JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING (ENGLISH EDITION) 2017; 4 (5): 496–502

Available online at www.sciencedirect.com

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Original Research Paper

Driver sleepiness, fatigue, careless behavior and risk of motor vehicle crash and injury: Population based case and control study

Abdulbari Bener [a,b,c,*], *Erol Yildirim* [d], *Türker Özkan* [e], *Timo Lajunen* [e,f]

[a] *Department of Biostatistics and Medical Informatics, Cerrahpaşa Faculty of Medicine, Istanbul University, Istanbul, Turkey*
[b] *Department of Evidence for Population Health Unit, School of Epidemiology and Health Sciences, University of Manchester, Manchester, UK*
[c] *International School of Medicine, Istanbul Medipol University, Istanbul, Turkey*
[d] *Department of Psychology, Istanbul Medipol University, Istanbul, Turkey*
[e] *Safety Research Unit, Department of Psychology, Middle East Technical University, Ankara, Turkey*
[f] *Department of Psychology, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

HIGHLIGHTS

- This study confirmed association between feeling fatigue, tiredness or sleepy, aggressive driving behavior among drivers with a substantial increase in the risk of a vehicle crash resulting in serious road injury.
- Young drivers are more likely to be involved in collisions during lane-changing than non lane-hanging drivers.
- The levels of acute driver sleepiness measured by the Stanford score were in strong association with the risk of injuries.
- The fatigue, sleep deprivation and excessive speed in cars are widespread risk factors of crashes and injuries.

ARTICLE INFO

Article history:
Received 25 May 2017
Received in revised form
16 July 2017
Accepted 17 July 2017
Available online 19 September 2017

Keywords:
Driver
Stanford sleeping
Fatigue
Risk
Road traffic crash and injury

ABSTRACT

Background: A few studies have been conducted to determine the relationship between road motor vehicle crashes (MVC) and serious injuries related to tiredness, fatigues and sleeping.
Aim: To determine the effects of aggressive behaviour, driver sleepiness and fatigue on MVC and related injuries among Turkish population.
Design and setting: Population-based case and control study conducted at the accident emergency departments of hospitals and roads.
Subjects: 515 car drivers involved in crashes with injury were admitted to hospital and 1030 car drivers involved while driving on public roads as control group during the study period.
Methods: The Manchester driver behaviour questionnaire (DBQ) measured the aberrant driving behaviours leading to accidents. Participants completed a fatigue severity scale (FSS) and Stanford Sleeping questionnaire an epworth scale with items related to socio-

* *Corresponding author*. Department of Biostatistics and Medical Informatics, Cerrahpaşa Faculty of Medicine, Istanbul University, Istanbul, Turkey. Tel.: + 90 212 414 3041; fax: + 90 212 632 0033.
E-mail addresses: abdulbari.bener@istanbul.edu.tr, abener99@yahoo.com (A. Bener).
Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2017.07.005

demographic information, driving experiences, adherence to traffic laws (such as speed limits and seat belt), and drivers' driving records.
Results: In a representative sampling, participant's age ranged from 25 to 65 and the mean and standard deviation were 36.5 ± 7.8 for cases and 37.0 ± 8.0 for controls. There was a significant difference in both group of drivers regarding BMI, level of education, marital status, driving experience, seat belt use, excessive speed limits, physical activity number of sleeping hours, mobile phone use, and cigarette smoking habit ($p = 0.017$). Also, there was a significant higher mean score on all the DBQ violation questions among case group in comparison with the control group ($p < 0.001$). Further, cases had higher prevalence of Epworth sleeping disorders ($p < 0.001$) and fatigue severity ($p = 0.003$) compared to control drivers. Multivariate logistic regression revealed that excessive speed, fatigue, lapses, errors, Stanford sleepiness score, violations, mobile phone use and Epworth sleepiness scale were significantly associated with injury involvement in vehicle crash, after adjusting for driving experience and annual mileage.
Conclusion: The current study confirmed that drivers with chronic fatigue, acute sleepiness, and careless driver behavior may significantly increases the risk of road crash which can be lead to serious injury.

1. Introduction

Motor vehicle crashes (MVC) and injuries are worldwide public health problems (Lyznicki et al., 1998; Philip et al., 1999; Sagaspe et al., 2010). Sleepiness and fatigue of drivers are significant causes and risk factors of MVC and fatalities. The percentage of sleepiness and fatigue varies from one country to another in the United State which is 1%–3% (Lyznicki et al., 1998), 10% in France (Philip et al., 1999; Sagaspe et al., 2010) and about 33% in Australia (Connor et al., 2002). The prevalence of driver sleepiness, fatigue and tiredness and their impact on the incidence of MVC and road traffic injuries documented very well in literature (Connor et al., 2002; Herman et al., 2014; Williamson et al., 2014) The pattern of acute tiredness, fatigue, chronic sleepiness, sleep disorders, and heavy workload has been related to decreased performance in psychomotor tests and driving simulators (Herman et al., 2014; Lajunen et al., 2004; Thompson and Stevenson, 2014) and increased rates of MVC, injuries and fatalities in selected populations (Bener et al., 2014). Meanwhile, the Manchester driver behavior questionnaire (DBQ) is commonly used to measure self-reported driving style and determine the relationship between driving behavior and accident involvement (Bener et al., 2013a, 2013b, 2014; de Winter and Dodou, 2010; Reason et al., 1990). Since most of road accidents are caused by human errors, DBQ is one of the most frequently used tools for studies carried to describes incorrect behaviors of the drivers in three basic dimensions such as errors, violations and lapses (Bener et al., 2013a, 2013b, 2014; Reason et al., 1990). Furthermore, changing behavior and attitudes have been major public health problem during the recent years world widely, therefore, Sun and Elefteriadou (2011) provided recommendations related to the implementation of study findings into micro-simulators to better replicate driver behaviors in urban street networks. The drivers' decisions to change lanes are associated with driver characteristics and driver attitudes (such as aggressive behavior) and depends on many factors (Sun and Elefteriadou, 2012).

Driver sleepiness and fatigue are a few of the most significant factors leading to MVC and serious injuries (Ellen et al., 2006; Philip et al., 2003; Stutts et al., 2003). These factors includes age, mental illness, fatigue, sleeping and speed highly associated with accident involvement (Philip et al., 2003, 2010; Sagaspe et al., 2010; Teran-Santos et al., 1999). Several epidemiological researches in France indicated that sleepiness in car caused a higher risk of MVC and injuries (Philip et al., 1999, 2003, 2010). Consequently, sleep restriction, driver fatigue and falling asleep at the wheel are some of the key factors contributing to road accidents. As we know from research, driver fatigue causes 1%–3% of road transport accidents with up to 20% of those accidents occurring on major roads and motorways (Jamroz and Smolarek, 2013).

The aim of present study was to determine the effects of aggressive behaviors, driver sleepiness and fatigue on MVC and injuries among Turkish population.

2. Subjects and methods

A case-control survey was conducted from July 2015 through June 2016 in Istanbul, Turkey. All participants had valid driving licenses and got guarantee about anonymity and confidentiality.

The present study was based on drivers who had been admitted to the Accident Emergency Department of Cerrahpasa Faculty of Medicine Teaching Hospital and Medipol Faculty of Medicine Teaching Hospital for the road motor vehicle crash and related injuries. The samples of 696 trauma cases were available for this survey during study period. A total number of 515 drivers with a 74.0% response rate took part in the study and were included in the statistical analysis. Trauma teams in hospitals, emergency department staff, paramedical staff were collaborated to ensure comprehensive case findings.

The control group consisted of drivers as representative of driving in Istanbul during the study period. The subjects were assigned by cluster sampling at randomly selected sites on the road. Surveys were continued for 10 months. Turkish drivers was selected from drivers aged between 25 and 65 years and matched with the case subjects. A representative sample of 1428 motor vehicles identified in roadside surveys (controls) and eligible drivers was approached for the study, but, 1030 drivers agreed to participate in the present research with a response rate of 72.1%. The recruitment of control drivers approximately matched two to one trauma cases.

2.1. Data collection

Data were collected by face-to-face interview with drivers by well-trained researchers in hospital or by available phone. The contact information for control drivers was obtained to do interview. MVC with injury data included socio-demographic information, driving history, driving experience, seatbelt usage, excessive speeding, annual mileage, traffic offenses, history of crash and injury involvement, mobile phone usage, text messages and habit of smoking.

2.2. Aberrant driver behaviors

The standard version of driver behavior questionnaire—developed by Reason et al. (1990)—consisted of 50 questions, which covered four classes of aberrant behavior: slips and lapses, mistakes, unintended violations and deliberate violations. Slips are defined as "actions-not-as planned" while lapse is a term reserved for more covert memory failures. Mistakes arise from deficiencies in the judgmental and/or inferential processes involved in the selection of an objective, or of the means to achieve it, or both. Violations are deviations from the practices believed to be necessary to maintain the safe operation of a potentially hazardous system. In current study, aberrant driver behaviors were measured by Manchester Driver Behavior Questionnaire (DBQ) with extended violations (Bener et al., 2009, 2013a, 2013b, 2014; Lajunen et al., 2004). The DBQ questionnaire has 10 items of ordinary violations, 8 items of lapses and 8 items of errors (Bener et al., 2009, 2013a, 2013b, 2014; Lajunen et al., 2004; Reason et al., 1990). In the DBQ questionnaire, there are 26 behaviors on a six-point scale (0 denotes never, and 5 denotes nearly all the time).

2.3. Fatigue measure and design of scale

Fatigue plays an adverse role on quality of life and performance. The driver fatigue is an extended definition includes sleepiness, drowsiness, reduced attention span and motivation to act, reduced alertness, changes in performance and propensity to make mistakes. Sleepiness and drowsiness can result from fatigue or the urge to sleep at night. The 9-item fatigue severity scale (FSS) is self-reported questionnaires that are used frequently to measure fatigue (Philip et al., 2003). The fatigue scale is composed of 9 items that describe fatigue symptoms commonly seen in subjects. Each item ranges from 1 to 7, where 1 denotes strong disagreement and 7 denotes strong agreement (Philip et al., 2003).

2.4. Measures of driver sleepiness: Stanford sleepiness scale and Epworth sleepiness scale

We conducted the Stanford sleepiness scale to quantify progressive steps in acute sleepiness. Additionally the Epworth sleepiness scale is used to measure chronic or usual daytime sleepiness (Philip et al., 2003). Epworth score varies in the range of 0–24: < 10 denotes normal; 10–15 moderate impairment, and 16–24 severe impairment (Connor et al., 2002; Johns, 2000).

The statistical analyses were carried out by SPSS (statistical package for social science window version #22). The student-t test was performed to determine the significance of differences between mean values of two groups. Differences in proportions of categorical variables between two or more groups were tested by Chi-square and Fisher's exact tests (two-tailed). Mantel–Haenszel test was used to calculate odd ratios (OR) and their 95% confidence intervals (CI). One-way ANOVA (analysis of variance) compares the means of several groups and present significant differences between group means. We performed multivariate logistic regression analyses of injury involvement as a function of aggressive driver behavior, sleepy, fatigue and other independent variables. The level $p < 0.05$ was considered as the cut-off value for significance.

3. Results and discussion

In a representative sampling, participant's age ranged from 25 to 65 and the mean and standard deviation were 36.5 ± 7.8 for cases and 37.0 ± 8.0 for controls. Table 1 shows the socio-demographic information of case and control groups. A significant difference was found in both groups of drivers case and control groups regarding BMI ($p = 0.033$), level of education ($p = 0.001$), marital status ($p = 0.015$), driving experience ($p = 0.025$), driving urban areas vice versa rural areas ($p = 0.001$), seat belt usage ($p = 0.001$), excessive speed limits ($p = 0.001$) and physical activity ($p = 0.014$).

Table 2 compares the lifestyle characteristics of studied subjects of cases and control groups. A significant difference was found between both groups of drivers' annual mileage (km) ($p < 0.001$), sleeping hours ($p = 0.025$), mobile phone use ($p = 0.008$), using text messages while driving ($p < 0.001$), and cigarette smoking habit ($p = 0.017$). Also, case drivers had a significantly higher mean score on all the DBQ violation questions comparing with control drivers ($p < 0.001$). Similarly, the mean scores of errors and lapses were higher in drivers of cases than control groups ($p < 0.001$) (Table 2). Further, case drivers had higher prevalence of Epworth sleepiness disorders ($p < 0.001$) and fatigue severity ($p = 0.003$) compared to control drivers.

Table 3 presents the pattern hospital admitted drivers due to causes of motor vehicle injuries compared with the control group. From the data Table 3, it is apparent that cases have

Table 1 – Socio-demographic of studied subjects by case and control drivers (N = 1545).

Variable	Case (N = 515) N (%)	Control (N = 1030) N (%)	p-value
Age group in years	36.5 ± 7.8	37.0 ± 8.0	0.221
< 30 years old	133 (25.8)	260 (25.2)	
30–39 years old	196 (38.1)	363 (35.2)	0.579
40–50 years old	155 (30.1)	334 (32.4)	
< 50 years old	31 (6.0)	73 (7.1)	
BMI group			
< 25 kg/m^2	120 (23.3)	264 (25.6)	
25–30 kg/m^2	237 (46.0)	514 (49.9)	0.033
< 30 kg/m^2	158 (30.7)	252 (24.5)	
Education level			
Elementary	137 (26.6)	178 (17.3)	
Intermediate	90 (17.5)	293 (28.4)	0.001
Secondary	212 (41.2)	315 (30.6)	
University	76 (14.8)	244 (23.7)	
Marital status			
Single	113 (21.9)	165 (16.0)	
Married	384 (74.6)	820 (79.6)	0.015
Widowed/divorced	18 (3.5)	45 (4.4)	
Driving experience			
< 5 years	55 (10.7)	152 (14.8)	
5–10 years	127 (24.7)	278 (27.0)	0.025
10–20 years	132 (38.6)	210 (20.4)	
> 20 years	201 (39.0)	390 (37.9)	
Seat belt use			
Never	208 (40.4)	316 (30.7)	
Seldom	71 (13.8)	143 (13.9)	0.001
Frequently	168 (32.6)	322 (31.3)	
Always	68 (13.2)	249 (24.2)	
Driving area			
Urban	387 (75.1)	689 (66.9)	0.001
Rural-semi urban	128 (24.9)	341 (33.1)	
Speed limits			
< 80 km/h	274 (53.2)	644 (62.5)	0.001
> 80 km/h	241 (46.8)	386 (37.5)	
Physical activity			
Yes	120 (23.3)	301 (29.2)	0.014
No	395 (76.7)	729 (70.8)	

Table 2 – Lifestyle characteristics of studied subjects by case and control drivers (N = 1545).

Variable	Case (N = 515) N (%)	Control (N = 1030) N (%)	p-value significance
Annual mileage per year (km)	18,072 ± 2237	17,650 ± 2270	0.001
No of sleeping hours	6.36 ± 1.06	6.15 ± 1.07	0.025
Mobile phone use while driving			
Never	110 (21.4)	200 (19.4)	
Seldom	90 (17.5)	222 (21.6)	
Frequently	102 (19.8)	255 (24.8)	0.008
Always	213 (41.4)	353 (34.3)	
Using SMS/text messages			
Never	252 (48.9)	507 (49.2)	
Seldom	78 (15.1)	223 (21.7)	0.001
Sometimes	110 (24.1)	175 (17.0)	
Often	75 (14.6)	125 (12.1)	
Smoking			
Never	344 (66.8)	729 (70.8)	
Ex-smoker	36 (7.0)	93 (9.0)	0.017
Current smoker	135 (26.2)	208 (20.2)	
Epworth sleepiness severity			
Normal	208 (40.4)	316 (30.7)	
Mild	71 (13.8)	143 (13.9)	
Moderate	168 (32.6)	322 (31.3)	0.002
Severe	68 (13.2)	249 (24.2)	
DBQ items	mean ± SD	mean ± SD	
DBQ violations	15.8 ± 8.7	13.9 ± 6.8	0.001
DBQ errors	11.0 ± 6.5	9.2 ± 5.3	0.001
DBQ lapses	10.6 ± 6.4	8.8 ± 4.8	0.001
Total DBQ scores	37.4 ± 15.8	31.9 ± 11.6	0.001
Total Epworth scores	11.7 ± 4.1	10.0 ± 2.9	0.001
Global fatigue scale 0 being worst and 10 being normal	3.77 ± 0.62	3.51 ± 0.60	0.003

more rate of careless driving, excessive speed, property damage, pedestrian injury, mobile phone, alcohol & drug use, traffic violation, cross red traffic light ($p < 0.001$). The level of acute driver sleepiness measured by the Stanford score was in strong association with the risk of injuries (Table 3).

Multivariate logistic regression revealed that excessive speed ($p < 0.001$), fatigue ($p < 0.001$), lapses ($p = 0.002$), errors ($p = 0.004$), Stanford sleepiness score ($p = 0.010$), violations ($p = 0.012$), mobile phone use ($p = 0.030$) and Epworth sleepiness scale ($p = 0.035$) were significantly associated with injury involvement in vehicle crash, after adjusting for driving experience and annual mileage (Table 4).

This study is considered as the first of its kind providing evidence relationship between fatigue, sleepiness and careless driver behavior which increase risk of injury in Turkish population. MVC and injuries remain major health problems (Bener et al., 2016) in both industrialized and developing countries (Roidl et al., 2014). Present study investigated the differences in driving behavior, fatigue and sleepiness among case and control groups in their relation to crash with injury. The study revealed that young drivers under age 40 (63%) were involved with higher risk of injury. This is consistent with a few previous studies (Bener et al., 2013a,b). The high accident risk among young drivers is a common problem worldwide.

The fatigue and sleep deprivation in cars are widespread risk factors for crashes and injuries (Connor et al., 2002; Philip et al., 1999; Sagaspe et al., 2010). Working sleeplessly increases fatigue and risk of behavioral errors and violation in drivers (Rajaratnam and Arendt, 2001). MVC from work to home is one of the main reasons of injury or fatalities among drivers (Philip et al., 1999, 2003, 2010), and understanding the factors of fatigue and sleepiness are becoming key issues in accident prevention.

Researches performed in high-income and middle-income countries showed that sleepiness among drivers has contribution to the burden of road traffic injuries (Lyznicki et al., 1998), with a three to six-fold increased risk of road accidents and population attributable estimates as high as 22% (Connor et al., 2002, 2011). The current study indicates that acute sleepiness and fatigue lead to increase of the burden of road accidents and injuries in Turkish population. The literature documented that over 90% of MVC injuries resulted in deaths in low and middle-income countries, although very a few epidemiological studies considered sleepiness and fatigue of drivers as risk factors for accidents

Table 3 – Pattern hospital admitted drivers due to causes of motor vehicle injuries compared with the control subjects (N = 1545).

Cause of injury variable	Case (N = 515) N (%)	Control (N = 1030) N (%)	Odds ratio (OR)	95% confidence interval (CI)	p-value significance[a]
Careless driving	175 (34.0)	261 (25.3)	1.51	1.20–1.90	< 0.001
Excessive speed	123 (23.9)	149 (14.5)	1.85	1.42–2.42	< 0.001
Property damage	104 (20.2)	83 (8.1)	2.88	2.12–3.93	< 0.001
Pedestrian injury	143 (27.8)	106 (10.3)	3.45	2.60–4.56	< 0.001
Mobile phone use	162 (31.4)	150 (14.5)	2.69	2.08–3.47	0.008
Alcohol & drug	48 (9.3)	54 (5.2)	1.85	1.24–2.78	0.002
Traffic violation	106 (20.6)	79 (15.7)	1.95	1.46–2.59	< 0.001
Cross red traffic light	125 (24.3)	158 (15.3)	1.78	1.36–2.30	< 0.001
Stanford sleepiness scale					
1 most alert (reference)	189 (36.7)	543 (52.7)	1.00	1.00	
2–3	254 (49.4)	412 (40.0)	1.77	1.41–2.22	< 0.001
4–7	72 (13.9)	75 (7.3)	2.76	1.92–3.97	< 0.001

Note: [a] Mantel haenszel test x^2 test.

Table 4 – Multivariable Logistic regression analyses of injury involvement as a function of aggressive driver behavior, fatigue and sleepy (N = 1545).

Variable	Odds ratio	95% confidence interval	p-value
Excessive speed	2.45	1.33–4.58	< 0.001
Fatigue	1.91	1.68–2.42	< 0.001
Lapses	2.35	1.53–3.96	0.002
Errors	2.69	2.24–3.58	0.004
Stanford sleepiness scale	1.65	1.41–1.94	0.010
Violations	1.93	1.22–3.07	0.012
Mobile phone use	1.96	1.49–3.91	0.030
Epworth sleepiness scale	1.82	1.57–2.20	0.035

Note: models adjusted for years of driving experience, annual mileage.

and injuries. The high prevalence of driving while drowsy reported from Argentinean (44%) (Perez-Chada et al., 2005), Brazilian drivers (22%) (Canani et al., 2005), and Thai drivers (75%) (Leechawengwongs et al., 2006). A study among Thai drivers attributed 23% of crashes to driver sleepiness (Leechawengwongs et al., 2006), while another study among Brazilian drivers reported significant proportions of crashes or near-miss crashes could be accounted for by excessive daytime sleepiness (18%), snoring (24%), and driver sleepiness (16%) (Perez-Chada et al., 2005). A case control study from Shenyang, China – the only etiological study focusing on car drivers that we are aware of finding a two-fold increase in crashes among drivers with chronic but not acute sleepiness (Liu et al., 2003).

Lane-changing behavior has increased substantially during the recent years in traffic flow modeling (Sun and Elefteriadou, 2011, 2012). Researchers have developed various algorithms to model the maneuvers on both highways and urban streets. However, the majority of these models was derived and validated using data such as vehicle trajectories, without many considerations of driver characteristics. In this study, an instrumented vehicle-based experiment was carefully designed to observe the drivers' action under various urban lane-changing scenarios (Sun and Elefteriadou, 2014). This study concludes by providing recommendations related to the implementation of study findings into micro-simulators.

The current study confirmed fatigue, sleepiness and careless driver behavior increase risk of injury. Several studies found that there was a correlation between levels of sleepiness and driving impairment (Herman et al., 2014; Philip et al., 2003). Our findings are consistent with the previous reported studies that confirm a correlation between fatigue, tiredness, sleepiness and driver performance reduction (Connor et al., 2002; Herman et al., 2014; Williamson et al., 2014). The findings of the current study will be beneficial in prevention of MVC, its related complications and which could be vital for policy decision makers, public health service directors, private sectors and stakeholders.

What is already known on this topic: the aggressive driver behavior, fatigue and sleepiness are considered to be potentially important risk contributors for MVC and related injuries or death. Reports estimates of the proportion of MVC attributable to driver sleepiness and fatigues varies between 10% and 30%.

What this study adds: the present case control study is considered as the first study to determine association between feeling fatigue, tiredness or sleepy, aggressive driving behavior among drivers with a substantial increase in the risk of a vehicle crash resulting in serious road injuries. The earlier prevention may reduce the incidence of MVC and related injury by up to about 20% or 30%.

4. Conclusions and methodological limitations

The current study confirmed that drivers with chronic fatigue, acute sleepiness, and careless driver behavior may significantly increases the risk of road crashes which can be lead to serious injuries. Also, the study confirmed that young drivers are more likely to be involved in collisions during lane-changing than non lane-hanging drivers. The levels of acute driver sleepiness measured by the Stanford score were in strong association with the risk of injuries.

The study design is based on a case and control study. Although the design was case and control, the data could not imply a causal relationship. However, if injury was not admitted to the accident and emergency or hospital or discharged directly after being treated in the emergency department, no medical file existed for that patient. Our findings may not be the main factor to explain driving impairment and sleepiness related to injuries. Stanford score greater than 4 is the measure most likely to be affected or somewhat inflated. Moreover, it is difficult to measure chronic sleepiness by self-reported questionnaires. The measurement of crash involvement was based on a self-report and may result as a bias.

Authors' contributions

Abdulbari Bener organized study, collected data, performed statistical analysis and wrote the first draft of the article. Erol Yildirim collected data and contributed to the interpretation of the data and writing the manuscript. Türker Özkan and Timo Lajunen have contributed to the interpretation of the data and writing the manuscript.

Ethics committee approval

Ethics committee approval was received for this study.

Informed consent

Informed verbal consent was obtained for this study.

Compliance with ethical standard

This article does not contain any studies with human participants or animals performed by any of the authors.

Financial disclosure

The authors declared that this study has received no financial support.

Competing interests

We have no financial interest to declare.

Acknowledgments

The authors would like to thank Istanbul Medipol University, and International Faculty of Medicine (Research protocol # 108400987-401) for their support and ethical approval.

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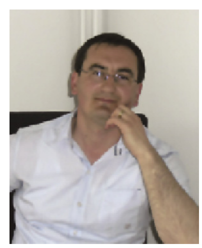
Abdulbari Bener is a professor of public health at the Cerrahpaşa Faculty of Medicine, Istanbul University and International School of Medicine, Istanbul Medipol University. He was professor of public health in the Department of Public Health at the Weill Cornell Medical College for a period January 2006–August 2014. Professor Bener was assistant medical director and head of the Medical Statistics & Epidemiology Department at Hamad Medical Corporation, Qatar during August 2002–July 2014. Add to this, he is advisor to World Health Organization and adjunct professor & coordinator for the postgraduate and master public health programs (MPH) of the School of Epidemiology and Health Sciences, University of Manchester. He has been an author or coauthor of more than 570 published journal articles. He is acting as an editor, associate editor, advisor editor and assistant editor for over 20 journals and referee for over 60 journals. He has contributed to more than 19 book chapters and supervised theses of 50 postgraduate students (MSc, MPH, MPhil and PhD).

Erol Yildirim is an associate professor, and he was graduated from Istanbul University, Department of Psychology in 2000. He has completed the Master of Clinical Cognitive Neuroscience at the Institute of Neurological Sciences of Istanbul University and completed his doctorate in the same university (Istanbul/Turkey). He has previously worked in Forensic Medicine Institute (Clinical Psychology Laboratory), and worked on clinical neuropsychology, executive functions and attention and their relation to memory, evaluation of cognitive functions in judicial process, and functional neuroimaging research areas, e.g., road safety, traffic safety culture, internet addiction.



Türker Özkan is an associate professor. Dr. Özkan's interests are related to cultural differences, the role of gender, sex, “extra-motives”, personality, explicit and implicit measures in safety in general and traffic and transport in particular. In addition, Dr. Özkan has studied about the acceptability of intelligent transportation systems, helmet usage and psychological models, seat-belt and child-seat usage, development of psycho-technical assessment tests, organizational and safety culture/climate in hospitals, traffic culture and traffic safety culture, human factor issues among professional and train drivers.

Timo Lajunen is an associate professor. Dr. Lajunen's interests are related to cultural differences, the role of gender “extra-motives”, personality, explicit and implicit measures in safety in general and traffic and transport in particular. In addition, he has studied about the acceptability of intelligent transportation systems, helmet usage and psychological models, seat-belt and child-seat usage, development of psycho-technical assessment tests, organizational and safety culture/climate in hospitals, traffic culture and traffic safety culture, human factor issues among professional and train drivers.