl et al. (2009)

used worry as an ecological measure of risk perception.

Previously, researchers found differences in perception of risk and worry due to age, gender, and education. According to Breakwell (2007), several studies found that, compared with men, women in general assessed risks as higher (Bord and O'Connor, 1997; Dosman et al., 2001; Gustafson, 1998; Jenkins-Smith and Silva, 1998). Women are more concerned about traffic risks than are men (Moen and Rundmo, 2006), although data suggest that traffic risk measured by injuries and fatalities is lower for women (Melhuus et al., 2015). Lawson et al. (2013) studied gender differences in cyclists' perceptions of safety, and found that both males and females more often described cycling as less safe than driving, and that older women perceived cycling as less safe than did younger women. Manton et al. (2016) found that females perceived their regularly used cycling route as more dangerous than did men. Moen and Rundmo (2006) found that, in contrast to women, men scored lower on their perceptions of probability, on expected consequences, and on worry. They also found that individuals below the age of 25 years regarded the consequences of accidents as the least serious and were the least worried when travelling by private modes of transport (including bicycles). The same age group perceived the probability of being in an accident as the highest among all age groups. Individuals with a university degree perceived the same risk as lower than did others and were less worried about being involved in an accident.

To date, few studies have measured risk tolerance among cyclists. Parkin et al. (2007) developed a model based on a risk threshold and provided a measure of acceptability of different cycling routes. The model demonstrated how different infrastructure layouts lead to a reduction in the perceived risk and make the route acceptable for cyclists. Parkin et al.'s model also showed that young and elderly people considered cycling less acceptable than did people in the age group of 35–44 years, and that males considered cycling more acceptable than did females.

1.4. Travel mode choice and demand for safety

A number of studies have investigated demands for safety priority or risk mitigation related to choice of mode of transport (Nordfjaern and Rundmo, 2010; Rundmo and Moen, 2006; Simsekoglu et al., 2015; Sjöberg, 1999), and some of them have included cycling (Nordfjaern and Rundmo, 2010). Nordfjaern and Rundmo (2010) found that in Norway, the demand for risk mitigation and priorities related to transport safety increased significantly between 2004 and 2008. Demand for risk mitigation can be defined as the public's demands for decision-makers to reduce specific sources of transport risks (Moen and Rundmo, 2004). In the present study, we defined the demand for safety priority as demands made by the public to decision-makers to prioritize road safety for cyclists.

Furthermore, attitudes towards traffic safety have been found important for road user behaviour (Iversen and Rundmo, 2004, 2009; Nordfjaern and Simsekoglu, 2013). In the present study, we hypothesized that also attitudes affect cyclists' behaviour, such as their frequency of bicycle use. In this article, we focus on how attitudes towards traffic safety, risk tolerance, safety priority, risk perception, and worry are associated with the choice to use a bicycle as a mode of transport.

1.5. Aims of the study

The Governmental target for the largest Norwegian cities, that all future growth in individual travel should be accommodated by walking, cycling, and the use of public transport, calls for more knowledge about factors affecting mode choice. In order to facilitate future growth in demand for cycling all year around, special focus should be directed towards risk perception, to examine whether cyclists perceive that the risk of cycling in winter is different compared with cycling in summer, and to explore any correlations between risk perception and the choice

to travel by bicycle. Consequently, the main aim of the present study was to investigate how people perceived risk when cycling in winter compared with summer conditions. An additional objective was to investigate the association between perceived risk and the decision to cycle.

The specific aims were as follows: (1) to examine differences in cyclists' risk perception and worry when cycling in winter and summer conditions, (2) to investigate whether cyclists' risk perceptions and worry were related to their decision to cycle during wintertime, (3) to examine whether risk perception and worry were associated with cycling frequency during wintertime, (4) to compare the role of risk perception and worry for cycling frequency during all four seasons, and (5) to examine the direct and indirect associations between risk perception, worry, and cycling frequency during wintertime. Additionally, some other potential predictors for cycling frequency were included in the analyses as independent variables, namely demographics, attitudes towards traffic safety, safety priority, and risk tolerance.

2. Methods

2.1. Sample

The study was based on a questionnaire survey that was completed online through a website for cyclists in Trondheim Municipality in Norway during spring 2017. In 2017, the website had 2240 members. We invited all members to participate in the study, and the response rate was 13% ($n = 291$). All respondents reported that they cycled on a daily basis during summer. There were 36% females and 64% males in the sample. Their age ranged from 20 years to 77 years ($M = 43.47$, $SD = 11.73$). A total of 69% of the respondents reported they had more than three years of university education, 19% had three years or less of university education, and 11% had received their highest level of education at upper secondary school. A total of 88% reported that they were employed; the remaining 12% were students or pensioners. A total of 3% of the respondents reported that they did not have a driving license, and 17% did not have access to a car or to other motorized vehicles.

2.2. Questionnaire and measure instruments

The questionnaire (see Appendix A) asked the respondents to evaluate the probability of being injured in an accident when cycling and the severity of its consequences, their worry about being injured in an accident, risk tolerance, and safety priority when cycling in winter and summer conditions. Winter and summer conditions referred to the cycling conditions, not the season. Winter conditions refer to conditions with temperatures below zero degrees Celsius and when there is the potential for snow and ice, whereas summer conditions refer to conditions when the temperature is above zero degree Celsius. This definition was well understood by the respondents who answered the questionnaire, and is clearly defined in the Norwegian language – *vinterføre* versus *sommerføre*. The questionnaire also contained questions about attitudes towards traffic safety, frequencies of cycling during the four seasons, age, gender, employment status, highest level of completed education, driving licence, and motorized vehicles at the respondents' disposal.

To measure risk perception, the respondents were asked to assess their probability of experiencing an accident that involved injury when cycling, and to judge the severity of the consequences if such an event were to occur. The scale for measuring the probability assessments was a five-point evaluation scale ranging from 'not at all probable' to 'very probable'. For the judgement of severity of the consequences, the scale ranged from 'not at all serious' to 'very serious'. The respondents were also asked to rate how worried they were about being involved in an accident when cycling, and the measurement scale ranged from 'not at all worried' to 'very worried'. To measure risk tolerance, the

respondents were asked the following question: 'To what extent do you tolerate being exposed to risk when cycling?' The five-point evaluation scale ranged from 'tolerate the risk absolutely' to 'do not tolerate any risk'. To measure safety priority, the respondents were asked to assess the following question: 'How important do you think it is that the authorities prioritize measures to improve safety for cyclists?' The five-point scale ranged from 'not at all important' to 'very important'.

Attitudes towards traffic safety were measured by a 13-item instrument (Moen and Rundmo, 2006; Nordfjaern et al., 2014b). We tested a revised version that we especially designed for cyclists. The respondents were asked to what extent they agreed or disagreed with 13 different statements and give their responses on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree).

In addition, the respondents were asked how often they cycled each season (winter, spring, summer, and autumn). For this measurement, a six-point evaluation scale was applied: 5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; and Never. Previous studies of bicycle use in Norway have found the same measure appropriate (Kummeneje and Tretvik, 2015; Tretvik, 2015).

2.3. Statistical procedures

Confirmatory factor analysis (CFA) was conducted to test the dimensional structure of the respondents' attitudes towards traffic safety. A two-dimensional factor structure was included, and nine indicators were used to measure the factors. The analysis fulfilled Tabachnick and Fidell's criteria for an acceptable sample size (Tabachnick and Fidell, 2014). To test internal consistency, the reliability of the indices Cronbach's alpha and corrected inter-item correlations were applied. Paired sample t-tests were used to investigate differences in risk perception (probability and consequence of being in an accident), worry, risk tolerance, and safety priority, between cycling in winter conditions and summer conditions. To predict whether respondents used their bicycle during wintertime, a hierarchical logistic regression analysis was carried out. In addition, hierarchical regression analysis was used to predict the amount of cycling done in all seasons.

To test the fit of the data to the regression model, additional structural equation modelling (SEM) was done. To examine the fit of the model to the data, the root mean square error of approximation (RMSEA) and the comparative fit index (CFI) were used. In addition, the chi-square degrees of freedom ratio were calculated. (χ^2/df). In accordance with established criteria, an RMSEA of 0.07 or less was considered to indicate satisfactory fit between the model and the data. A CFI above 0.90 was considered to indicate satisfactory fit. The same was the case for an X^2/df ratio of 4:1. Standard criteria were used for the evaluation of RMSEA and critical N.

3. Results

3.1. Risk perception for winter and summer conditions

The paired sampled t-tests showed significant differences in the respondents' assessment of risk during winter and summer cycling conditions. This was also the case for the subjective assessments of the probability of an accident ($t = 5.837$, $p < 0.001$) and for how worried the respondents were being in an accident ($t = 6.786$, $p < 0.001$). The respondents perceived greater risks for cycling in winter conditions compared with cycling in summer conditions. However, it is interesting to note that there were no significant seasonal differences in the respondents' judgements of the severity of the consequences if an accident were to occur. Further, there were significant differences in risk tolerance ($t = 3.585$, $p < 0.001$) as well as priority given to safety ($t = -2.134$, $p < 0.05$). A high score on risk tolerance indicated low risk tolerance, and similarly a high score on priority given to safety indicated low priority. Table 1 shows that the respondents tolerated less risk when cycling in winter compared with cycling in summer

Table 1
Differences in risk perception when cycling in winter and summer conditions.

	Winter cycling conditions		Summer cycling conditions		t-value (Sig. 2-tailed)
	Mean	SD	Mean	SD	
Probability	2.98	1.099	2.67	1.013	5.837***
Consequence	3.24	.999	3.28	.952	-.980
Worry	2.65	1.230	2.29	1.030	6.786***
Risk tolerance	2.66	1.117	2.49	1.044	3.585***
Safety priority	4.52	.935	4.58	.950	-2.134*

*p < .05, **p < .01, ***p < .001.

conditions, and that they thought more priority should be given to safety when cycling in winter conditions compared with when cycling in summer conditions.

The standard deviations for all variables were relatively high and there were variations in the respondents' perceptions of risk for both cycling in summer conditions and cycling in winter conditions.

3.2. Dimensional structure of attitudes towards traffic safety among cyclists

Table 2 shows the results of a confirmatory factor analysis (CFA) for the 9-item measure of cyclists' attitudes towards traffic safety. Four of the original 13 items were excluded during the factor analysis because they did not load, thus resulting in two dimensions. The first dimension was called 'Attitudes towards traffic rules' and consisted of six items related to the respondent's evaluation of violations of the rules for pragmatic reasons, based on statements such as 'The traffic rules for cyclists are too complicated to adhere to in practice' and 'Many traffic rules for cyclists are unnecessary'. The second dimension was called 'Attitudes towards controlling cyclists' and was measured by three items, based on statements such as 'There should be more traffic surveillance for cyclists' and 'There should be severe punishments for cyclists who break traffic rules'. Two of the items in the dimension 'Attitudes controlling cyclists' were inverted before conducting the analysis (see Table 3). As shown in Table 2, the tested measurement instrument had feasible reliability (Cronbach's $\alpha = 0.831$ and 0.632). The SEM showed that the fit of the model to the data was satisfactory ($\chi^2/df = 3.52$, RMSEA = 0.095 , CFI = 0.95 , SRMR = 0.057 , Critical N = 139.03). However, although the RMSEA was above the criteria of 0.07 , all other fit measures were fully in accordance with accepted criteria.

The mean scores and standard deviations for the factors (Table 2) showed that the cyclists in the sample scored higher on the dimension 'Attitudes towards traffic rules' than on 'Attitudes towards controlling cyclists'. There were more statistical variations in the first dimension than in the second dimension.

A considerable number of cyclists reported attitudes that were not ideal. Ideal attitudes were those that disagreed with the statements. Table 3 shows that 30% of the respondents agreed on what were not ideal attitudes towards traffic safety. This concerned attitudes towards both traffic rules and controlling cyclists. In addition, a relatively large percentage of the respondents reported that they neither agreed nor disagreed with statements indicating ideal attitudes towards traffic safety. However, it is interesting to note that 43% of the respondents were in agreement in items showing ideal attitudes towards traffic rules and 46% had ideal attitudes towards controlling cyclists. A total of 50%

Table 2
Reliability and internal consistency and fit statistics of the model.

Dimensions	Number of items	Mean	SD	Cronbach's α	Corrected inter-item correlation, max, min	Average corrected inter-item correlation
Attitudes towards traffic rules	6	2.84	.801	.831	.685, .498	.603
Attitudes towards controlling cyclists	3	2.73	.729	.632	.687, .221	.456

of the respondents wanted more traffic surveillance for cyclists and 67% wanted more traffic safety campaigns to be implemented. Only 22% wanted punishments for cyclists who broke traffic rules.

3.3. Predictors of the decision to cycle during the winter season

Table 4 shows the results of a logistic regression analysis performed to identify winter cyclists. The independent variables were entered in six blocks, respectively demographics, attitudes (towards traffic safety), risk tolerance, priority given to safety, risk perception, and worry. Table 4 shows the Block χ^2 values after each block was entered, and the result after all of the blocks were entered (full model). Demographics (gender, age, and education level) were entered as controlling variables in the analysis as the first block (Block $\chi^2 = 13.73$, $p < 0.01$, Cox & Snell's $R^2 = 0.05$, Nagelkerke's $R^2 = 0.07$). Gender was found to be a significant predictor variable ($B = -1.01$, Wald = 12.01 , $p < 0.001$). Female respondents cycled less often than male respondents during wintertime. Age and educational level were not found to be associated with whether the cyclists used their bicycle during wintertime.

Attitudes towards traffic safety were not found significantly related to whether cyclists used their bicycle during winter. Adding risk tolerance significantly improved the model (Block $\chi^2 = 43.05$, $p < 0.001$, Δ Cox & Snell's $R^2 = 0.14$, Δ Nagelkerke's $R^2 = 0.20$). Risk tolerance for cycling in winter conditions increased the likelihood of cyclists using their bicycle during the wintertime. In addition, risk tolerance for cycling in summer conditions decreased their likelihood of cycling during wintertime. Next, the role of priority given to safety was investigated, which significantly improved the model (Block $\chi^2 = 9.64$, $p < 0.01$, Δ Cox & Snell's $R^2 = 0.02$, Δ Nagelkerke's $R^2 = 0.04$). The variables measuring safety priority significantly influenced whether the respondents used their bicycle during the wintertime. Additionally, risk perception significantly improved the model. However, the improvements to the model were modest with regard to probability assessments and to judgments of the severity of consequences (Block $\chi^2 = 9.85$, $p < 0.05$, Δ Cox & Snell's $R^2 = 0.03$, Δ Nagelkerke's $R^2 = 0.04$).

Finally, worry was added to the model and was found as an important predictor variable of winter cycling (Block $\chi^2 = 12.81$, $p < 0.01$, Δ Cox & Snell's $R^2 = 0.04$, Nagelkerke's $R^2 = 0.06$). Worry about cycling in winter conditions reduced cyclists' likelihood of cycling during winter. Thus, the results of the final block of the analysis showed that risk tolerance and worry were especially important for whether the respondents used their bicycle during the winter season. Additionally, perceived risk, priority given to safety, and gender were related to bicycle use during the wintertime. All of these variables lost prediction power after all of the blocks were entered into the model. This may indicate that these predictor variables had an indirect effect on the respondents' decision to cycle during wintertime.

3.4. Predictors for cycling frequency during the winter season

Respondents who used their bicycle during the wintertime were asked about the frequency of bicycle use. Accordingly, the next step in the analysis was to examine how the same group of predictors used in the logistic regression analysis predicted the frequency of bicycle use among that group. The independent variables were entered into the analysis in six blocks. The two final steps are presented in Table 5. In total, the predictor variables explained an acceptable percentage of variance ($R^2 = 0.32$). Among the demographic variables, only gender

Table 3
Dimensions of cyclists' attitudes towards traffic safety (%).

	Disagree	Neither agree/nor disagree	Agree
Attitudes towards traffic rules	43	28	30
It is no wonder that many cyclists violate traffic rules	25	31	44
Many traffic rules for cyclists are impossible to comply with	45	26	29
The traffic rules for cyclists are too complicated to adhere to in practice	50	27	23
Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving	34	20	46
It is more important to get ahead as a cyclist than always to follow the rules	63	20	17
Many traffic rules for cyclists are unnecessary	38	44	18
Attitudes towards controlling cyclists	46	23	31
There should be more traffic surveillance for cyclists (inverted)	50	23	27
There should be severe punishments for cyclists who break traffic rules (inverted)	22	28	50
It is not important to have road safety campaigns directed towards cyclists	67	18	16

Table 4
Predictors of cyclists' decision to cycle during wintertime (full model).

	Block χ^2 (df)	B	Wald	Odds ratio
Block 1: Demographics	13.73 (3)**			
Gender (male = 0, female = 1)		-0.36	0.90	0.70
Age		0.00	0.05	1.00
Education		0.36	1.98	1.44
Block 2: Attitudes	1.70 (2)			
Attitudes towards traffic rules		0.36	2.40	1.44
Attitudes towards controlling cyclists		0.28	1.22	1.32
Block 3: Risk tolerance	43.05 (2)***			
Risk tolerance, winter conditions		-1.09	13.42***	0.34
Risk tolerance, summer conditions		0.70	5.59*	2.01
Block 4: Safety priority	9.64 (2)**			
Safety priority, winter conditions		0.55	2.29	1.74
Safety priority, summer conditions		0.54	1.54	1.74
Block 5: Risk perception	9.85 (4)*			
Probability, winter conditions		-0.07	0.06	1.71
Probability, summer conditions		-0.09	0.09	0.93
Consequence, winter conditions		-0.24	0.77	0.92
Consequence, summer conditions		0.50	2.61	0.079
Block 6: Emotions	12.81 (2)**			
Worry, winter conditions		-0.64	6.29*	1.65
Worry, summer conditions		-0.04	0.03	0.53
Cox & Snell's R ²	0.29			
Nagelkerke's R ²	0.42			

Dependent variable 1 = cycle at least 1–2 times per week, 0 = cycle monthly, rarely, or never.

*p < .05, **p < .01, ***p < .001.

was found to be associated with cycling frequency in wintertime. Female respondents cycled less than male respondents during wintertime. The results showed that risk tolerance in both winter and summer conditions was the most important predictor of cycling frequency. The more the cyclists tolerated exposure to risk when cycling in winter condition, the more they cycled during the winter season. We found the opposite case for risk tolerance when cycling in summer conditions: the less the cyclists tolerated exposure to risk when cycling in summer conditions, the more they cycled during the winter. Additionally, safety priority was found to be related to cycling frequency during wintertime. The more important the respondent thought it was to prioritize safety for cyclists in winter conditions, the more they cycled during wintertime. When risk perception was added to the model, the explained variance significantly improved (Table 5). The less the cyclists perceived the probability being in an accident and the less serious they perceived the severity of consequences, the more they cycled during wintertime.

Additionally, worry related to cycling in winter conditions was found to be an important predictor of cycling frequency. The more

Table 5
Dimensions of cycling frequency during winter (standardized beta coefficient). The table shows the two final steps (Model 5 and 6).

	Model 5	Model 6
Block 1: Demographics		
Gender (male = 0, female = 1)	-.12*	-.11
Age	.05	.04
Education	.05	.07
Block 2: Attitudes		
Attitudes towards traffic rules	.13*	.12*
Attitudes towards controlling cyclists	.06	.07
Block 3: Risk tolerance		
Risk tolerance, winter conditions	-.45***	-.35***
Risk tolerance, summer conditions	.28***	.22*
Block 4: Safety priority		
Safety priority, winter conditions	.17*	.14
Safety priority, summer conditions	.01	.05
Block 5: Risk perception		
Probability, winter conditions	-.18*	-.06
Probability, summer conditions	.07	.03
Consequence, winter conditions	-.20*	-.15
Consequence, summer conditions	.15	.15
Block 6: Emotions		
Worry, winter conditions		-.29**
Worry, summer conditions		.06
R ²	.28	.32
F Change	4.294**	6.236**

*p < .05 **p < .01, ***p < .001.

worried the cyclists were, the less they used their bicycle during the winter season. Attitudes towards traffic rules were found to significantly influence bicycle use when the other variables were included in the model. When worry was included in the model, the risk-perception predictors (probability and severity of consequences) decreased significantly. This may indicate an association between the factors measuring worry and perceived risk, and that perceived risk could have an indirect effect on behaviour. Gender seemed to be a good predictor for cycling frequency as long as worry was not included in the model. This result may be related to gender differences in worry.

3.5. Predictors of cycling frequency during all seasons of the year

The next step in the analysis was to predict and compare cycling across all seasons. Four hierarchical multiple regression analyses were performed and the results are summarized in Table 6.

The model explained the largest amount of the variance in cycling frequency during winter (R² = 0.32). The model was least successful in explaining cycling frequency during summer (R² = 0.09). Thus, we did not find the model a good fit for predicting cycling frequency during summer. The model explained an identical amount of variance in cycling frequency during spring (R² = 0.15) and autumn (R² = 0.15). During these two seasons, both risk tolerance and risk perception were significantly associated with frequency of cycling.

Table 6
Predictors of cycling frequency in winter, spring, summer, and autumn.

	Winter		Spring		Summer		Autumn	
	R ²	F Change	R ²	F Change	R ²	F Change	R ²	F Change
Block 1: Demographics	.07	6.738***	.01	1.042	.02	2.056	.02	1.631
Block 2: Attitudes	.08	1.859	.02	1.182	.04	1.913	.04	2.727
Block 3: Risk tolerance	.22	21.979***	.07	6.393**	.05	2.371	.06	3.188*
Block 4: Safety priority	.23	3.026*	.08	1.330	.06	.686	.07	.422
Block 5: Risk perception	.28	4.294**	.13	4.049**	.08	1.726	.14	5.797***
Block 6: Worry	.32	6.236**	.15	1.914	.09	.849	.15	1.281

*p < .05, **p < .01, ***p < .001.

To summarize, the results showed that risk perception was significantly associated with cycling frequency during winter. However, perceived risk was not strongly related to cycling frequency during the other seasons. Additionally, worry was found important for cycling frequency, but only during winter.

3.6. Model for predicting cycling frequency during the winter season

We examined a path model for predicting frequency of cycling during the winter season (Fig. 1), which included both direct and indirect associations between risk perception (probability and consequence), worry, risk tolerance, attitudes towards safety, gender, and priority given to safety. Gender and safety priority were included as exogenous variables in the model. Risk perception, worry, risk tolerance, and attitudes towards safety were entered as mediating variables. The aim of the model was to predict cycling frequency during the winter season, which therefore was the endogenous variable. Due to lack of success in explaining cycling frequency during summer, autumn, and spring, the analysis was restricted to cycling during winter.

As shown in Fig. 1, worry was the strongest predictor of cycling frequency (B = -0.33): the more worried the respondents were, the lower was their cycling frequency. Other significant direct predictors of cycling frequency were safety priority (B = 0.18), risk tolerance (B = -0.15), and gender (B = -0.14). There was also a small but significant direct association between attitudes towards safety (B = 0.07) and cycling frequency. Risk perception was indirectly associated with cycling frequency by worry. The assessment of the probability of an accident (B = 0.44) contributed more to the variation in worry than did the perceived severity of consequences (B = 0.23). The model explained

38% of the variance in worry and 26% of the variance in cycling frequency. The fit of the model to the data was acceptable ($\chi^2/df = 0.97$, CFI = 0.99, SRMR = 0.038).

4. Discussion

4.1. General discussion

The results showed seasonal differences in cyclists’ perceptions of risk and worry when cycling. Their perception of risk was higher and they tended to be more worried about being involved in an accident when cycling in winter conditions compared with cycling in summer conditions. There were no differences in the perceived severity of consequences. With darkness and with icy and snowy roads in Norway, it is natural that cycling in winter may be perceived as a bigger challenge than in summer, and the probability of being involved in an accident in winter was judged to be higher. One reason why the consequences were not perceived as increased might have been that the type of accidents the cyclists imagined they could be involved in did not differ with winter and summer conditions. Novelty and familiarity associated with risk have been found to influence how people assess risk (Fischhoff et al., 1978). People perceptions of risks they are familiar with, may be lower than their perceptions of unknown risks. Most cyclists in Norway have experienced cycling in summer conditions, but fewer have experienced cycling in winter conditions, and this may influence how they perceive seasonal differences in risks.

Most of the serious accidents among cyclists in Norway happen during the summertime (Melhuus et al., 2015). One reason for this may be enhanced risk exposure, since more people cycle during the summer,

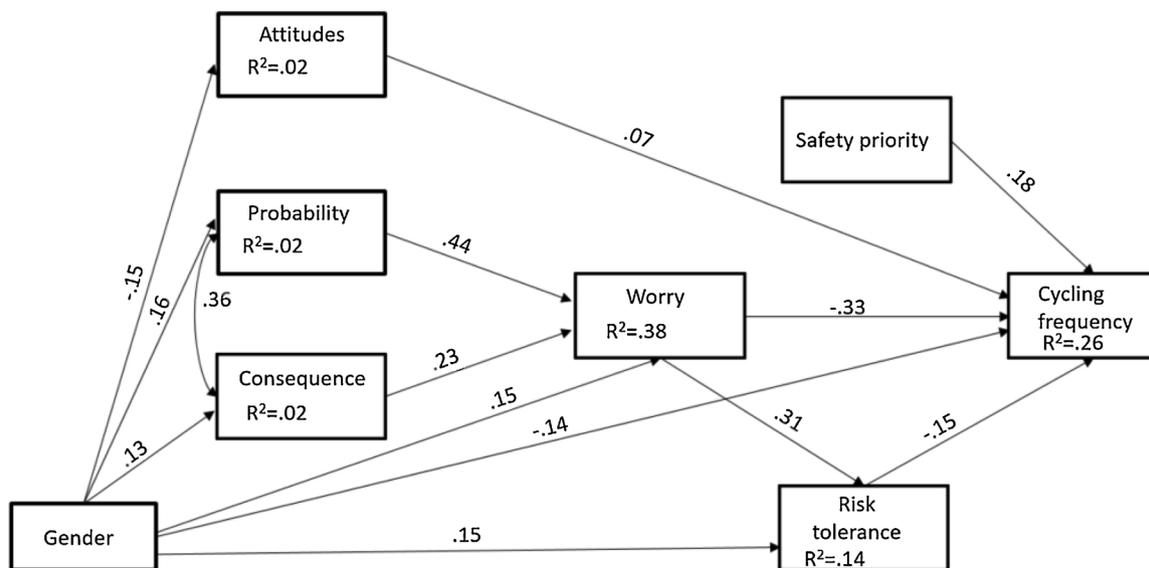


Fig. 1. Heuristic path model for predicting cycling frequency during the winter season.

resulting in higher numbers of accidents. Another explanation could be that people who cycle during the winter often cycle during all seasons of the year. It may be argued that such cyclists are more experienced and safer in traffic than cyclists who only cycle during the summer. It is interesting to note that in our study the respondents assessed the risk of being involved in an accident as higher when cycling in winter conditions than in summer conditions, although very few cycling accidents happen during the winter months. One explanation for fewer registered cycling accidents in winter might be that cyclists perceive the risk of being involved in an accident as high and therefore are more cautious when cycling in winter conditions.

The results showed that risk perception and worry were important factors in cyclists' decisions to cycle during the winter season. The assessment of risk had less influence on cycling frequency during the other seasons of the year. One possible explanation for this is that in general there is a very low perception of risk when cycling in summer conditions and that a cyclist has to experience that the risk is above their threshold before it will influence their behaviour. Finally, our findings showed that worry could be seen as an anticipatory integral emotion caused by the cognitive evaluation of risk, which is in accordance with findings by [Loewenstein et al. \(2001\)](#). The results showed that worry (as an emotion) influenced cycling frequency during the winter season. If the risk of being injured in a cycling accident was perceived as low, the cyclists tended to be less worried and worry did not influence their choice about whether to cycle. This difference emerged when cycling during winter was compared with cycling during the other seasons. The present study did not aim to investigate the role of anticipated emotions.

A further interesting finding was that women tended to tolerate risk less than did men and they were more worried and perceived the risk of accident as higher compared with men. This finding corresponds to findings from previous research ([Breakwell, 2007](#); [Moen and Rundmo, 2006](#)). Attitudes towards traffic rules had a small effect on cycling frequency during wintertime when controlled for the other variables in the analysis. Women had more ideal attitudes towards traffic rules than did men. In previous research, attitudes towards traffic rules have been found associated with risk-taking behaviour in traffic ([Iversen and Rundmo, 2004, 2009](#); [Nordfjaern and Simsekoglu, 2013](#)).

4.2. Methodological discussion

The response rate the present study was low and can be seen as a limitation. Relatively low response rates are common in transport population studies (e.g. [Backer-Grondahl et al., 2009](#); [Castanier et al., 2012](#); [Moan, 2013](#)) probably partially due to the low immediate personal salience of the research topic ([Galea and Tracy, 2007](#)). Furthermore, web surveys have been found to have lower response rates compared with postal surveys ([Shih and Xitao, 2008](#)). However, low response rates do not necessarily constitute a methodological problem. This is only the case if the overall sample is not representative of the target population ([Krosnick, 1999](#)). The target group of the present study was cyclists who cycled on a daily base. We assumed that people who often cycled visited the web page (i.e. where the respondents were recruited) more often than did those who cycled less often. It is natural to assume that users of the web page who never cycled or rarely cycled, would have had little interest in visiting the web page with discussions on topics related to cycling (i.e. cycling conditions, weather, closed roads, infrastructure, maintenance of the roads). When we compared the study sample with the target population we found similarities in the demographic characteristics. In the present study, 69% of the respondents reported they had more than three years of university education. This finding is in accordance with [Hjorthol et al. \(2014\)](#), who found that persons with university education cycled more than others did. [Hjorthol et al. \(2014\)](#) found no gender differences in cycling activity among Norwegians, which is in contrast with the present study where 65% of the sample were men.

According to [Iversen and Rundmo \(2002\)](#), it is important to consider the social and situational context of risk assessments. For example, media coverage of related topics could influence how a population assesses risk. In Norway, cycling accidents account for 10% of people killed and injured in traffic ([Statistics Norway, 2017](#)). There has been little media focus on cycling accidents compared with other types of road accidents. The media not only cover traffic accidents, but also politicians, road authorities, and researchers, who communicate their views on the risks of cycling to the public. For example, the Norwegian Public Roads Administration communicates information about safety winter cycling in the media. Thus, interesting topics for future research are the way the media, road authorities, and researchers influence cyclists' risk perceptions in general, and particularly how cyclists' perceptions of risk are influenced by whether they cycle in different seasonal conditions.

Worry was in the present study found to be a consequence of risk perception. As well as being a consequence of perceived risk, people's risk perceptions may be influenced by feelings. However, the present study did not intend to investigate the role of anticipated affect. For future research, it would be interesting to investigate whether the emotional state of cyclists influences their perception of risk. Another interesting future research path would be to explore how different winter operational standards and procedures affect risk perception among cyclists. Other than accidents, perceived risk when cycling in winter conditions may be influenced by factors such as discomfort (even extreme discomfort) and the potential for adverse health impacts of cycling in winter conditions. We did not study these factors, but they would be worth considering in future research.

The results of the present study may be transferable to other places in Norway that have similar weather conditions during the year as Trondheim, and to other countries with snow and darkness during the winter months. Trondheim has the highest number of daily cyclists in Norway and a comprehensive focus on winter cycling. Other places in Norway where fewer trips are made on bicycles may benefit from the results from Trondheim with respect to increasing the numbers of cyclists.

5. Conclusions

The present study have shown that there are seasonal differences in how cyclists perceive the risk and how worried they are about being involved in an accident. As expected, cyclists perceived the latter risk as higher and were more worried being in an accident when cycling in winter conditions compared with when cycling in summer conditions. Structural equation modelling showed that risk perception was a significant predictor of worry, and worry predicted cycling frequency during the winter season.

The results of our study contribute to an understanding of why cyclists cycle less during the winter than in other seasons of the year. From a pro-environmental perspective, it is important that people who use bicycles for their daily travels do not change to motorized modes of transport during the winter season. Campaigns aimed at increasing the number of cyclists could be ineffective if they do not take into account that the risk of being involved in an accident is perceived differently for the different seasons of the year. When encouraging people to cycle more often, it is important to bear in mind that not only should bicycles be safe to use. Bicycles should also be perceived as safe to use by the road users. To increase the number of winter cyclists, it is important to take into account that there were no seasonal differences in the perceived severity of the consequences of involvement in an accident, and that the respondents perceived the probability of being in an accident as higher when cycling in winter conditions than in summer conditions, although fewer accidents occur during winter. This result may be a starting point to guide governments when planning interventions and public health sensitization programmes.

Appendix A

Questionnaire about risk perception and travel behaviour among cyclists

1 Have you used your bicycle once or more during the last year? (yes; no)

If you have answered that you have used your bicycle once or more during the last year:

- 2 How often do you cycle during ...
- Winter (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
 - Spring (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
 - Summer (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
 - Autumn (5 or more times per week; 3–4 times per week; 1–2 times per week; Monthly; Rarely; Never)
- 3 How probable do you think it is that you will experience an accident with injury when cycling in ...
- Winter conditions (1 = not at all probable; 5 = very probable)
 - Summer conditions (1 = not at all probable; 5 = very probable)
- 4 If you experienced an accident, how serious do you think the consequences would be when cycling in ...
- Winter conditions (1 = not at all serious; 5 = very serious)
 - Summer conditions (1 = not at all serious; 5 = very serious)
- 5 How worried are you being involved in an accident when cycling in ...
- Winter conditions (1 = not at all worried; 5 = very worried)
 - Summer conditions (1 = not at all worried; 5 = very worried)
- 6 To what extent do you tolerate being exposed to risk when cycling in ...
- Winter conditions (1 = tolerate the risk absolutely; 5 = do not tolerate any risk)
 - Summer conditions (1 = tolerate the risk absolutely; 5 = do not tolerate any risk)
- 7 How important do you think it is that the authorities prioritize measures to improve safety for cyclists cycling in ...
- Winter conditions (1 = not at all important; 5 = very important)
 - Summer conditions (1 = not at all important; 5 = very important)
- 8 To what extent do you agree or disagree with the following statements? (1 = strongly disagree; 5 = strongly agree)
- Many traffic rules for cyclists are impossible to comply with
 - Sometimes it is necessary to bend the rules as a cyclist to make sure of arriving
 - Cyclists should always follow the rules
 - Cyclists who never violate the rules do not necessarily behave more safely than others
 - It is no wonder that many cyclists violate traffic rules
 - The traffic rules for cyclists are too complicated to adhere to in practice
 - Many traffic rules for cyclists are unnecessary
 - There should be more traffic surveillance for cyclists
 - There should be severe punishments for cyclists who break traffic rules
 - It is not important to have road safety campaigns directed towards cyclists
 - It is OK to bend the rules if no other road users are present
 - It is OK to cycle after drinking alcohol
 - It is more important to get ahead as a cyclist than always to follow the rules
- 9 Gender? (male; female)
- 10 Year of birth? (year)
- 11 Highest level of education completed? (1 = primary or lower

secondary school; 2 = upper secondary school; 3 = three years or less of university education; 4 = more than three years of university education)

12 Employment status? (1 = employed; 2 = student; 3 = pensioner; 4 = other)

13 Do you have a driving licence? (yes; no)

14 Do you have a motorized vehicle at your disposal? (yes; no)

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