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Drink driving and speeding in Sao Paulo, Brazil: empirical cross-sectional study (2015–2018)

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ABSTRACT

Objectives To evaluate the prevalence of drink driving and speeding during 2015–2018 in Sao Paulo, Brazil.

Design Cross-sectional observational study.

Setting Roads representing the five main regions of the city of Sao Paulo in Brazil, one of the world's largest urban areas.

Participants Drivers (N=10 294) stopped at routine roadside breath testing checkpoints and those driving in selected roads for speeding measurement (N=414 664).

Primary and secondary outcome measures Microwave radar guns were used to measure the speed of vehicles, while the prevalence of drivers under the influence of alcohol was observed in police checkpoints. Data were collected during three consecutive years (2016–2018) following a baseline study established in 2015 using a city-level representative sample of observational data representing all days of the week.

Results Alcohol-related fatalities kept at a constantly high percentage, with 39% of road traffic deaths involving alcohol in 2016. Drivers testing above the legal breath alcohol concentration limit showed a decreasing trend, from 4.1% (95% CI 2.9% to 5.5%) at baseline to 0.6% (95% CI 0.2% to 1.2%) in the end of 2018 (p<0.001); however, more than half of drivers refused breath tests at checkpoints despite steep legal penalties. The prevalence of speeding among all vehicles decreased from 8.1% (95% CI 7.9% to 8.2%) to 4.9% (95% CI 4.7% to 5.1%) by the end of 2016 (p<0.001), but then increased again to 13.5% (95% CI 13.2% to 13.9%) at the end of the study period (p<0.001).

Conclusions Drink driving rates have reduced, likely due to an increase in drivers refusing breath alcohol tests, while speeding rates have increased significantly by the end of the study period, particularly among motorcycles. Future strategies aiming at reducing road traffic injuries in the major Brazilian city should tailor drink driving and speeding enforcement based on the new evidence provided here.

Strengths and limitations of this study

► A cross-sectional study aiming at monitoring the prevalence of drink driving and speeding in the city of Sao Paulo, Brazil, was implemented in 2015 as part of the Bloomberg's Initiative for Global Road Safety, using an international and validated method.

► This is one of the largest and longest studies ever developed for monitoring road traffic risk factors in Brazil. The data presented highlight the great challenges public authorities have faced at controlling drink driving and speeding behaviour in the city.

► This study does not provide a causal connexion between interventions conducted in the city and the changes in the prevalence of the road traffic risk factors observed; however, the data presented correspond to population-level measurements for more than a 3-year period.

counterparts.[1] Variations in legislation, regulation and enforcement are likely the most important contributors to the heterogeneity of road safety outcomes across countries with different income levels,[2 3] with other factors such as safer roads, different modes of transportation and postcrash response also playing an important role in this association.[1]

Despite the scarcity of literature on the effectiveness of road traffic injuries (RTIs) interventions in LMICs, studies conducted in developed countries show that improved legislation and enhanced enforcement lead to lower RTI rates.[4–6] In the Latin America region, where injuries have become one of the leading causes of death among young adults,[7] many traffic safety strategies have already been put into place,[8] but monitoring systems able to measure their impact are scant.[9]

Over the past two decades, Brazil has made several attempts to change road safety laws with the main goal of strengthening the enforcement of road safety risk factors such as drink driving and speeding. These measures

INTRODUCTION

Currently, the vast majority of road traffic fatalities occur in low-income and middle-income countries (LMICs), despite the fact that these countries have lower levels of motorisation than their higher income

involved the reduction of the blood alcohol concentration (BAC) limit for drivers, increased fines for driving under the influence of alcohol and changes in speed limits for arterial roads.

Since the enactment of the first national road traffic legislation in 1998,[10] Brazil has experienced a relatively constant rate of traffic fatalities at approximately 20 deaths per 100000 inhabitants. The federal government introduced a new law in 2008 that reduced the legal BAC limit for drivers from 0.06% to 0.02%, followed by increased fines for other risky behaviours.[11] This was complemented by enhanced training for police enforcement and strengthened mass media campaigns focusing on drink and driving, particularly in Sao Paulo, and by 2012 the national BAC limit was further reduced to a zero tolerance law.[12]

Previous studies have supported the effectiveness of such enactment, both in terms of reducing RTIs and the frequency of driving under the influence of alcohol[13 14]; however, another study using nationally collected data for three major Brazilian capitals showed a null effect attributed to the law in reducing traffic-related mortality rates in these locations, raising concerns about data quality, regional disparities and different methods using secondary mortality data from multiple sources in Brazil.[15 16]

Interventions targeting speeding have taken place at a regional rather than a national level. In Sao Paulo, in July 2015, there was a reduction of the speed limits of the marginal roads (arterial roads that run through the city) from 90 km/h to 70 km/h as a public health measure to reduce the mortality along these routes. Nonetheless, the speed limits were reverted to the original limits along these express roadways in January 2017.

Although some success in reducing RTIs during the last decade was achieved at the regional level in cities such as Sao Paulo,[13] the same was not observed at the national scenario.[17] Moreover, the number of road traffic deaths involving motorcycle drivers has grown more than 10-fold during the last decade, currently accounting for almost one-third of all road traffic fatalities nationally.[17] In Sao Paulo, road traffic deaths have remained constant since 2015, after a steep decline during the beginning of the decade.[18]

With the goal of monitoring the most prevalent risk factors in road safety, Sao Paulo was selected as one of the 10 cities to participate in the Bloomberg Initiative for Global Road Safety (BIGRS), which started in the second half of 2015.[9] In this paper, we present the prevalence of drink driving and speeding in Sao Paulo during this project. These data will help decision-makers to focus on prevention efforts directed towards this emerging public health issue for LMICs.

METHODS
Design and participants
The purpose of the monitoring and evaluation arm of the BIGRS project was to collect observational data on key road safety risk factors (drink and driving, speeding, seatbelt and helmet use) to construct an epidemiological baseline and help to monitor road safety in the city of Sao Paulo, Brazil. A baseline study was performed during the third quarter of 2015, with six additional studies performed twice a year (during the first and third quarters) until the end of 2018.

In order to obtain city-level prevalence parameters, eight different locations were randomly selected to represent the main regions of the city for non-alcohol risk factors, including speeding. Site selection was based on a previous list of sites created by the Traffic Engineering Company of Sao Paulo (CET), which includes the eight administrative regions covering all five zones of the city. This list had a total of 108 predetermined zones currently used by CET for enforcement strategies. We excluded regions that included high-speed roads within the limits of the city and/or locations where observations could not be made safely. A final list with 98 possible sites that fulfilled requirements for conducting the study was reached (ie, operability of data collection and safety of the researchers involved). A random number generator was used to select potential sites, and the final selection criterion was to choose six sites with at least one location representing each of the five main zones of the city. We selected six locations for the first round of data collection in 2015 (baseline) and then added two more sites by the third wave of data collection using the same procedure described above (figure 1).

In the case of drink driving, the military police from the State of Sao Paulo is responsible for determining the locations and conducting roadside breath testing checkpoints in both areas with higher and lower rates of alcohol consumption. Sobriety checkpoints were established according to the schedule of the police force, but usually lasted for around 4 hours, divided into two or three locations in the same neighbourhood, so drivers would not avoid the checkpoint after it was initiated. Sixty-nine checkpoints comprising all five zones of the city (North, South, West, East and Centre) were followed by the research team during the study period. Participants in the roadside observations were drivers along sampled roadways. Participants relate to the study's risk factors through the presence or absence of the outcomes (eg, positive alcohol breath test for drivers or vehicles driving above the posted speed limit), with no personal identification made.

Drink driving data collection
Drink driving observations were carried out between 21:30 and 04:00 during weekdays and weekend days. All locations across the city followed the same standard police procedure. Once a vehicle was pulled over, researchers collected demographic anonymised data on participants and recorded the value of the alcohol breathalyser test administered, without interfering at any stage with the police procedure or participants. There were approximately 1000–1900 observations per round, totalling
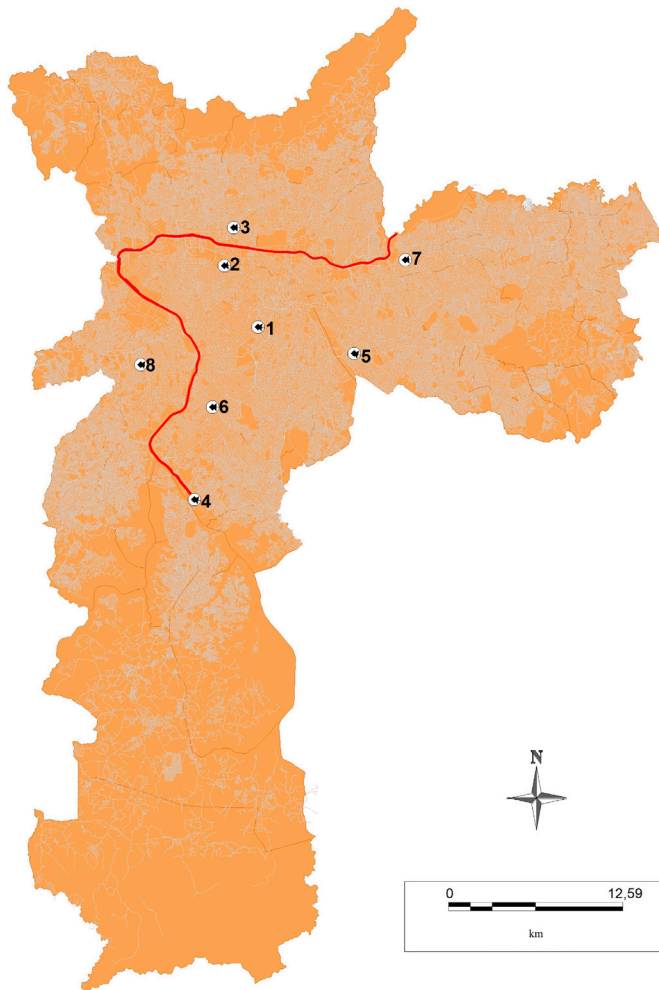
Figure 1 Selected sites for speeding observations in the city of Sao Paulo (locations 1–6 were introduced since 2015, while 7 and 8 were added by the third wave of data collection in 2017). Map scale (1:314.700 cm). *Red lines show the arterial roads where speed limit alterations were implemented during the study period. Speed limits at the chosen sites did not change throughout the project and were set at 50 km/h in almost all locations, except for location 7 in which the speed limit was slower (40 km/h).

individuals that refused the test were actually under the influence of alcohol.

We also assessed data on road traffic deaths and BAC values (positivity ≥0.02%) obtained from medical examiner toxicological reports from the Institute of Legal Medicine of the State of Sao Paulo during 2015 (N=574) and 2016 (N=512) (66.3% and 64.3% of all road traffic deaths, respectively). Road traffic death rates (per 100 000 population and 10 000 registered vehicles) and population estimates from 2005 to 2016 (the latest year for which data on road traffic mortality were available) were retrieved from the Foundation State System for Data Analysis.[18]

Speeding data collection

Trained observers collected data on traffic volume, type of vehicle (two-wheeled motorcycles, private cars such as sedans and sport utility vehicles (SUVs), trucks or buses), estimated age of drivers and number of passengers in each vehicle. Two research assistants were assigned to one site per day. Every site was observed for a minimum of 1 weekday (Monday–Friday) and 1 weekend-day (Saturday–Sunday), such that every site was observed for a minimum of two full days. The study team carried out observations in 1.5 hour blocks of time in order to represent each site at different times of the day, usually from 7:30 to 19:00, comprising five observation blocks with 30 min interval periods between each of them for each day. Every round of data collection lasted on average 2 months. There were approximately 41 800–89 100 observations per round, totalling 414 664 vehicles for which speed was measured during the entire study period.

Microwave radar guns (LTI 20-20 UltraLyte 100 LASER Speed Measuring System, Tele-Traffic (UK), Warwick, UK) were used to measure the speed of passing vehicles. The instant speeds of vehicles travelling over the legal speed limit were recorded. Speed limits at the chosen sites did not change throughout the project and were set at 50 km/h in almost all locations, except for one (location 7) in which the speed limit was slower (40 km/h).

Statistical analysis

Prevalence estimates for the outcomes studied were calculated for all periods of data collection and compared using Poisson exact 95% CIs. Royston p trend test for verifying linear trends in proportions (p<0.05) were performed using STATA V.13.1.[19]
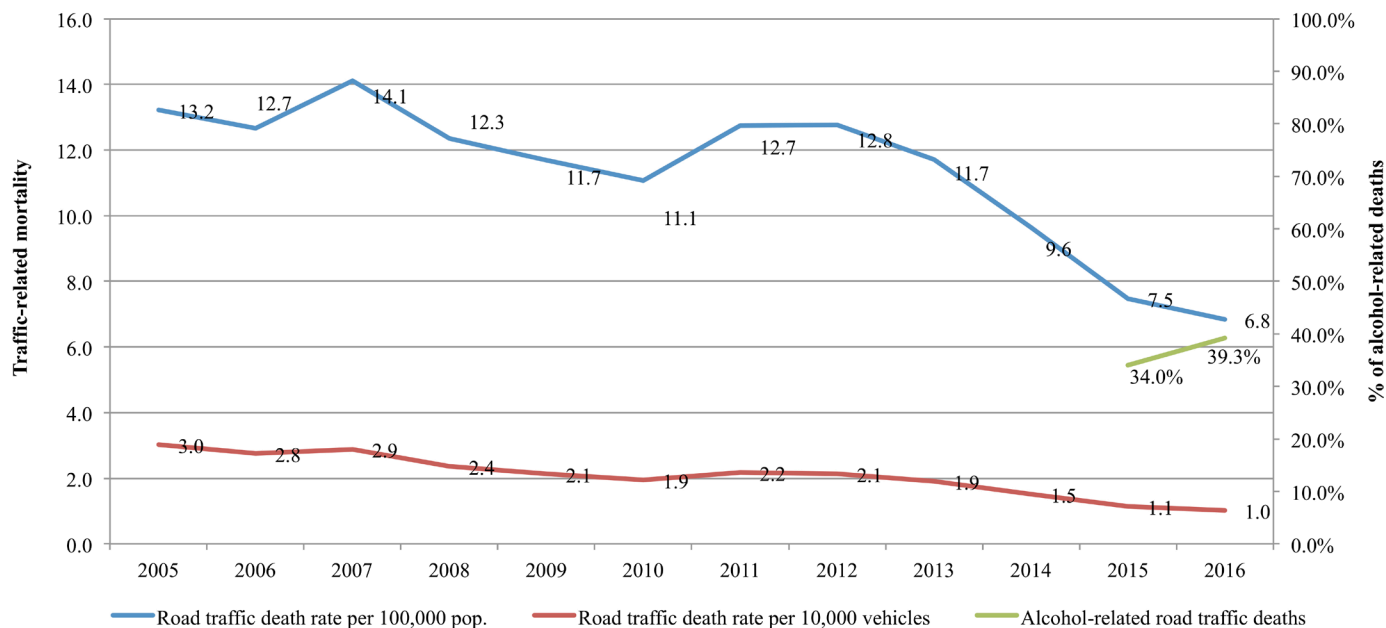
Patient and public involvement

This research was done without patient or public involvement in study design, analysis or reporting.

RESULTS
Drink driving

Road traffic death rates have been gradually reduced since 2005 by almost twofold, from 13.2 (95% CI 12.5 to 13.9) to 6.8 (95% CI 6.4 to 7.3) per 100 000 population in

10 294 drivers stopped and observed during the study period.

The police used a passive breathalyser test to screen for drivers under the influence of alcohol and then used a confirmatory breathalyser to establish the quantitative result. Participants could refuse the test at any stage, with an administrative fine of around US$800 (or US$2934.70 in Brazilian reais) and temporary (up to 12 months) suspension of their driver's license equivalent to being caught with a BAC between 0.02% and 0.06%. Criminal penalties (full suspension of driver's license and up to 36 months of imprisonment) only apply to those with a BAC of 0.06% or higher. We have considered refusals as negative cases in order to provide conservative estimates, so our drink driving estimations are only for drivers actually testing above the limit. Nonetheless, we also present data on the upper limit of drink driving, that is, assuming all

Figure 2 Time trend of estimated road traffic death rates and proportion of alcohol-related road traffic deaths in the city of Sao Paulo, Brazil. *A blood alcohol concentration cut-off of 0.02% was used. Source: State System for Data Analysis Foundation[18] and Institute of Legal Medicine of the State of Sao Paulo.

2016 (p<0.001). The proportion of alcohol-related road traffic deaths based on routine data obtained from the coroner's office showed that the percentage of deaths involving alcohol use by all victims did not change significantly between 2015 (34.0% (95% CI 29.4% to 39.1%)) and 2016 (39.3% (95% 34.0% to 45.1%)) (p=0.22) (figure 2). The vast majority of alcohol-positive deaths presented BAC levels equal or higher than 0.06% in both years (96% and 98% in 2015 and 2016, respectively), the BAC limit for criminal penalties under the Brazilian legislation.

Most drivers stopped at random roadside breath testing checkpoints were men (85.7% (95% CI 83.9% to 87.5%)) aged 25 and older (93.3% (95% CI 91.5% to 95.2%)) and driving sedans (82.7% (95% CI 81.0% to 84.5%)). Overall, during the entire study period, the prevalence of drivers above the legal limit was 2.0% (95% CI 1.7% to 2.3%), while the proportion of those positive for any alcohol (including refusals) was 11.3% (95% CI 10.6% to 11.9%) (table 1).

Drivers testing above the legal limit presented a decreasing trend, from 4.1% (95% CI 2.9% to 5.5%) at baseline to 0.6% (95% CI 0.2% to 1.2%) in the end of 2018 (regression slope: −0.006; SE: 0.001; p<0.001). Conversely, the rate at which drivers refused the breath test increased since the beginning of the study, from 57.7% (95% CI 46.2% to 71.3%) in 2015 to 73.3% (95% CI 56.3% to 93.7%) in 2018 (regression slope: 0.016; SE: 0.006; p<0.01). Considering all those screened positive for any alcohol and all the refusals together, the prevalence has declined from 14.1% (95% CI 11.9% to 16.6%) at the beginning of the study to 7.4% (95% CI 5.9% to 9.1%) in the end of 2018 (regression slope: −0.010; SE: 0.001; p<0.001) (table 1).

Speeding

Overall, the speeding rate during the entire study period was 8.9% (95% CI 8.8% to 9.0%), with motorcycles presenting the highest prevalence (37.9% (95% CI 37.3% to 38.6%)) for speeding and representing more than one-third of all vehicles above the speed limit (36.3% (95% CI 35.6% to 36.9%)). Most vehicles observed speeding was at a speed that was less than 20% higher than the posted speed limit (71.7% (95% CI 70.8% to 72.5%)), with the majority of those presenting speeding levels below 10% (65% (95% CI 64.1% to 66.0%)). Almost one quarter (24.4% (95% CI 23.9% to 24.9%)) was at a speed between 20% and 50% higher than the speed limit, while only 3.9% (95% CI 3.7% to 4.1%) were at a speed higher than 50% of the posted speed limit. Motorcycles composed more than half of all vehicles observed at a speed higher or equal than 20% of the speed limit (51.6% (95% CI 50.2% to 53.0%)) (table 2).

At baseline, the prevalence of speeding was 8.1% (95% CI 7.9% to 8.2%) among all vehicles, which decreased to 4.9% (95% CI 4.7% to 5.1%) in 2016 (regression slope: −0.013; SE: 0.001; p<0.001). Observed speeding prevalence increased again by the beginning of 2017 (7.9% (95% CI 7.7% to 8.1%)), and by the end of 2018 speeding among all vehicles had increased to 13.5% (95% CI 13.2% to 13.9%) (regression slope: 0.017; SE: 0.001; p<0.001), the highest prevalence observed during the entire study period. This same pattern was observed for speeding when stratified by vehicle type, with motorcycles presenting speeding prevalence estimates at least four times higher than that observed for other vehicles (table 2).

Table 1 Demographic characteristics and alcohol breath testing results from drivers who were submitted to random roadside breath testing within the limits of the city of Sao Paulo (2015–2018)

	Baseline 2015 (N=1057)	Round 2 2016 (N=1923)	Round 3 2016 (N=1177)	Round 4 2017 (N=1480)	Round 5 2017 (N=1701)	Round 6 2018 (N=1792)	Round 7 2018 (N=1164)	Total 2015–2018 (N=10294)
Sex								
Male	84.8%	84.8%	86.5%	87.7%	86.4%	85.9%	83.7%	85.7%
Female	15.2%	15.2%	13.5%	12.3%	13.6%	14.1%	16.3%	14.3%
Age								
Under 18	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
18–24	17.3%	12.2%	2.0%	4.7%	2.2%	3.8%	5.8%	6.6%
25–59	76.4%	82.1%	95.1%	92.2%	94.9%	92.1%	89.5%	89.2%
60 and over	6.2%	5.6%	2.8%	3.1%	2.8%	4.1%	4.6%	4.2%
Screening breathalyser								
Negative	85.9%	86.6%	86.7%	87.8%	88.9%	92.1%	92.6%	88.7%
Positive +refusal*	14.1%	13.4%	13.3%	12.2%	11.1%	7.9%	7.4%	11.3%
Only positive	6.0%	6.9%	3.7%	4.1%	2.8%	3.9%	2.9%	4.4%
Refusal	8.1%	6.5%	9.6%	8.1%	8.3%	4.0%	4.5%	6.9%
Confirmatory breathalyser								
Under LOD (≤0.04)†	13.4%	25.7%	10.2%	19.4%	14.8%	14.9%	18.6%	17.4%
Low positive (>0.04 to ≤0.34)	24.8%	21.0%	15.3%	12.2%	10.1%	9.9%	8.1%	15.3%
High positive (>0.34)	4.0%	4.7%	2.5%	1.7%	0.5%	0.0%	0.0%	2.2%
Total above legal limit (excluding refusals)	4.1%	3.4%	2.4%	1.7%	1.2%	0.8%	0.6%	2.0%
Total % of refusals‡	57.7%	48.6%	72.0%	66.7%	74.6%	75.2%	73.3%	57.6%

*It includes the refusals among those screened positive for any alcohol and/or with clinical signs of intoxication.

†All breath alcohol concentration (BrAC) are shown on mg/L. The BrAC limit for administrative sanctions is 0.04 mg/L, while the criminal sanctions are set at 0.34 mg/L. Under lower limit of detection (LOD) denotes either a true negative or results under 0.05 mg/L (the LOD used for administrative sanctions).

‡It includes the total refusals observed from the screening and confirmatory tests requested.

DISCUSSION

By establishing one of the first large-scale observational studies on the prevalence of behavioural risk factors associated with RTIs in Brazil, we provided valuable insights into the current status of drink driving and speeding in Latin America's largest city.

Fatal crashes involving alcohol-positive victims have remained relatively stable compared with similar studies conducted more than a decade ago,[20] with the majority of decedents presenting high BAC levels (≥0.06%). Moreover, not all victims involved in crashes had BAC estimates available; therefore, other measures such as the rate of fatal drunk drivers during nighttime, BAC among pedestrians and alcohol-related deaths adjusted for common biases in selecting victims who are submitted to blood alcohol analysis might serve as a better strategy for future comparisons.[21][22] This is particularly the case at the national level where there is not a current systematic monitoring programme on alcohol use by fatally injured drivers.

Conversely, drunk drivers identified by police random roadside breath testing declined during the study period, despite the challenges attributed to the growing refusal rate. Given that the proportion of drunk drivers declined by more than half, while the refusal rate increased by less than one-third in the same period, not all of the reduction in observed drink driving prevalence can be attributed to increased refusals.

The general prevalence of drivers under the influence of any alcohol (including refusals) measured in Sao Paulo was relatively smaller compared with other studies conducted nationally and internationally using similar methodologies.[23–26] Drink driving enforcement has shown to be one of the greatest contributors to reducing alcohol-impaired driving around the globe.[6][25][27] Since the reduction of the legal BAC limit in Brazil, Sao Paulo has demonstrated to be one of the leading cities in Brazil in enhancing enforcement with important reductions in road crashes and driving after drinking.[13][23] However, current legislation allows drivers not to take

Table 2 Prevalence and extent of speeding among different vehicle types in the city of Sao Paulo (2015–2018).

	Baseline 2015 (N=89 058)	Round 2 2016 (N=41 800)	Round 3 2016 (N=61 526)	Round 4 2017 (N=64 767)	Round 5 2017 (N=53 755)	Round 6 2018 (N=51 892)	Round 7 2018 (N=51 866)	Total 2015–2018 (N=414 664)
All vehicles above speed limit*	8.06%	8.26%	4.92%	7.89%	8.90%	12.47%	13.54%	8.93%
Motorcycles	37.81%	33.61%	22.73%	39.06%	35.49%	46.20%	42.91%	37.92%
Private cars	6.84%	6.25%	4.17%	5.49%	6.76%	9.72%	10.91%	7.01%
Trucks	3.92%	4.79%	3.01%	3.80%	4.28%	5.48%	5.81%	4.34%
Buses and minivans	4.05%	4.75%	2.51%	3.29%	2.24%	3.44%	5.02%	3.57%
All vehicles above speed limit (<20%)	6.05%	5.93%	3.87%	5.79%	6.37%	8.61%	8.99%	6.40%
Motorcycles	23.32%	19.59%	15.71%	25.10%	22.14%	26.23%	22.97%	22.64%
Private cars	5.47%	4.93%	3.37%	4.32%	5.18%	7.40%	8.11%	5.44%
Trucks	3.19%	3.84%	2.48%	3.21%	3.48%	4.38%	4.44%	3.50%
Buses and minivans	3.46%	4.10%	2.19%	2.96%	2.03%	3.07%	4.07%	3.08%
All vehicles above speed limit (≥20%)	2.01%	2.32%	1.05%	2.10%	2.53%	3.87%	4.55%	2.53%
Motorcycles	14.48%	14.02%	7.03%	13.96%	13.35%	19.97%	19.94%	15.28%
Private cars	1.37%	1.32%	0.80%	1.17%	1.58%	2.32%	2.81%	1.57%
Trucks	0.73%	0.95%	0.53%	0.59%	0.80%	1.10%	1.37%	0.84%
Buses and minivans	0.58%	0.66%	0.33%	0.33%	0.21%	0.37%	0.95%	0.49%

*General and total prevalences refer to all vehicles observed, and not only the vehicle types specified here.

the breathalyser test by avoiding higher penalties such as prison time when they refuse the test,[28] and this should be taken into account in developing new strategies aiming to reduce the number of refusals.

General speeding rates observed in Sao Paulo were below 10% for most of the study period, with more than one-quarter of overspeeding vehicles driving at a speed 20% or higher than the posted speed limit. Although these rates are at a similar level with other studies conducted internationally,[6 25 26 29] motorcycles presented a much higher speeding rate compared with other vehicles. This may be related to the fact that motorcycle use has been increasing in Brazil,[30] while the enforcement of violations such as speeding among motorcyclists is more difficult to perform.

The decline in general speeding rates observed in the locations studied was coincidental with a reduced speed limit intervention implemented in the main arterial roads of the city, with a subsequent increase in these rates after speed limit reductions in these same arterial roads were reverted. Although it is difficult to attribute the observed changes to the speed limit reduction in different roads than those observed, it could be hypothesised that lower speed limits along the main arterial roadways of the city might have contributed to a general reduction in

speeding prevalence in a representative sample of the city's roads (spillover effect). Nonetheless, changes in enforcement and in the traffic flow that were not evaluated in the current research could also be associated with the changes observed; therefore, it is difficult to isolate their effects.[31 32]

LIMITATIONS

The roadside observation measurements used in this study correspond to population measurements only, and are derived from an observational study design; therefore, causal attribution to the associations reported is challenging. Moreover, our observations for speeding were not conducted in the arterial roads where most of the speed reduction interventions took place. Nonetheless, spillover effects or the enhancement of enforcement could have occurred as a result of the changes in the speed limit implemented during the study period, which should be examined by further studies on this topic.

Drivers and passengers were not distinguished among all road traffic fatalities studied, but earlier studies using the same population and in other Brazilian regions have showed similar BAC positivity estimates between all victims and drivers.[20 33] Also, drivers could have used

artifices (such as traffic warning devices) to avoid sobriety checkpoints; however, in the last rounds of observations, most drivers testing positive were at checkpoints visible in common traffic warning cellphone apps.

Other factors (ie, economic fluctuations) that might have happened in the same period of the study and could interact with the prevalence of the risk behaviours studied were not addressed here. Nevertheless, our measurements used standardised protocols during the entire study period and the locations were randomly chosen to be representative of the natural traffic flow in the city for more than a 3-year period.

CONCLUSIONS

In conclusion, measured drink driving rates in Sao Paulo appear to have decreased by half in the last 3 years, but the growing refusal rate for breath testing remains an important challenge for a general deterrence effect expected from these actions. Moreover, speeding rates have increased significantly by the end of the study period, despite conflicting interventions in speed limits implemented in arterial roads of the city in the same period, particularly among motorcycles. The model used to measure the traffic safety risk factors demonstrated here offers the opportunity to be applied in other developing regions where the RTI burden has assumed epidemic proportions and effective strategies are urgently needed.

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Competing interests None declared.

Patient consent for publication Not required.

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Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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