Fatally injured drivers in Norway 2005–2015—Trends in substance use and crash characteristics

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ABSTRACT

Objective: Norway introduced a “Vision Zero” strategy in 2001, using multiple approaches, aiming toward a future in which no one will be killed or seriously injured in road traffic crashes (RTCs). Official statistics show that the number of fatally injured road users has declined substantially from 341 deaths in 2000 to 117 in 2015. In-depth crash investigations of all fatal RTCs started in Norway in 2005. The aim of this study was to investigate whether fatal crash characteristics, vehicle safety features, and prevalence of drugs and/or alcohol among fatally injured drivers and riders has changed during 2005–2015, accompanying the reduction in road fatalities.

Methods: Data on all car/van drivers and motorcycle/moped riders fatally injured in RTCs during 2005–2015 were extracted from Norwegian road traffic crash registries and combined with forensic toxicology data.

Results: The proportion of cars and motorcycles with antilock braking systems and cars with electronic stability control, increased significantly during the study period. The prevalence of nonuse of seat belts/helmets and speeding declined among both fatally injured drivers and riders. In addition, the prevalence of alcohol declined, though no significant change in the total prevalence of other substances was noted.

Conclusion: The observed changes toward more safety installations in cars and motorcycles and lower prevalence of driver-related risk factors like alcohol use, speeding, and nonuse of seat belts/helmets among fatally injured drivers/riders may have contributed to the decrease in road traffic deaths.

Introduction

Road traffic crashes (RTCs) are the second leading cause of death among children aged 5–14 years and the fourth leading cause of death among people aged 15–49 years (Ritchie and Roser 2018). Common risk factors of RTCs are speeding, driving under the influence of alcohol or other psychoactive substances, distracted driving, and unsafe road infrastructure. Other risk factors of severe injuries or death are nonuse of motorcycle helmets or seat belts, unsafe vehicles, and inadequate postcrash care (Pietrasik 2018).

Norway introduced a “Vision Zero” strategy in 2001, based on the Swedish initiative of 1997, aiming to work toward a future in which no one will be killed or seriously injured in RTCs (Elvebakk and Steiro 2009). Several actions were initiated to improve the roads to reduce the probability of collisions; for example, by implementing guardrails and profiled road markings between lanes and on the roadside. At the same time, more safety features have been implemented in new vehicles, such as antilock braking systems (ABS) and electronic stability control (ESC). The number of automatic speed cameras increased, including cameras to detect average speed over longer distances, and actions like police controls and information campaigns were initiated to increase the use of seat belts in cars and helmets among motorcycle riders. The campaigns began in 2003, supplemented with posters/billboards along the roadside to encourage safe driving. Because fines for traffic offenses have had limited effects on recidivism, a system with penalty points for traffic offenses such as exceeding the speed limit, unlawful overtaking, etc., was introduced in 2004 as a
supplement. Eight penalty points in 3 years will result in driving licence suspension for 6 months (Norwegian Public Roads Administration 2018). In 2007, a multiprofessional, national working group presented a proposal for a national trauma system in Norway, which all of Norway’s regional health trusts implemented in the years following (Dehli et al. 2015), which might have improved postcrash care.

In order to reduce the prevalence of drunk or drugged driving, the legal blood alcohol concentration (BAC) limit was reduced from 0.5 to 0.2 g/kg in 2001, and legal concentration limits in blood were introduced for 28 drugs in 2012/2016 (Ministry of Transport and Communications 2016). Maximum limits for daily doses of prescription drugs allowed in combination with motor vehicle driving were specified, including stimulants, opioids, sedatives, hypnotics, and other psychopharmaceuticals. The requirements were revised with gradually stricter dose limits in 2011, 2013, and 2016. The police also increased the focus on preventing driving under the influence of alcohol and/or drugs: Automatic number plate recognition equipment was implemented in a few districts in 2010, which made it easier to detect drivers who had been convicted of alcohol- and/or drug-related offenses, because the vehicle’s registration number is linked to the owner and therefore also to the owner’s license and criminal records. Control activities have become more focused on times and places where drunk/drugged driving was most common in recent decades.

Official statistics show that the number of fatally injured road users has declined from 341 deaths in 2000 to 117 in 2015. The reduction in fatalities applies to car drivers, car passengers, motorcycle occupants (drivers and passengers), and pedestrians (Statistics Norway 2018). The aim of this study was to investigate whether fatal crash characteristics, vehicle safety features, and prevalence of drugs and alcohol among fatally injured drivers and riders changed during 2005–2015, accompanying the reduction in road fatalities.

Methods

Study design, setting, and participants

A descriptive cross-sectional study was conducted, using register data from all car and van drivers and motorcycle and moped riders fatally injured in RTCs in Norway between January 1, 2005, and December 31, 2015. Confirmed suicide cases were not included in the databases used in this study, which is in accordance with international standards on reporting road traffic deaths (Adminaitė et al. 2018).

Data sources

Since 2005, all fatal RTCs have been investigated in-depth by crash investigation teams; the data generated are recorded in a database. The investigations include collection of time-sensitive information at the crash site, estimation of speed, crash reconstruction, technical documentation of the vehicles, etc. In all fatal cases, the significance of different risk factors related to the vehicle, driver, and road are evaluated in multidisciplinary meetings including health personnel and technical experts on roads and vehicles. The purpose is documentation and analysis of factors related to the car, road, or driver that contributed to or caused the crash and to reveal factors that contributed to the outcome of the crash, in order to suggest improvements to prevent future incidences.

The police report all severe RTCs to the Road Traffic Accident Registry, which is operated by Statistics Norway and is the basis for national statistics on RTCs. In addition, the police perform an individual evaluation of RTCs to investigate possible criminal offenses, and they request toxicological analysis of drivers/riders in 60–70% of cases. Toxicological investigation has not been requested for all drivers/riders mainly for economic or administrative reasons or lack of legal justification. Most of the collected blood samples are analyzed at the forensic toxicological laboratory in Oslo, which has been part of Oslo University Hospital (Norway) since January 2017; about 5% are analyzed at the Department of Clinical Pharmacology, St. Olav University Hospital (Trondheim, Norway). Both laboratories participate in international interlaboratory comparisons and proficiency testing programs and are accredited by the Norwegian body for accreditation of laboratories (Norwegian Accreditation, Lillestrøm, Norway; http://www.akkreditert.no/en).

For this study, Statistics Norway extracted data on fatally injured motor vehicle drivers and riders from the Road Traffic Accident Registry, excluding other types of road users. National identification numbers were used by Statistics Norway to include additional data from the Forensic Toxicology Database at Oslo University Hospital. Forensic autopsy cases from St. Olav University Hospital were linked to the extracted drivers and riders based on age and sex and date, time, and location of the crash. This set of fatally injured motor vehicle drivers and riders, both those toxicologically investigated and those not, were further coupled with data from the crash investigation team database; that coupling was performed by researchers at Oslo University Hospital based on age, sex, and date and time of the crash. Drivers of cars or vans and riders of motorcycles or mopeds were selected and included in a research database.

We were unable to perform culpability analysis of the included drivers/riders because we did not have access to police reports. Therefore, some of the included subjects were not culpable for the fatal crash.

Variables

A research database was established containing information about crash type, type of vehicle, number of vehicles involved, time of the crash, age and sex of the driver/ riders, results from the toxicological analyses (if performed), as well as recorded data on speeding, use of seat belt/motorcycle helmet, ABS, and ESC as dichotomous variables.

The toxicological results were only included if they were quantified in a blood sample that had been collected within 24 h after the RTC or if it was less than 1 day from incidence to death in cases where a blood sample was
taken during autopsy. The drugs included in this study were those with defined legal limits in the Norwegian Road Traffic Act of 2016 (Ministry of Transport and Communication 2016), except a few benzodiazepines rarely detected among Norwegian drivers (etizolam, clobazam, lorazepam, triazolam).

The drug ketamine was omitted from this study, because it often is given by health personnel after an RTC. Findings of diazepam and morphine were also omitted if it was documented or likely that administration took place after the crash. Gamma-hydroxybutyrate has been assigned a legal per se limit for driving but was omitted from this study due to risk of postmortem formation and, hence, false-positive results (Castro et al. 2014). Alcohol concentrations were omitted if combined with negative results for the alcohol metabolites ethyl glucuronide (EtG) and ethyl sulfate (EtS), because a lack of these metabolites indicates that the presence of alcohol was due to postmortem production (Høiseth et al. 2010).

**Statistical methods**

**Grouping of data**

Benzodiazepines, z-hypnotics, and opioids were grouped as medicinal drugs. Amphetamines, methylphenidate, and cocaine were grouped as stimulants. The drivers were divided into 4 age groups: <25, 25–34, 35–44, and ≥45 years. Night was defined as from 10 p.m. to 4 a.m. and weekends from 10 p.m. Friday to 4 a.m. Monday. Time of RTC was categorized as weekday, weeknight, weekend day, and weekend end. Year of incidence was grouped into the time periods 2005–2010 and 2011–2015.

Data analyses were performed using SPSS version 23 (IBM Corporation, Armonk, NY). Pearson’s 2-sided chi-square test was used to test for significant differences in characteristics or drug/alcohol prevalence when comparing 2 time periods. Fisher’s exact test was used to generate P values in cases with expected counts less than 5. Adjusted odds ratios were determined by logistic regression analysis. A significance level of 5% was used for interpretation. Trends in death numbers were analyzed by use of exponential regression.

**Ethical approval**

This study was approved by the Regional Committee for Medical and Health Research Ethics (approval number 2010/2191), by the Higher Prosecution Authority of Norway, and by the Council for Confidentiality and Research of the Norwegian Ministry of Justice. All included drivers and riders were checked against the Norwegian Registry of Withdrawal from Biological Research Consent and the Registry of Autopsy Material Research Refusal.

**Results**

**Participants**

During 2005–2015, 950 car/van drivers were fatally injured in RTCs; of those, results from drug/alcohol analysis were available for 602 (63.4%). In addition, 270 motorcycle riders were fatally injured in RTCs; results from drug/alcohol analysis were available for 170 (63.0%).

**Trends in number of deaths**

The annual number of fatally injured car/van drivers declined during the study period; the annual percentage change was estimated by regression to be −6.7 (95% confidence interval [CI], −10.1, −3.2). The number of fatally injured motorcycle/moped riders also declined; the annual percentage change was estimated by regression to be −7.1 (95% CI, −11.3, −7.3; Figure 1). The percent-wise declines were thus similar for fatally injured drivers and riders, although the number of riders was about one-third that of the drivers. The declining trend was observed among both male and female drivers and riders and among all age groups of drivers, whereas the declining trend in fatally injured riders was observed primarily among those less than 45 years old; the number of fatally injured riders aged 45 years or older, however, showed an increasing tendency during the study period (annual percentage change 3.4; 95% CI, −6.1, 13.9; not shown in figure).

**Characteristics**

The proportions of fatally injured drivers and riders who had been speeded prior to the crash or who had not used a seat belt/helmet declined from 2005–2010 to 2011–2015. In addition, the proportion of cars and motorcycles with ABS and cars with ESC increased significantly from the first time period to 2011–2015 (Table 1).
Characteristics regarding age and sex of the fatally injured drivers and riders, time of crash, and type of crash are presented in Table A1 (see online supplement) for 2 time periods: 2005–2010 and 2011–2015. A faster decline in fatal RTCs for young drivers and male drivers compared to older drivers and female drivers resulted in higher proportions of female drivers and drivers aged 45 years or older in 2011–2015 compared to 2005–2010. In addition to the data presented in Table A1, we found that female drivers less frequently exhibited the risk factors speeding and nonuse of seat belts compared to male drivers and drivers less than 45 years old: 21.1% of female drivers had been speeding compared to 46.7% of male drivers ($\chi^2 = 44, 290, P < .0005$). Nonuse of seat belts was reported for 25.8% of female drivers and 44.3% of male drivers ($\chi^2 = 23,025, P < .0005$). Drivers aged 45 years or older were speeding in 22.1% of the cases and did not use a seat belt in 29.0% of the cases, compared to >41% and >47% among the younger age groups, respectively (data not shown).

A significant decline in both speeding and nonuse of seat belts was still observed among all fatally injured drivers when adjusted for variations in age and sex in the 2 time periods; the adjusted odds ratio for speeding in 2011–2015 compared to 2005–2010 was 0.712 (95% CI, 0.525–0.966; $P = .029$); the adjusted odds ratio for nonuse of a seat belt in 2011–2015 compared to 2005–2010 was 0.712 (95% CI, 0.535–0.947 P = .019).

A slight majority of all fatally injured drivers had been involved in a head-on collision; this proportion did not change in 2011–2015 compared to 2005–2010 (Table A1).

### Alcohol and drug use across characteristics groups

The prevalence of alcohol and drugs in relation to age, sex, and time of the week are presented in Table 2. Alcohol was the least prevalent among female drivers and drivers and riders aged 45 years or older. In addition to the findings presented in the table, we found that drugs and/or alcohol were most frequently found in roadway departure crashes; 62.7% of drivers and 35.9% of riders involved in roadway departures had used drugs and/or alcohol above the legal limit, of which alcohol was most prevalent (46.1% alcohol and 29.8% drugs among drivers; 25.0% alcohol and 17.2% drugs among riders). In most cases, a roadway departure involves a single vehicle. When considering crashes involving at least 2 vehicles, 19.1% of the investigated drivers and 16.7% of the investigated riders had used drugs and/or alcohol above the legal limit when causing or being involved in a fatal RTC. Drugs were more prevalent than alcohol among the drivers and riders involved in multiple-vehicle crashes (13.9% drugs and 7.4% alcohol among drivers; 11.8% drugs and 4.9% alcohol among riders).

### Alcohol and drug use

#### Toxicological findings

Drug and/or alcohol findings above the legal per se limits corresponding to a BAC of 0.2 g/kg were found in blood samples from 35.5% ($n = 214$) of the 602 investigated drivers and 24.7% ($n = 42$) of the 170 investigated riders. Alcohol was found in blood samples from 21.9% ($n = 132$) of the drivers and 12.4% ($n = 21$) of the riders. Blood samples from 555 (92.2%) of the drivers and 164 (96.5%) of the riders were analyzed for both drugs and alcohol; 47 (7.8%) of the drivers and 6 (3.5%) of the riders were only analyzed for alcohol because drug testing was not requested. Among the samples from drivers who were investigated for drug use, drug concentrations above the legal limits were found in 21.6% ($n = 120$), medicinal drugs in 14.8% ($n = 82$), stimulants in 8.3% ($n = 46$), and delta-9-tetrahydrocannabinol (THC) in 7.0% ($n = 39$). Among analyzed samples from riders, drugs were found in 15.2% ($n = 25$), medicinal drugs in 7.3% ($n = 12$), stimulants in 8.5% ($n = 14$), and THC in 6.1% ($n = 10$). In both drivers and riders, THC was the individual drug most frequently detected, followed by amphetamines. Among those fatally injured who were tested for drugs in addition to alcohol, 13.0% of drivers and 7.9% of riders were found to be multisubstance users (drug–drug or drug–alcohol). For more results, see Table A2 (online supplement).
Trends in alcohol and drug use

Due to some changes in analytical cutoff concentrations used at the forensic laboratories during the study period, cutoff values equal to the limits for graded sanctions corresponding to a BAC of 0.5 g/kg were used to compare trends in drug and alcohol use over time. Data for 2 time periods, 2005–2010 and 2011–2015, are provided in Table 1.

The proportion of investigated drivers and riders with BACs at or above the graded sanction limit declined during the study period, although this was not found to be statistically significant among the riders (Table 1). The reduction in alcohol prevalence among drivers remained significant when adjusted for age group and sex; the adjusted odds ratio for finding BAC/C21 <0.351 in 2011 compared to 2010 was 0.555 (95% CI, 0.351–0.877; P = .012; data not shown).

The total prevalence of drugs at or above the equivalent limits for graded sanctions did not tend to increase or decrease among drivers or riders (Table 1). Some differences in drug classes were, however, noted. An increased prevalence of cannabis among both drivers and riders was observed, although nonsignificant.

Discussion

The annual number of fatally injured car/van drivers and motorcycle/moped riders declined substantially during the study period. By comparing the 2 time periods 2005–2010 and 2011–2015, we found that a significantly smaller proportion of drivers fatally injured in 2011–2015 were driving too fast or did not use a seat belt, compared to the larger group of drivers fatally injured in 2005–2010. A similar trend was observed for riders regarding speeding and use of helmet. In Norway, an increasing proportion of drivers and riders tend to respect the speed limits (Sagberg and Bjørnskau 2016), and the prevalence of seat belt use increased gradually during the study period among drivers and front seat passengers in normal traffic (Norwegian Public Roads Administration 2017). The declining trends in unsafe driving behaviors such as speeding and nonuse of seat belts/helmets among fatally injured drivers/riders seems thus to reflect the reduced prevalence of these risk factors in the general driving population, which can at least partly explain the reduction in fatalities.

Furthermore, the annual proportion of both fatally injured drivers and riders who had used alcohol prior to the crash declined during the study period, whereas no significant increase or decrease in total prevalence of drug use was noted. The decline in alcohol use might be a result of extensive campaigns against drunk driving. Similar campaigns against drug-impaired driving have not been held.

The reduction in fatalities on Norwegian roads is also related to improvements made to the road infrastructure and to new cars sold during the study period. Installation of profiled road markings has had a large effect: A study comparing roads before and after markings were installed showed that head-on crashes on those roads were reduced by 41% and roadway departures on the left side of the road were reduced by 48% after the installation (Nordli 2015). New cars and vans sold during the study period have, in general, been safer. The findings in the present study, in which the prevalence of ABS in cars more than doubled and the prevalence of ESC tripled from the time period 2005–2010 to 2011–2015, illustrate this. Modern cars also have seat belt reminders. This has been mandatory for the driver’s seat since 2009 in the European Union (EU), and beginning in September 2019, EU and United Nations Economic Commission for Europe regulations will require seat belt reminder systems in all front and rear seats in new cars (European Transport Safety Council 2018).

In Norway, the decrease in the death rate during the study period was greatest for young male drivers, which resulted in an increased prevalence of female drivers and drivers aged 45 years or older among those fatally injured. Lower prevalences of the risk factors speeding, nonuse of seat belts, and use of alcohol were, however, also observed among female and older fatally injured drivers. Hence, the observed reduced prevalence of those risk factors among the total number of fatally injured drivers can therefore partly be explained by the changing sex and age distributions.

### Table 2. Alcohol and drug findings above the legal limits corresponding to a BAC of 0.2 g/kg, divided into driver/rider characteristics groups.

| Age group (years) | Male | Female |
|------------------|------|--------|
| <25              | 161  | 474    |
| 25-34            | 121  | 90     |
| 35-44            | 229  | 29     |
| ≥45              | 76   | 128    |

| Time of crash   | Male | Female |
|-----------------|------|--------|
| Weekday         | 369  | 125    |
| Weekend         | 32   | 32     |
| Weekend night   | 76   | 128    |

| Sex           | Car and van drivers | Motorcycle and moped riders |
|---------------|----------------------|----------------------------|
| Male          | 474                  | 159                        |
| Female        | 128                  | 10                         |

| Alcohol (%) | Drugs (%) | Alcohol and/or drugs (%) |
|------------|-----------|--------------------------|
| n           | n         |                          |

| Sex           | Alcohol (%) | Drugs (%) | Alcohol and/or drugs (%) |
|---------------|-------------|-----------|--------------------------|
| Male          | 25.9        | 21.7      | 40.1                     |
| Female        | 7.0         | 16.4      | 21.9                     |

| Time of crash | Alcohol (%) | Drugs (%) | Alcohol and/or drugs (%) |
|---------------|-------------|-----------|--------------------------|
| Weekday       | 8.1         | 18.7      | 23.8                     |
| Weekend       | 32.8        | 18.4      | 42.4                     |
| Weekend night | 37.5        | 40.6      | 65.6                     |

| Day was defined as from 4 a.m. to 10 p.m. and night from 10 p.m. to 4 a.m. Weekend was defined as 10 p.m. Friday to 4 a.m. Monday. |
Results adjusted for sex and age revealed, however, that the reduction in prevalence of the driver-related risk factors could not solely be explained by the changing sex and age distributions. This means that measures to reduce drink driving, speeding, and nonuse of seat belts likely have had an effect on the general population of drivers. High rearrest rates among drugged and drunk drivers in Norway have previously been found (Christophersen et al. 2002), implying that drug and alcohol use among these drivers is difficult to prevent. The results in the present study indicate that a combination of preventive measures and safer roads and vehicles has contributed to reducing the number of road traffic fatalities among both alcohol/drug-impaired drivers and sober drivers.

The number of fatalities among the oldest age group of drivers and riders decreased the least (increased for riders); this group also had the greatest number of fatally injured drivers and riders. This indicates that further investigation should be performed to reveal which measures might help the most to prevent fatal RTCs among older drivers and riders. Bedard et al. (2002) calculated the individual contribution of driver characteristics on fatality risk among drivers injured in single-vehicle crashes in the United States and found that female gender and older age were associated with higher fatality risk. They suggested that specific safety measures for older and female drivers should be considered. The increased risk of older drivers has also been acknowledged by the EU, and it has been shown that some crash types are more prevalent among older drivers; for example, crashes at intersections (European Commission 2015). Increasing numbers of deaths among older motorcycle riders have recently been found in several countries, and the combination of riders getting older and the fact that older riders more often invest in more powerful engines/bikes, and hence drive at higher speed, has been suggested as an explanation for the overrepresentation of older riders among those fatally injured (Fitzpatrick and O’Neill 2017).

Only minor changes in crash type were found when comparing fatally injured drivers and riders in the 2 time periods. One part of the Vision Zero strategy has been to prevent head-on collisions by preventing drivers and riders from accidentally crossing the centerline of the road. In Norway, profiled road markings were installed on a few Norwegian roads in 2006 and on several hundred kilometers of roads in the following years. Although the annual number of fatal head-on collisions has declined, a slight majority of all fatal RTCs in both 2005–2010 and 2011–2015 were head-on collisions, which implies that more effort should be made to prevent these types of crashes.

The observed change toward more safety installations in cars and motorcycles and decreases in speeding, nonuse of seat belts/helmets, and alcohol use indicate that preventive measures have contributed to the reduction in fatalities. The results from the present study suggest that in addition to further improvements on the roads to prevent head-on collisions, efforts should be maintained to reduce the use of drugs and alcohol among drivers and riders and prevent speeding and nonuse of seat belts/helmets, in order to further reduce fatalities. Road safety information campaigns combined with roadside controls, automatic speed cameras, strict enforcement, and similar interventions are endorsed as continued countermeasures for road safety reform. Specific measures should be sought for older drivers, such as more restrictive driving license policy, particularly related to mental and somatic health and use of medicinal drugs.

Limitations

Data on characteristics and vehicle safety installations were available for all included fatal crashes; however, data on drug and/or alcohol use based on blood sample testing were available for only 63% of the drivers and riders. The police might not have requested toxicological analysis in cases where it was clear that the fatally injured driver/ride was nonculpable for the crash, which might have overestimated the prevalence of drug/alcohol findings. A legislative process to increase the proportion of legal autopsies of fatally injured drivers has started; this will lead to toxicological investigation of a large proportion of future drivers and riders fatally injured in RTCs.

We were unable to perform culpability analysis on the included drivers/riders; hence, some of the included drivers/riders were likely nonculpable for the crashes.

The distributions of age, sex, and time and type of crash were slightly different for the 2 studied time periods, for both those investigated for alcohol/drug use and those who were not investigated (Table A3, see online supplement). This might have affected our findings, although most likely to a small extent.

Data from about 5% of the fatally injured drivers and riders who were investigated for alcohol and/or drug use during 2005–2010 were not available to the researchers. For 3% of the analyzed samples, a BAC below 0.28 g/kg was not reported. Ten percent of the samples were not analyzed for LSD, and a few drivers might have used psychoactive substances for which analyses were not performed.

For blood samples taken some time after death, it is possible that postmortem redistribution of drugs may have occurred. Therefore, the determined drug concentrations may not always have reflected the actual concentrations at the time of crash.

The EU recommends that natural deaths in which the driver died from, for example, a heart attack before the crash should be excluded from national road fatality statistics (Adminaite et al. 2018); however, this was not done in this study due to lack of reliable health data.

Finally, our study was based on a small data set with fairly poor statistical power.

Acknowledgments

Thanks to Arild Engbretsen, who is responsible for the crash investigation team database operated by the Norwegian Public Roads Administration; to Terje Hammer for extracting information from the Forensic Toxicology Database at Oslo University Hospital; and to the Department of Clinical Pharmacology at St. Olav University Hospital for providing forensic data from the middle region of Norway.
Disclosure statement
All authors declare that they have no conflict of interest.

Data availability statement
We do not have permission to share nonaggregated research data.

Funding
This study did not receive external funding.

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