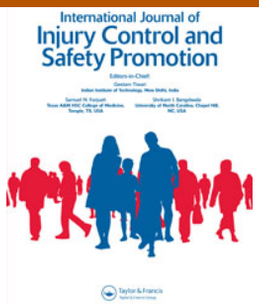

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Gender differences in cyclists' crashes: an analysis of routinely recorded crash data

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ABSTRACT

Previous research on gender differences in road crashes has focussed uniquely on car drivers and there has been little research examining such differences among cyclists. In this study, we investigated gender differences in bicycle crashes, using routinely recorded crash data. The present paper focussed on characteristics related to the type of crashes (type of collision and opponent vehicle), the infrastructure (road type and type of road segment), the environmental (season, road surface condition and weather) and time period (time of the day and day of the week). Results revealed that, compared to women cyclists, men cyclists were more likely to be involved in a crash regardless the cyclists' age. Moreover, we found gender differences in terms of type of road segment, type of opponent vehicle, type of manoeuvre of the opponent vehicle and of the cyclists, type of collision, time of the day, day of the week and season.

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Cycling; gender differences; crash; fatality; injury; road safety

Introduction

Cycling is being encouraged because is considered both healthy (Götschi, Garrard, & Giles-Corti, 2016; Kelly et al., 2014) and environment-friendly mode of transportation (de Nazelle et al., 2011; Macmillan et al., 2014; Xia, Zhang, Crabb, & Shah, 2013). However, cyclists are considered minority road users for several reasons (Prati, Marín Puchades, & Pietrantoni, 2017) and cycling is linked to safety concerns (Heinen, van Wee, & Maat, 2010; Prati, Marín Puchades, De Angelis, Fraboni, & Pietrantoni, 2018; Schepers, Hagenzieker, Methorst, van Wee, & Wegman, 2014). To this end, safety considerations contribute to raising barriers to cycling and its promotion (Jacobsen & Rutter, 2012) and researchers have begun to focus their attention on cyclists' accidents and their contributory factors (Prati et al., 2018). Research suggests that men and women differ in terms of risky behaviour and involvement in accidents, including road crashes (Al-Balbissi, 2003; Cordellieri et al., 2016; Factor, Mahalel, & Yair, 2008; Massie, Campbell, & Williams, 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamariña-Rubio, Pérez, Olabarria, & Novoa, 2014; Tom & Granie, 2011; Williams & Shabanova, 2003). However, much research has focussed uniquely on car drivers (e.g. Elvik, Vaa, Erke, & Sorensen, 2009) and there has been little research examining gender differences in cycling crashes (e.g. Cordellieri et al., 2016).

In the present study, we focus on gender differences in characteristics of bicycle crashes. We used data on cyclists' crashes in Italy, which can be considered a country with low-cycling culture or emerging cycling culture (Aldred & Jungnickel, 2014; Oosterhuis, 2016). Compared to cyclists in other European countries, Italian cyclists tend to report positive attitudes towards cyclists but also the lowest ratings on infrastructure quality and provisions (Prati et al., 2019). According to the Special Eurobarometer 422a – Quality of transport (European Commission, 2014), bicycle is the most used mode of transport in Italy for 8% of women and for 4% of men. However, when it comes to sport or recreational cyclists in Italy, the number of men cyclists is about 2.4 per 100 inhabitants, while among women cyclists is 0.4 per 100 inhabitants (ISTAT, 2005, 2017).

Although our investigation was largely exploratory, we advanced general hypotheses, based on the previous research in other contexts. Given the focus of the present research it is critical to define 'gender', particularly as contrasted with 'sex'. Sex refers to a person's biological sex (e.g. genitals and secondary sex characteristics), while gender refers to the psychological, social and cultural aspects that influences the sense of being a girl or a boy as well as a woman or man (Oakley, 1991). The terms feminine and masculine are used to refer to the qualities that a society considers to be typical of women or men, respectively (Oakley, 1991).

Gender differences in likelihood of involvement in a fatal crash

Even though the relative rates of involvement in injury is higher for women than for men (Elvik et al., 2009), there is evidence that men road users are at a higher risk of

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experiencing a fatal crash (Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Santamariña-Rubio et al., 2014; Sospedra-Baeza, 2018). Literature also suggests that gender differences in crash involvement are moderated by drivers' age. Young women drivers tend to have a lower average crash rate than young men drivers, whereas the reverse is true among drivers above 30 years of age (Elvik et al., 2009). A cross-sectional study looking at unsafe behaviours and crash involvement of Italian cyclists (Marín Puchades, Pietrantoni, Fraboni, De Angelis, & Prati, 2018) found men reporting of being involved in near crashes and crashes more frequently than women. The authors were not able to find gender differences in unsafe cycling behaviours. Another study based on crash data highlighted that in Italy men cyclists are more likely to sustain a fatal injury than women cyclists (Prati, Pietrantoni, & Fraboni, 2017) and that gender differences gets more pronounced in urban municipal roads. In addition, another study conducted in Spain found that the risk of severe or, especially, fatal injury is significantly higher among men cyclists than among women cyclists (Santamariña-Rubio et al., 2014). Due to the low numbers of cyclists injured, the authors did not investigate whether an interaction between sex and age of cyclists in fatality risk exists. Thus, the present study also aims to explore the gender differences among cyclists in fatality risk, while taking into account potential age-related effects. Based on the evidence, we expect that the risk of suffering a fatal injury is higher for young men cyclists than for young women cyclists (Hypotheses 1).

The effect of gender differences in mobility patterns

Gender differences in cycling crashes may be related to differences in mobility patterns which are a function of cycling culture or utilitarian cycling culture (Garrard, Handy, & Dill, 2012). Gender equality and, more specifically, the traditional sexual division of labour (e.g. housework and caring duties) influence women's participation in transport cycling (Prati, 2018). Given the scarcity of studies examining gender differences in mobility patters of cyclists in Italy, it is interesting to look at studies made in other countries as well. Specifically, it was found that women cycle shorter distances than men (Heinen et al., 2010). In particular, the mean distance of women cyclists from the city centre tends to be less than that of men cyclists (Garrard, Rose, & Lo, 2008), suggesting that women cyclists tend to use the bicycle mainly in the urban context. Therefore, we may expect that women cyclists may be likely to be involved in crash on urban roads compared to men cyclists (Hypothesis 2). In addition, cycling in daylight conditions is more common than in darkness and this difference is more pronounced in women cyclists compared to men cyclists (Bergström & Magnusson, 2003; Heesch, Sahlqvist, & Garrard, 2012). Thus, we may expect that men cyclists may be less likely to be involved in crash during daytime (Hypothesis 3). In a study about gender differences in commuting, Cristaldi (2005) found that Italian women tend to commute on foot or by bike more than men (especially in the North) and argued that the commuting patterns of Italian women tend to align with those of Western countries. In general, women cyclists tend to use the bicycle for non-commuting trips such as travelling with children and shopping (Garrard et al., 2012), while men are overrepresented among Italian sport and recreational cyclists (ISTAT, 2005, 2017). Regarding the latter, there is clear evidence that sport and recreational cyclists account for the majority of bicycle trips on week-end compared to week days (Amoros, Chiron, Thélot, & Laumon, 2011; Billot-Grasset, Viallon, Amoros, & Hours, 2014; Spotswood, Chatterton, Tapp, & Williams, 2015). Considering all the evidence gathered so far, we expect that, compared to women cyclists, men cyclists will be more likely to be involved in crashes on weekends (Hypothesis 4). Since sport and recreational cyclists are more likely to ride on rural roads and during summer (Amoros et al., 2011; Blaizot, Papon, Haddak, & Amoros, 2013; Buning, Cole, & Lamont, 2019), we expect that, compared to women cyclists, men cyclists will be more likely to be involved in crashes during summer (Hypothesis 5).

The effect of gender differences in risky behaviours, violations and errors

Cultural factors may play a major role in explaining gender differences in the occurrence of risky behaviours (i.e. behaviours that have the potential to be a contributing factor to crashes, such as speeding, distracted cycling or errors) and violation of regulations among road users (Santamariña-Rubio et al., 2014). For example, it is interesting to mention the concept of hegemonic masculinity proposed by Connell (1995) which refers to how and why men maintain dominant social roles over women, and other 'feminine' identities, in a given society, through practices that legitimizes powerful men's dominant position. Specifically, ideals of hegemonic masculinity are likely to encourage the development of a traditional heterosexual masculine identity which is associated with the adoption of such kinds of behaviours. Indeed, risky driving style is associated with masculinity, while safety skills increase as a function of femininity (Özkan & Lajunen, 2005, 2006). In addition, gender differences in road safety attitudes and perceived risk (Cordellieri et al., 2016; Frings, Rose, & Ridley, 2012; Rhodes & Pivik, 2011) may explain the excess of risky behaviours or violations in men road users compared to their women counterparts (e.g. Al-Balbissi, 2003; Feenstra, Ruiter, Schepers, Peters, & Kok, 2011; Nallet, Bernard, & Chiron, 2010; Özkan & Lajunen, 2006; Rhodes & Pivik, 2011; Tom & Granie, 2011; Turner & McClure, 2003). Albeit scant, there is some evidence to suggest that violations and risk-taking behaviours are more frequent among men cyclists than women cyclists. For instance, men cyclists engage more frequently in non-compliant behaviour than women, such as ignoring the traffic signals (Bernhoft & Carstensen, 2008; Johnson, Newstead, Oxley, & Charlton, 2013; Yan, Ma, Huang, Abdel-Aty, & Wu, 2011), cycling without helmet and cycling without appropriate lights in the night (Cobey, Stulp, Laan, Buunk, & Pollet, 2013). Therefore, we hypothesize that, compared to women, men cyclists are more likely

to be involved in road crashes in which a cyclists' violation of rules is committed (Hypothesis 6).

The effect of hegemonic masculinity on road users' behaviour

In considering the concept of hegemonic masculinity to hypothesize the more or less risky behaviour of one gender rather than the other, it is possible to extend this notion to the type of interactions between road users. Hegemonic masculinity is constructed on superiority of one gender over the other (Connell, 1995). In other words, cultural characteristics of hegemonic masculinity may have an influence on road users' behaviour when sharing the road with cyclists (already at risk of being considered vulnerable road users). Although in Italy hegemonic masculinity is not present in the majority of men, it is normative (Magaraggia, 2013). Despite findings from Walker (2007) might suggest that drivers tend to be more cautious (i.e. giving more later space) when overtaking cyclists with feminine characteristics, we would argue that the normative effect of the hegemonic masculinity would be more prevalent in the Italian context (Magaraggia, 2013). As a consequence, we hypothesize that, compared to men, women cyclists are relatively more likely to be involved in crashes in which the opponent vehicle did not respect the priority rules (Hypothesis 7).

The effect of gender differences in cycling behaviours

In a study conducted among a sample of 4596 UK cyclists, women cyclists were found to be overrepresented in the number of fatal collisions involving heavy-goods vehicles compared to men cyclists (Frings et al., 2012). The majority of such fatal collisions are related to the so-called right-hook scenario (or left-hook for right-side driving countries) in which a cyclist, attempting to overtake an heavy-goods vehicles on the nearside at junctions, remains undetected by the truck driver and thus gets run over. Although in general, women cyclists appeared to perceive cycling as riskier than men, they were more likely to underestimate the risks involved with overtaking heavy-goods vehicles (Frings et al., 2012). Therefore, we hypothesize that gender will influence the type of the crash with women being more susceptible to crashes with heavy-goods vehicles than men cyclists (Hypothesis 8).

Our last hypothesis derives from the results of a study on bicycle-vehicle interactions at intersections using video-based data (Stipancic, Zangenehpour, Miranda-Moreno, Saunier, & Granié, 2016). The study found that women cyclists were more likely than men cyclists to be involved in dangerous conflicts with vehicles at intersections. Therefore, we expect that women cyclists are more likely to be involved in bicycle crashes at intersections compared to men (Hypothesis 9).

Method

Data

To investigate gender differences, we used data on cyclists' crashes gathered from the Italian National Institute of Statistics (ISTAT). This database is the result of a combined action from different stakeholders and public institutions that collect and provide information and descriptions of all road crashes: Italian Ministry of Transport and Infrastructure, local Municipalities, National Police agencies, Italian Automobile Club, as well as the ISTAT. The dataset includes all modes of transport and every road crash that has been reported to one of the institutions above mentioned. Data from the ISTAT were fully anonymized before we accessed them.

We focused on those road crashes that happened between 2011 and 2013 with a total number of 575,093 road crashes that occurred on the Italian roads. We decided to select this specific time interval for two main reasons. Firstly, the 2013 database was the most recent available ISTAT data at the time of the study. Secondly, a three-year period database allowed us to analyze a large sample and, at the same time, to control for changes in traffic regulations. Indeed, the latest change to the national traffic law dated back to 2010 (Law 29/7/2010 n. 120), where minor changes involving bicycle use were present.

The ISTAT database registered and classified all the road crashes considering the mode of transport involved. For the purposes of the current research, we extracted 49,621 crashes in which at least one cyclist ended up injured or killed. The ISTAT database differentiates between crashes that result in injuries or fatalities (within 30 days from the crash).

We compared the relevant data based on the following road crash characteristics: type of road segment, type of road, type of opponent vehicle, opponent vehicle manoeuvre, cyclist's manoeuvre, type of collision, time of the day, day of the week, season, road surface condition and weather. Concerning type of road, according to the Italian Road Code, urban municipal roads are inside urban communities with more than 10,000 inhabitants and are different from national, regional and provincial roads that are inside urban communities with fewer than 10,000 inhabitants. Rural roads are outside urban communities.

Statistical analysis

A series of chi-square tests was used to examine gender differences for each characteristic of bicycle crashes. To account for multiple testing, we used the Bonferroni adjustment procedure and only probability values equal to or less than .005 were considered significant. A cell-by-cell comparison of observed and estimated expected frequencies was used to understand the nature of the association. Specifically, when the data conform to a 2×2 table, we reported odds ratio. In case of a $2 \times k$ table, to identify those specific cells making the greatest contribution to the chi-square test finding, we calculated standardized residuals

(Agresti, 2013). As the standardized residual is a z-score, if the value exceeds ±1.96 then the null hypothesis is rejected at the $\alpha = .05$ significance level, if it exceeds ±2.58 then the null hypothesis is rejected at the $\alpha = .01$ significance level, and if it exceeds ±3.29 then the null hypothesis is rejected at the $\alpha = .001$ significance level. As MacDonald and Gardner (2000) have suggested, we applied a Bonferroni adjustment to the z critical of 1.96 to take into account the number of cells in the contingency table.

Chi-square analyses were used to test all the hypotheses, except Hypothesis 1 because it involved three variables. Specifically, we tested Hypothesis 1 using a three-way loglinear analysis to investigate gender differences among cyclists in fatality risk, while also considering age-related effects (gender × severity × age).

Although there is no clear distinction between dependent and independent variable in both chi-square and log-linear, according to the proposed theoretical background, gender was considered the independent variable. In chi-square analyses, each crash characteristic was considered as dependent variable. In the three-way loglinear analysis, the outcome of the crash (non-fatal versus fatal injury) was considered dependent variable, while age was conceptualized as moderating variable.

To determine effect size for a chi-square test of independence, we used the phi coefficient (Φ) when the data conform to a 2 × 2 table and Cramer's V in case of a 2 × k table. According to Cohen (1988), phi values and Cramer's V values (in a 2 × k table), of .10, .30 and .50 correspond to an effect size that could be described as small, medium and large, respectively. In case of a 2 × 2 table, we also calculated odds ratios. Rosenthal (1996) proposed the following qualitative size categories for odds ratios: about 1.5 = small effect (or weak association), about 2.5 = medium (or moderate), about 4 = large (or strong) and about 10 = very large (or very strong).

Results

To examine gender differences among cyclists in fatality risk while also considering age-related effects (Hypothesis 1), we conducted a three-way loglinear analysis (gender × severity × age). Results showed that while the higher-order interaction (gender × severity × age interaction) was not significant, χ^2 (5) = 1.56, $p = .906$, the relationship between gender and severity proved significant, χ^2 (1) = 85.76, $p < .001$, $\Phi = -.04$. Odds ratios (0.43, 95% CIs = 0.36, 0.52) indicated that the odds of fatal injury were 2.33 times higher among men cyclists compared to women. These findings partially support the Hypothesis 1, men cyclists are at a higher risk of suffering a fatal crash than women, regardless their age.

Regarding Hypothesis 2, gender was associated with types of road, χ^2 (2) = 984.84, $p < .001$, $V = .14$. Standardized residuals in S1 Table indicated that the odds of having a crash on urban roads were more likely among women cyclists, while the men cyclists were more prone to have a crash on rural roads and on urban provincial, regional and national roads. Thus, Hypothesis 2 was supported.

Concerning Hypothesis 3, gender was related to the time of the day in which the cycling crash took place, χ^2 (3) = 223.48, $p < .001$, $V = .07$. Standardized residuals in S2 Table indicated that men cyclists were more likely to be involved in a crash during evening or late night, while women cyclists were more likely to have a crash during daytime. Thus, Hypothesis 3 was supported.

Women and men cyclists had a different likelihood of being involved in a crash during the weekdays and weekend (Hypothesis 4), χ^2 (1) = 285.85, $p < .001$, $\Phi = -.08$. Specifically, odds ratios (0.66, 95% CIs = 0.63, 0.69) indicated that the odds of a cycling crash during the weekend were 1.52 times higher among men cyclists compared to women. Therefore, Hypothesis 4 was supported.

Results for Hypothesis 5 indicated that gender was associated with the season in which the cycling crash took place, χ^2 (3) = 19.85, $p < .001$, $V = .02$. Standardized residuals in S3 Table revealed that women cyclists were more likely to report a crash during autumn, while men cyclists during summer. Therefore, Hypothesis 5 was supported.

We conducted a chi-square goodness-of-fit test of the manoeuvre of the cyclist involved in the crash to examine gender differences in violation of regulations (Hypothesis 6). The test showed that the manoeuvre of the cyclist involved in the crash differed by gender χ^2 (9) = 48.68, $p < .001$, $V = .03$. Standardized residuals in S4 Table indicated that men cyclists were more likely to have a crash while overtaking and speeding. Therefore, this finding provided support for Hypothesis 6.

The type of manoeuvre of the opponent vehicle was different according to the gender of the cyclist involved, χ^2 (6) = 31.58, $p < .001$, $V = .04$. Standardized residuals in S5 Table indicated that women cyclists had a greater odd of having a collision with a vehicle turning right, ignoring a stop sign, or a red traffic light. This finding supports Hypothesis 7 that women cyclists are more likely to be involved in crashes in which the opponent vehicle did not respect the priority rules.

Concerning Hypothesis 8, gender was related to type of opponent vehicle, χ^2 (6) = 31.58, $p < .001$, $V = .03$. Standardized residuals in S6 Table showed that women cyclists were more likely to have a collision with a car and a bus. Men cyclists were more likely to be involved in collisions involving multiple vehicles and in crashes where no other road user was involved. This finding failed to support Hypothesis 8.

Finally, regarding Hypothesis 9, the relationship between gender and type of road segment was significant, χ^2 (2) = 23.85, $p < .001$, $V = .02$. Standardized residuals in S7 Table indicated that women cyclists were more likely to have a crash at crossroads, while men cyclists were more likely to have a crash in other road sections. There were no gender differences for crashes at roundabouts. Therefore, Hypothesis 9 was supported.

Discussion

The present study aimed to investigate gender differences in cycling crashes by analysing routinely recorded crash data

gathered from the ISTAT.Past studies examined gender differences in crash rate and driving behaviour of road users (e.g. Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamariña-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003). Nonetheless, studies that would focus solely on the population of cyclists are lacking and the present paper tries to fill in this gap.

First, consistent with previous research on road users (e.g. Al-Balbissi, 2003; Cordellieri et al., 2016; Factor et al., 2008; Massie et al., 1995; Pulido et al., 2016; Rhodes & Pivik, 2011; Santamariña-Rubio et al., 2014; Tom & Granie, 2011; Williams & Shabanova, 2003), we found that men cyclists are 2.33 times more likely to suffer a fatal injury than women (Hypothesis 1). Concerning Hypothesis 1, however, the results do not suggest any interaction between age and gender in determining the severity of cycling crashes (Elvik et al., 2009). Regardless of age, men cyclists are more likely to be involved in a fatal crash compared to women. These gender differences could be explained by social and cultural factors that account for gender differences in mobility patterns, risk perception, attitudes and risky behaviours (e.g. Al-Balbissi, 2003; de Winter & Dodou, 2010; Nallet et al., 2010; Özkan & Lajunen, 2006; Prati, 2018; Rhodes & Pivik, 2011; Tom & Granie, 2011). Concerning mobility patterns, we found that men cyclists are more likely to be involved in crashes in rural areas (Hypothesis 2) and previous research documented that, in Italy, the risk of fatal injury is higher in rural areas than in urban areas (Prati, De Angelis, Marín Puchades, Fraboni, & Pietrantoni, 2017; Prati, Pietrantoni, et al., 2017). In the present study, we also found some evidence of systematic differences across gender in risky behaviours and violations (Hypothesis 6). Compared to women, men cyclists were more likely to be involved in a crash while travelling too fast and overtaking. Sport cycling generally means riding faster (Blaizot et al., 2013), and thus it is possible to expect more frequent and more severe injuries in the population that practices it. Higher speed presents an increased risk of severe bicycle-vehicle conflict which may in turn explain a higher rate of fatal crashes among men cyclists (Stipancic et al., 2016). Consistent with these findings, in the present study, men cyclists were more likely to be involved in a crash while travelling at high speeds (S4 Table). However, no evidence of gender difference was found for the following violations: not keeping a safe distance, ignoring stop signs or red traffic lights, not respecting the right of way, and driving in a forbidden direction or on opposite sides of the road. The lack of difference may suggest that women are closing the gap to some extent. There is evidence that some groups of women drivers (young women in particular) were found to be increasingly involved in risk-taking behaviour and violations (Romano, Kelley-Baker, & Voas, 2008).

Finally, men are highly over-represented among sport and recreational cyclists in Italy (ISTAT, 2005, 2017). As such, they are more likely to ride on rural roads (Hypothesis 2), on weekends (Hypothesis 4) and during the summer (Hypothesis 5). Indeed, our results reveal a higher occurrence of crashes among men cyclists on weekends and during the summer period. Severity of bicycle crashes results higher on rural roads than on urban roads, which may also be an explanation for a higher occurrence of fatal crashes among men (Boufous, de Rome, Senserrick, & Ivers, 2012; Moore, Schneider, Savolainen, & Farzaneh, 2011; Prati, De Angelis, et al., 2017; Prati, Pietrantoni, et al., 2017). Ideals of hegemonic masculinity shape the patriarchal character of sport in Western countries (e.g. Adams, Anderson, & McCormack, 2010; Bryson, 1987; Connell, 1995; Dunning, 1986; Koivula, 1999; Wellard, 2002) and this can explain why men cyclists are over-represented among sport or recreational cyclists and, in turn, are more likely to be involved in a crash on rural roads, on weekends, and during summer.

As already mentioned, we presume that such gender differences in mobility patterns, risk perception, attitudes and risky behaviours derive from a socially constructed ideas about masculinity and femininity that are specific to the Italian culture (Beall, 1993; West & Zimmerman, 1987). The development of a traditional masculine identity that stems from ideals of hegemonic masculinity is indeed associated with risky behaviours and violation of regulations (Santamariña-Rubio et al., 2014). Moreover, the concept of hegemonic masculinity may also present a threat to women cyclists in certain situations. In the present study, consistent with the cultural norms of hegemonic masculinity in the Italian context (Magaraggia, 2013), we found that women cyclists are more likely to be involved in road crashes where the opponent vehicle did not respect the priority rules (Hypothesis 7). Such result suggests that in the societies with high masculinity it may be less important to respect the priority rules when the cyclist is a woman.

Second, women cyclists are more likely than men to be involved in crashes at crossroads (Hypothesis 9), and in crashes due to a right-turn (nearside turn) manoeuvre of the opponent vehicle (S5 Table). The former finding is consistent with the results of a previous study suggesting that women cyclists are more likely than men cyclists to be involved in dangerous conflicts with vehicles at crossroads (Stipancic et al., 2016). Such crashes tend to take place in urban areas where the density of crossroads is higher. It is also possible that the finding that women are more involved in crashes with bus and cars is related to the fact that women cycle more in urban areas. Although the expectation that buses are more frequent in urban road is reasonable, there is no evidence supporting this claim; therefore, future research is needed to investigate difference in traffic vehicles between urban and rural environment.

Third, women cyclists were more likely to have a collision with a car and a bus but not with a heavy-goods vehicles (Hypothesis 8) as was predicted based on the findings of Frings et al. (2012). It is important to mention that the probability of a collision with heavy-goods vehicles is influenced by the portion of the road in which the cyclists is riding, the percentage of trucks present in the traffic at a specific place and time and by the frequency of intersection in the cyclists journey as well.

In our study, we found that women cyclists were more likely to be involved in a crash involving a right-turn (near-side turn) manoeuvre of the opponent vehicle (S5 Table). This finding is consistent with the hypothesis of a tendency of women cyclists to not perceive nearside overtaking as an especially risky manoeuvre (Frings et al., 2012). The fact the women cyclists were more likely to be involved in a crash at crossroads may further support this finding.

Limitations

The results of the present study should be considered in light of its research limitations. A limitation is that the ISTAT database does not provide exposure data (i.e. difference on bicycle use across gender). For instance, the number of kilometres ridden by bicycle may be higher for men than for woman and this may contribute to the fact that the men cyclists are more likely to suffer a fatal injury than women cyclists. To account for the lack of exposure data, we have considered data on gender differences in bicycle use from other research. Another limitation is that the ISTAT database does not provide information that indicates whether a violation was recorded. Therefore, we calculated the injuries and the rate of injury is unknown. However, it is important to note that the ISTAT database provides the most complete and reliable database of road crashes in Italy.

Practical implications

The practical implications of our study can be seen at different levels such as social, political and institutional. First, our study suggests that errors and risky behaviours are different between men and women cyclists. These aspects should be addressed in bikeability training as well as in public awareness initiatives. Both types of intervention should be sensitive to such gender differences. Road safety education should take into account cultural constructions of masculinity and femininity (Walker, Butland, & Connell, 2000). Future road safety advertisements and health campaigns should evaluate how the message is effective for both men and women (Lewis, Watson, & Tay, 2007; Ulleberg, 2001) and coherently develop an intervention or a campaign tailored to both genders and related crash patterns (e.g. rural road vs urban road; speeding or crossroad crashes). This information is likely to guide the design and implementation of road safety advertisements and health campaigns.

Second, the findings of the present study bring up questions about the priorities of transport politics decisions about investments in cycling infrastructure. A gender-balanced representation in governance/power structures is required (Prati, 2018). Compared to men, women tend to be more concerned with the vehicular traffic and to prefer routes with maximum separation from motorized traffic (Akar, Fischer, & Namgung, 2013; Garrard et al., 2008, 2012; Heesch et al., 2012). In the present study, we showed that bicycle infrastructures that minimize the interaction with motorized vehicles could be beneficial for the safety of women cyclists.

Conclusion

The present study focused on gender differences in bicycles crashes and fatal injury risk. One of the main outcomes was that, compared to women cyclists, men cyclists report a higher risk of suffering a fatal injury, the effect size of the relationship was medium. Furthermore, results showed that crash characteristics are different for men and women cyclists. Albeit small, the effect size of the differences across gender in cycling crashes was statistically significant. Socio-cultural factors, such as cycling culture and hegemonic masculinity, as well as psychological factors, such as gender differences in road safety attitudes and risk perception, are likely to explain such differences.

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