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Reducing the legal blood alcohol concentration limit for driving in developing countries: a time for change? Results and implications derived from a time–series analysis (2001–10) conducted in Brazil

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ABSTRACT

Aims In Brazil, a new law introduced in 2008 has lowered the blood alcohol concentration limit for drivers from 0.06 to 0.02, but the effectiveness in reducing traffic accidents remains uncertain. This study evaluated the effects of this enactment on road traffic injuries and fatalities. **Design** Time–series analysis using autoregressive integrated moving average (ARIMA) modelling. **Setting** State and capital of São Paulo, Brazil. **Participants** A total of 1 471 087 non-fatal and 51 561 fatal road traffic accident cases in both regions. **Measurements** Monthly rates of traffic injuries and fatalities per 100 000 inhabitants from January 2001 to June 2010. **Findings** The new traffic law was responsible for significant reductions in traffic injury and fatality rates in both localities ($P < 0.05$). A stronger effect was observed for traffic fatality (−7.2 and −16.0% in the average monthly rate in the State and capital, respectively) compared to traffic injury rates (−1.8 and −2.3% in the State and capital, respectively). **Conclusions** Lowering the blood alcohol concentration limit in Brazil had a greater impact on traffic fatalities than injuries, with a higher effect in the capital, where presumably the police enforcement was enhanced.

Keywords Alcohol, drink-driving, enforcement, fatalities, injuries, law, road traffic.

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INTRODUCTION

In 2004, road traffic accidents ranked ninth in the world's leading causes of death and burden of disease, being responsible for 1.3 million deaths and 41.2 million years lost due to premature mortality and disabilities globally. If this scenario already shows that road traffic accidents are a major public health issue world-wide, the future projections are of greater concern, as road traffic fatalities are estimated to increase to 2.4 million in 2030, due primarily to the economic growth attributed to low- and middle-income regions [1].

Moreover, in these countries the costs of transport accidents in terms of medical treatment and lost productivity correspond to a significant portion of the public budget. For example, the annual expenditure for traffic accidents on Brazilian roads is estimated in R$22 billions, which is equivalent to 1.2% of Brazil's nominal gross domestic product (GDP) [2].

The association between alcohol consumption and road traffic accidents is well documented in the literature, as are the main psychopharmacological effects of alcohol on human behaviour, which are considered important risk factors for violence and accident events [3]. There is substantial evidence that alcohol impairs motor coordination and decision making in drivers, thus enhancing risk-taking behaviour and the likelihood of accidents [4].

The measurement of blood alcohol concentration (BAC) is considered a feasible method for inferring the influence of alcohol on drivers' performance, including indirect analysis by breathalyzers, which is an effective method of providing accurate BAC estimates during field

impairment testing [5]. A large study comparing crash and non-crash drivers found that the relative risk of a crash begins to increase at 0.04–0.05 g/dl BAC, and increases steadily at BACs higher than 0.10 [6], which is in accordance with international recommendations regarding traffic safety suggesting that countries should adopt BAC limits of 0.05 or below [7].

However, many countries do not yet have a drink-driving law or have BAC limits that are above 0.05 [7]. This is especially relevant for low- to middle-income countries, where there is scarce evidence on drink-driving attitudes and strategies aiming to control drunk drivers. In fact, the vast majority of publications on alcohol's association with traffic accidents derive from high-income countries which, more often than not, also have lower road traffic death rates as well as reporting a number of strategies which demonstrate positive effects of reducing driving under the influence (DUI) of alcohol [8].

Brazil is the southern hemisphere's biggest country, with almost 200 million inhabitants, and despite its remarkable economic development during the last decade, traffic accidents are still one of the main causes of death, with approximately 35 000 people dying every year [7]. Additionally, according to a national telephone survey of the general population, binge drinking has increased steadily, from 16.2% in 2006 to 18.9% in 2009 [9].

Previous research on fatal traffic accident victims in the city of São Paulo (the major urban centre of Brazil) found that 39.4% of those presented BACs higher than 0.01, with 42.3% of drivers presenting BACs of greater than 0.06 [10]. Aiming to tackle this serious public health issue, a new national law introduced in June 2008 has reduced the BAC limit for drivers from 0.06 to 0.02 [11]. This new enactment also made a distinction between administrative (fine and temporary driver's licence suspension) and criminal sanctions (full suspension of driver's licence and detention) based on BAC results, which strengthened the punishment for those driving above the legal limits (see Fig. 1 for more details).

The effectiveness of such a strategy has already been demonstrated by Fell & Voas [12] in a large review of independent studies in 14 states in the United States. The meta-analysis conducted by these authors indicated that lowering the BAC limit from 0.10 to 0.08 resulted in a 14.8% reduction in alcohol-related traffic fatalities, and that lowering the BAC limit to 0.05 would possibly produce an additional reduction of 6–18% [12]. Similarly, a traffic legislation change carried out by the Japanese government in 2002, which lowered the permissible BAC from 0.05 to 0.03, showed significant

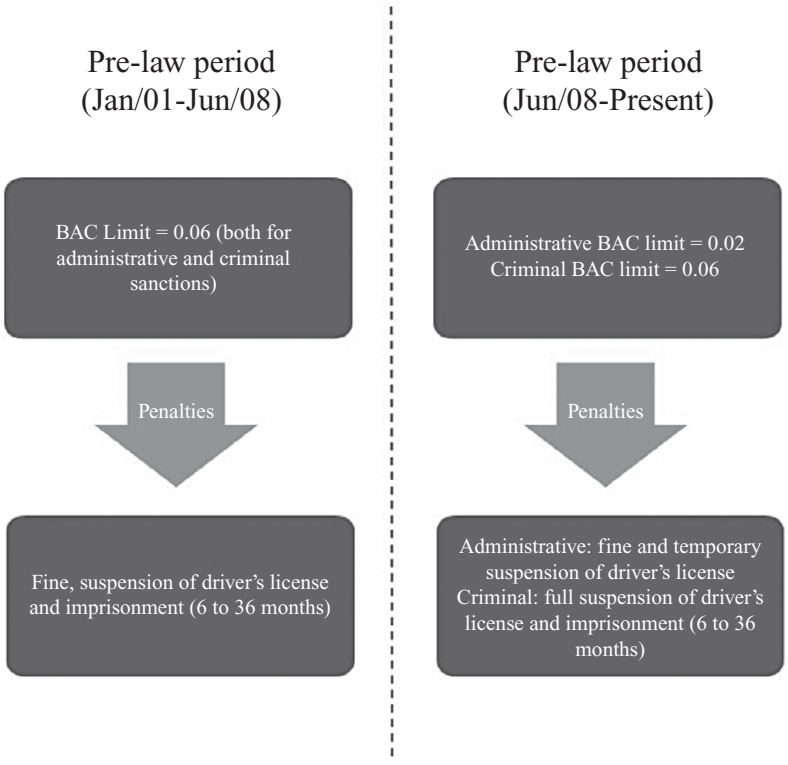

Figure 1 Changes in Brazilian law concerning blood alcohol concentration (BAC) limit for drivers after the new traffic law implemented in June 2008. *Penalties are determined by the responsible jurisdictions and might be subject to changes according to judge's interpretation

reductions in all alcohol-related and non-alcohol-related traffic injuries during the post-law period [13].

While these interventions might be transferable to developing countries, where there are scant scientific data on this issue [14], the effectiveness of the new traffic law in reducing traffic accidents in Brazil remains uncertain and should be addressed, taking into account typical differences between developed and developing countries. For instance, health and social disparities among countries may influence policy intervention results, and local research evidence may play a major role in the promotion of low-cost and effective strategies in developing countries [15].

The aim of this investigation was to analyse the effects of lowering the BAC limit for road traffic injuries and fatalities in both the State and capital of São Paulo in Brazil, and test the hypothesis that effects caused by the new traffic law vary according to outcomes (injuries versus fatalities) and two distinct regions might serve as a proxy for differences in law enforcement regarding DUI (State versus capital).

The hypothesis that differences in traffic law enforcement vary between the two distinct regions studied is based primarily on the greater rates of police activity (e.g. rate of stolen vehicles retrieved per inhabitants) observed in the capital compared with the State [16], which supports the assumption that DUI investigations follow the same discrepant pattern in those regions.

To our knowledge, this represents the first study on the effectiveness of lowering legal BAC limits with the goal of diminishing road traffic accidents in developing countries, and may inform similar countries where scientific data on this issue have not advanced.

METHODS

Study design, data source and procedures

The Public Security Office of São Paulo is responsible for the collection of data and statistics on traffic accidents in the State of São Paulo, which has 645 municipalities distributed across 248 600 km^2 with almost 42 million inhabitants, including the city of São Paulo, which accounts for 26.7% of the entire State's population.

Traffic accident-injured victims are attended immediately by emergency units and police officers at the event scene, while fatal victims are submitted to necropsy at the nearest medico-legal examination centre. Accordingly, information on traffic accident victims is gathered by police officers based on the victim's outcome, which in turn is compiled in a database coordinated by the Public Security Office.

It is important to note that while most fatal cases are registered, injured victims, especially those with less severe trauma, have a greater likelihood of not being attended by police officers because victims may rapidly leave the accident site, or due to the absence of the police officers at the time of accident (e.g. police strike period).

Data extracted from police reports on injuries and deaths caused by road traffic accidents were collected from January 2001 to June 2010, comprising 1 471 087 non-fatal and 51 561 fatal traffic accident cases during the entire study period (9 years and 6 months). The number of cases per month used in the present analysis was based on the accident's profile collected by police officers at the event scene and represents the number of accident events but not the total number of traffic accident victims in the given period.

In cases where an accident included both injuries and fatalities, only the most severe was included in the database. Additionally, the number of fatalities is most probably an underestimation of the actual number of fatal victims, as it has been estimated by previous studies that 61.6% of deaths occur on the same day of the traffic accident [17], with the remaining usually not being covered by the police reports used in the present study.

The data collected for the State of São Paulo did not include cases from the city of São Paulo, which means that the cases for each region are mutually exclusive. Monthly rates of traffic injuries and fatalities per 100 000 inhabitants derived from population data during the study period [18] were used as the main outcome variables.

Time–series analysis was conducted using a fitted autoregressive integrated moving average (ARIMA) model with adjustment for seasonality, and the effects of the new traffic law were evaluated by an intervention analysis for each outcome and region.

The research was based on confidential data maintained by the Public Security Office of São Paulo and was approved by the Research Ethics Committee of the University of São Paulo Medical School.

Statistical methods

To evaluate the effect of the new legislation on traffic injuries and fatalities, interrupted time–series analysis was performed using ARIMA models. Time–series data have special features, such as non-stationary and autocorrelations, which may derive biased and inefficient estimates when modelled inappropriately [19]. ARIMA modelling requires data to be stationary, assessed using the Dickey–Fuller test. If the raw data are not stationary, they are de-trended through the differencing process.

Furthermore, ARIMA modelling allows specification of temporal structure for error terms through the autoregressive (AR) or moving-average (MA) process. As monthly data were used in the current analysis, seasonal

pattern was also incorporated into ARIMA models, which are specified by the expression (*p*,*d*,*q*) (*P*,*D*,*Q*). The first term (*p*,*d*,*q*) refers to regular model specification; e.g. first-order difference (*d*) and AR (*p*) or MA (*q*) error structure. The second term (*P*,*D*,*Q*) is the seasonal component; e.g. the seasonal difference (*D*), and corresponding seasonal error structure (*P* or *Q*). The residuals of the estimated model should be white noise, which was tested using the Box–Ljung *Q*-test and also evaluated by examining the autocorrelation (AC) and partial autocorrelation (PAC) of estimated residuals.

Rates of traffic injuries and fatalities per 100 000 inhabitants were analysed as outcome series in the model, with a total of 114 monthly observations for each outcome series in both State and capital of São Paulo. In the interrupted time–series analysis, intervention was represented as a dummy variable. To estimate the effect of the new traffic law implementation, a dummy variable was created with 90 months before intervention coded as 0 and 24 months after intervention coded as 1.

An additional dummy variable was included in the intervention analysis to establish the effect of a strike period in the police force between September and November 2008, which probably reduced the collection of data on traffic casualties and could not be interpreted as a direct effect of the new traffic law. The models were fitted using EViews version 5 [20] and $P < 0.05$ was considered significant.

RESULTS

Traffic injuries have been increasing since 2001, both in the State and capital of São Paulo, and began declining even before the introduction of the law, showing a greater reduction in the post-law period (Fig. 2). Traffic fatalities in the State, however, remained constant from 2001 until 2008, whereas in the capital traffic fatalities have been decreasing since 2001 (Fig. 3), with both regions showing a trend for reduction on this outcome after the law.

Table 1 presents the results for the time–series and intervention analysis, which demonstrate the effects of the new traffic law implementation on traffic casualties in terms of estimated rates per month, as well as the possible interventional effect caused by the police strike period on the outcomes.

Four ARIMA models are presented separately for rates of traffic injuries and fatalities in the State and capital of São Paulo. In addition to the intervention effect estimates, each model presents the specification of ARIMA modelling. For example, the expression (0,1,1) (1,0,0) for injuries in the State of São Paulo indicates the model which was fitted on the first-order difference of the injury series and the error structure which was specified by a first-order moving average, as well as a seasonal (12-month lag) autoregressive term. Also shown in Table 1 for each model are the results from the Box–Ljung *Q*-test on

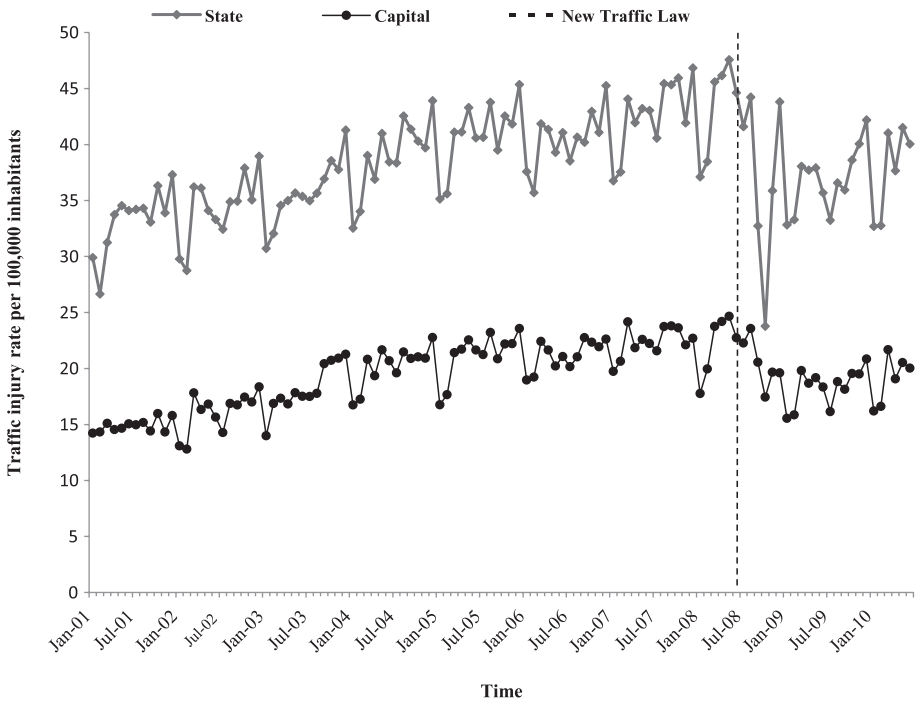

Figure 2 Trends in traffic injury rates (per 100 000 inhabitants) in the State and capital of São Paulo covering the period from January 2001 to June 2010

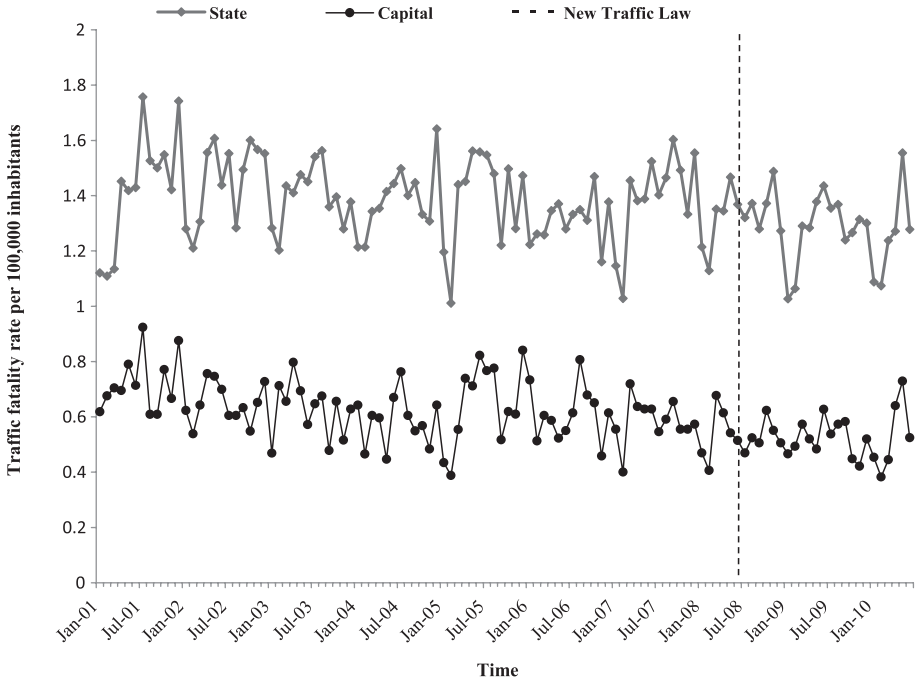

Figure 3 Trends in traffic fatality rates (per 100 000 inhabitants) in the State and capital of São Paulo covering the period from January 2001 to June 2010

Table 1 Estimated effects of the new traffic law implemented in June 2008 on traffic injury and fatality rates (per 100 000 inhabitants) in the State and capital of São Paulo derived from interrupted autoregressive integrated moving average (ARIMA) modelling of data from January 2001 to June 2010.

	Estimate	*SE*	*P-value*	*Q(12)*	*P-value*
Traffic injuries					
State of São Paulo (0,1,1) (1,0,0)				16.58	0.084
New traffic law	−0.705	0.304	0.023*		
Police strike	−11.42	1.289	<0.001*		
Capital of São Paulo (0,1,1) (1,0,0)				15.05	0.130
New traffic law	−0.441	0.217	0.044*		
Police strike	−2.072	0.745	0.007*		
Traffic fatalities					
State of São Paulo (1,0,0) (1,0,0)				10.68	0.383
New traffic law	−0.100	0.042	0.020*		
Police strike	0.072	0.071	0.315		
Capital of São Paulo (1,0,0) (0,0,0)				11.42	0.409
New traffic law	−0.104	0.032	0.002*		
Police strike	0.032	0.072	0.660		

*Interventional effect was considered statistically significant ($P < 0.05$). SE: standard error.

residual correlation. Test statistics for all lags were performed and the Box–Ljung statistics at lag 12 are presented for the seasonality pattern of series.

Across all four models, the new traffic law reduced traffic injury and fatality rates significantly ($P < 0.05$). Traffic injury rates reduced by 0.71 and 0.44 per 100 000 inhabitants per month in the State and capital of São Paulo, respectively, while fatality rates decreased by 0.10 per 100 000 inhabitants per month in both regions.

In other words, a somewhat stronger effect was observed for traffic fatality (a decrease of −7.2 and −16.0% in the average monthly rate in the State and capital of São Paulo, respectively) compared to traffic injury rates (−1.8 and −2.3% in the State and capital, respectively) in the post-law period, with the effect being higher in the capital for all the outcomes than in the State.

The police strike was associated significantly with lower records of injuries, but not with fatality rates, for

the State and capital. As shown from the Box–Ljung *Q*-test, the model fit was good in terms of residual autocorrelation for the two models on fatality rates, whereas fitting for the other two models on injury rates was somewhat less satisfactory, but still acceptable.

DISCUSSION

The results presented here indicate that the traffic law which reduced the BAC limit for driving in Brazil since June 2008 had a significant impact on traffic injuries and fatalities in both the State and capital of São Paulo, being responsible for a greater decline in fatality than injury rates. Moreover, the reduction effects of the legislation intervention were found to be greater in the capital than in the State.

Time–series analysis has proved to be a better method of interpreting the change in trend associated with intervention [13,21]. Therefore, the findings presented here based on this methodology may provide a clearer understanding of the effectiveness of lowering BAC limits for drivers, as research on interventions for controlling alcohol-related accidents presents numerous methodological weaknesses [22], particularly for low- and middle-income countries where data on this issue are scarce and in great demand [23].

In a study on the effectiveness of BAC limit reduction in 22 US states, Kaplan & Prato [24] demonstrated that lowering the BAC limit to 0.08 was more effective in reducing the number of alcohol-related traffic fatalities than traffic accidents, which is in accordance with our findings, and suggests that BAC reduction laws may have a greater influence on those drivers who are more likely to be involved in severe traffic accidents.

Although establishing a correlation between BAC level and severity of outcomes in traffic accident victims stills remains inconclusive [25], there is evidence that lowered legal limits show the strongest effects at highest BAC levels [26]. In view of these findings, it may be hypothesized that the new enactment was more effective in reducing more severe traffic accidents, which might be those most related with heavy drinking habits, as a consequence of a differential deterrence effect of the legislation [27]. However, future research regarding BAC law compliance across different drinking groups and society levels is needed to address this important issue, because the interventional effect may vary considerably depending upon the country/population characteristics, as the results presented here suggest.

Differences regarding the effect of the new traffic law between the two regions studied may be explained by divergent police enforcement and other supporting measures, such as media coverage and preventive actions in each locality. As noted above, the assumption that traffic police enforcement, including DUI measures, is greater in the capital than in the State of São Paulo sustains this argument, as the effects of the new enactment were more pronounced in the capital than the State.

The law was preceded by wide media coverage throughout the entire country during the initial months after the enactment, which may have promoted compliance and enforcement. Additionally, private initiatives by cab drivers and bar owners also aimed to reduce drunk driving. There is some evidence showing that media advocacy can increase public and political attention to alcohol problems, but public information campaigns and designated driver schemes are generally ineffective in reducing harmful alcohol use [28].

Furthermore, the decrease in traffic injuries in both regions was observed even during the period before the law, when preventive actions and police enforcement were already being used for controlling alcohol-impaired driving, which points to the importance of enactment of such a law as a reinforcement strategy.

Nevertheless, it remains to be seen if the observed effects are temporary and restricted to immediate post-law period, and how differences in supporting measures may help to explain the disparity observed between the two regions studied, in order to achieve a more general deterrent effect by improving sanctions for drunk drivers and local awareness of this issue.

At the same time, public authorities must be cautious about major changes in drink-driving laws such as lowering BAC limits and increasing penalties because these measures may increase the likelihood of refusing a BAC test in order to avoid criminal conviction [29], which has been demonstrated to be a great challenge for the current situation regarding DUI investigations in Brazil [30], as well as in other developing countries.

A recent cohort study conducted in France revealed that negative drinking-driving attitudes have increased during the last decade, despite the remarkable decreases in alcohol consumption and road fatalities observed during the same period due to substantial enhancement of traffic law enforcement in that country [31]. The authors concluded correctly that perceived punishment is less effective among DUI offenders, as the chance of being placed under arrest is much lower than with other traffic law offences such as speed limit violations. In light of this, the right combination of different strategies aiming to control the use of alcohol by drivers, including public support and the involvement of several levels of government for improving police enforcement effectiveness [26], may hold the key to successfully reducing alcohol-related traffic accidents.

When analysing an intervention strategy in series observations over time, it is also very important to account for the impact of other policies or events that

might influence observed trends, and lead to erroneous estimates of the effectiveness of the intervention variable under study.

The police strike that affected the data collection during a 3-month period was responsible for significant changes in traffic injuries observed in the State and capital of São Paulo, but did not influence traffic fatality reports in these regions. This was due mainly to the greater likelihood of non-fatal traffic victims not being registered during the police strike period compared to fatal traffic victims. Hence, this finding is important for supporting the notion that traffic casualties are subject to numerous overlooked interventions and/or policies, which should be included in future research that is fundamental for guiding new traffic legislation.

This study has several limitations that must be acknowledged. First, the data obtained did not provide victims' BAC in the traffic casualties studied; therefore we were not able to analyse the effect of the new law on BAC-positive victims compared to those who did not drink.

In addition, the method of data collection used in police reports may present bias that could have influenced the differential findings for injuries compared to fatalities. Other indicators including alcohol-related traffic accidents should be incorporated in the present database, further improving the integration of routine police reports with toxicological data and the quality of future investigations.

Secondly, it was not possible to account for other concomitant policies or trends in alcohol consumption and motor vehicle utilization that might affect the occurrence of traffic casualties during the study period. For example, a developing country such as Brazil is undergoing an increase in both alcohol use and motor vehicle utilization as a consequence of economic growth in recent years, which probably contributes to an underestimation of the law's effect on traffic accidents.

However, the use of time–series analysis (ARIMA modelling) has helped to overcome many difficulties in interpreting the effects of a specific intervention using time–series data, and also make possible inferences about a major police strike which could have led to serious misinterpretation.

Finally, this research focused only on observations collected for a particular Brazilian region, which may present important differences in traffic accident rates, police enforcement and contextual factors from other regions in the country or internationally. Nevertheless, our study represents the first and necessary attempt to develop permanent efforts in evaluating traffic measures concerning alcohol-impaired driving in a large developing region that might help to reverse the high morbidity and mortality from traffic accidents, as has been carried out in high-income countries in the last 30 years [32].

Perhaps the best strategy to combat alcohol-related traffic accidents is improvement of the currently established strategies, rather than a search for new and revolutionary measures. Our results suggest that lowering BAC limits was a successful strategy in Brazil and can be one of those tools, but special attention must be given to possible differential deterrence effects relying on police enforcement level and other extralegal factors that should be addressed by other regions sharing the same problem.

Future research conducted in developing regions, associated with the knowledge acquired in developed countries, may introduce new inputs for the amelioration of this global health issue and be decisive for the accomplishment of further strategies aiming to control the large number of casualties and financial costs associated with alcohol consumption by drivers.

Declarations of interest

T. Kahn works for the Public Security Office of São Paulo, which is responsible for the collection of data on traffic accidents in the State of São Paulo. J.C. Ponce is a forensic criminal expert involved in the investigation of crimes in the city of São Paulo. All the others authors are involved solely in academic research and declare no other conflict of interest. The corresponding author received a grant from CAPES Foundation, Ministry of Education of Brazil, for developing his doctoral studies at the University of São Paulo Medical School. The sponsor has not participated in the study design or in any decision concerning the writing and submission of the manuscript for publication.

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