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Road safety impact of Ontario street racing and stunt driving law

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ABSTRACT

Objective: The purpose of this study was to conduct a process and outcome evaluation of the deterrent impact of Ontario's street racing and stunt driving legislation which came into effect on September 30, 2007, on collision casualties defined as injuries and fatalities. It was hypothesized that because males, especially young ones, are much more likely to engage in speeding, street racing and stunt driving, the new law would have more impact in reducing speeding-related collision casualties in males when compared to females.
Methods: Interrupted time series analysis with ARIMA modelling was applied to the monthly speeding-related collision casualties in Ontario for the period of January 1, 2002 to December 31, 2010, separately for young male drivers 16–25 years of age (primary intervention group), mature male drivers 26–65 years of age (secondary intervention group), young female drivers 16–25 years of age (primary comparison group) and mature female drivers 26–65 years of age (secondary comparison group). A covariate adjustment using non-speeding casualties was included.
Results: A significant intervention effect was found for young male drivers with, on average, 58 fewer collision casualties per month, but not for mature male drivers, when non-speeding casualties were controlled for. No corresponding effect was observed in either comparison (females) group.
Conclusion: These findings indicate a reduction in speeding-related casualties among young males of 58 fewer casualties per month subsequent to the introduction of Ontario's street racing and stunt driving legislation and suggest the presence of a general deterrent effect.

1. Introduction

Street racing has a long history, largely becoming popular in the past century when cars became affordable and widely available to the public (Smart et al., 2010). Recently, street racing and associated driving behaviours, which are linked to increased risk of motor vehicle collisions, injuries and deaths, have been identified as a road safety problem in the research literature (Knight et al., 2004; Smart et al., 2011, 2012; Vingilis and Smart, 2009). Social surveys conducted in various international jurisdictions have found that the prevalence of self-reported street racing among young male drivers ranged between 18.8% and 69% (Fergusson et al., 2003; Arnett et al., 1997). Vingilis et al. (2011) found that 20.4% of Ontario high school students in grades 11 and 12 reported street racing in the previous year and the adjusted odds for males racing was 12 times higher than for females.

Street racing typically involves extreme speeding. Therefore, all the dangers of speeding are highly relevant to street racing. The review of evidence suggests that a 1% increase in speed increases a driver's fatality risk by 4–12% (Vanlaar et al., 2008). The Traffic Injury Research Foundation reported that over 20% of all collisions in Canada involve excessive speeding or driving too fast for conditions and that in 2006 alone, such collisions resulted in about 800 deaths and about 3000 severe injuries (Vanlaar et al., 2008). After impaired driving, speeding is identified as the second most common contributor to motor vehicle fatalities (Vingilis and Smart, 2009). Police collision reports in Canada and most other jurisdictions do not include separate codes for racing, although street racing information can be added to the incident description section of the collision form (Peak and Glensor, 2004). Witnesses are often required to identify a driver's involvement in street racing

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activities. In the case of a collision, drivers are often not willing to admit to street racing and passengers and spectators of racing vehicles are not eager to be witnesses (Folkman, 2005; Vingilis and Smart, 2009). Thus, it is reasonable to assume that some collisions related to racing are identified as speeding-related in the official reports and statistics "because of the challenge for police to detect and list street racing as a contributor to collisions" (p. 150) (Vingilis and Smart, 2009).

1.1. New legislation

In the province of Ontario, new street racing/stunt driving legislation (Bill 203 – Ontario's Street Racers, Stunt and Aggressive Drivers Legislation), was introduced on September 30, 2007. The definition of racing includes driving behaviours of one or more motor vehicles where the elements of competition or chasing are present, while motor vehicles are driven at a speed which clearly exceeds the allowed speed limit. Stunt driving included the following activities: causing some or all tires to lose traction with the surface of the highway while turning; spinning tires or causing a vehicle to circle; lifting some or all tires from the surface of the highway; driving while the driver is not sitting in the driver's seat; preventing another vehicle from passing; driving two or more motor vehicles side by side where one of the motor vehicles occupies a lane for oncoming traffic; driving as close as possible to another vehicle, pedestrian or object without a reason; a ban on driving a motor vehicle on a highway with a connected nitrous oxide system and driving 50 km/h over the speed limit (Service Ontario, 2011).

Most charges for racing and stunt driving offences are laid for speeding 50 km/h or higher over the posted speed limit. Street racing and stunt driving offences, if detected, result in the following punishment under the new regulation:

1. an immediate 7-day roadside vehicle impoundment and driver's licence suspension, prior to conviction;
2. upon conviction, a fine ranging $2000–$10,000, 6 demerit points, possible imprisonment for up to 6 months, up to 2 years licence suspension for the first conviction;
3. if second conviction occurs within 10 years of first conviction, up to 10 years licence suspension (Service Ontario, 2011).

One of the purposes of new legislation, such as Ontario's street racing/stunt driving law, is deterrence. Classical deterrence theory states that there is an inverse relationship between violation of the law and the certainty, severity and swiftness of the punishment (Davey and Freeman, 2011). The higher the certainty of detection by police and punishment upon detection, the higher the severity and celerity of the punishment, the higher the chance that drivers will refrain from potential violations of traffic laws (Vingilis, 1990). Thus, legislation with certain, severe and swiftly administered sanctions should deter illegal street racing and stunt driving activities.

Deterrence theory would also suggest that in order for the law to be effective in deterring the offenders, it has to be publicized and well enforced (Vingilis et al., 1988). To increase public awareness about the stunt driving law, a number of activities were implemented by the Ministry of Transportation of Ontario (MTO), such as educational campaigns targeting high school students, development and distribution of brochures on speeding and stunt driving, presenting information on the new legislation in the Driver's Handbook, installation of road signs on major Ontario highways with the information on penalties under the new law (Personal communication, 2013). Mass media in Ontario widely covered the details of the legislation, especially in the first two years of its implementation, mainly due to controversial opinions

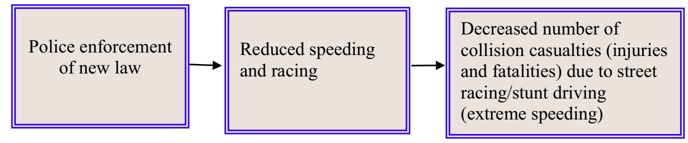

Fig. 1. The causal model of Ontario street racing/stunt driving legal intervention.

raised by this law in the public (Daigle et al., 2014). Some suggested the law unconstitutional due to a provision of the possibility of imprisonment for up to 6 months, with no fault of harm or injury.

Enforcement of the law with roadside licence suspensions and subsequent convictions are expected to increase the perception of certainty of punishment. Vehicle impoundment is considered to be a severe penalty by street racing and stunt driving offenders (Leal et al., 2009), as not only it entails removal of the vehicle from an offender, but also imposes towing and storage fees on the driver who may possibly face an increase in vehicle insurance for a street racing/stunt driving conviction. A fine charged upon conviction, even at a minimum amount of $2000, is also a severe penalty relative to income level, especially for a young driver. Immediate suspension of a licence is a manifestation of the punishment's swiftness.

Ontario's street racing/stunt driving legislation has not been formally evaluated in terms of its road safety impact. Researchers in other jurisdictions have evaluated vehicle impoundment provisions of similar legislation, the results of which provide mixed evidence about the deterrent effect of vehicle impoundment laws (Leal et al., 2009; Leal, 2010; Clark et al., 2011). These studies, however, did not use a multiple time series design to examine the impact of the legislation.

A previous study examined whether Ontario's street racing/stunt driving legislation had an effect on extreme speeding convictions which included the provision of licence suspensions that did not exist for speeding before this new law came into effect (Meirambayeva et al., 2014). A significant reduction in monthly convictions for speeding 50 km/h or more over the posted speed limit was found for male drivers after the introduction of the Street Racers, Stunt and Aggressive Drivers law (the intervention parameter estimate = −45.1, P = .004). No pre-post change in monthly convictions for speeding 50 km/h or more over the posted speed limit was found for female drivers after the introduction of the new law (the intervention parameter estimate = −2.89, P = .3). The purpose of this study was to conduct a process (implementation) and outcome evaluation of the impact of Ontario's street racing/stunt driving legislation on casualties (injuries and fatalities) from speeding-related collisions. In order to strengthen the validity of the findings, we followed standard program evaluation methodology, by using both a theory-based causal model and multiple measures to allow for triangulation (e.g. Grembowski, 2001; Rossi et al., 1999; Weiss, 1998). Triangulation includes "theory triangulation" whereby results are congruent with existing theory and "methods triangulation" whereby different data sources, data collection procedures and measures show consistency in the direction of results (Grembowski, 2001). The use of administrative data can be problematic because the data are not captured for research purposes and can have quality and other problems; triangulation can strengthen validity of findings as the different bias and measurement error on one measure and data collection method can be offset by another (Grembowski, 2001; Rossi et al., 1999). The causal model, based on deterrence theory, of this legal intervention is presented in Fig. 1. According to deterrence theory, an intervention should be well publicized and adequately enforced to make the public aware of the punishment in relation to the offence. As an intermediate outcome, the drivers may respond by less speeding, which should result in improved safety on the roads, measured by reduced collision injuries.

To assess implementation, we examined roadside suspensions for racing/stunts for the period of September 30, 2007–December 31, 2011, as a surrogate measure of enforcement. These administrative suspensions constituted new penalties and did not exist prior to September 30, 2007. Thus, any indication of suspensions being laid for racing/stunts after September 30, 2007 would be due to enforcement of the new law. To assess outcomes, we examined an intermediate outcome to measure change in speeding and a criterion outcome of speeding-related casualties by sex and age before and after the new legislation. To check whether there was a change in highway speed, we examined changes in the average daily highway speed data, obtained from MTO for three counting stations which collect traffic and speed data on provincial highways for the pre–post time periods using the moving-block time series bootstrap method. The criterion outcome measure included motor vehicle speeding-related casualty data analyzed using multiple interrupted time series design. Based on previous studies that young male drivers (aged 16–25), were the most likely to engage in street racing and associated risky driving behaviours than any other category of drivers, followed by mature male drivers (aged 26–65), we hypothesized that these two groups would be the most likely to be deterred and show a significant decrease in motor vehicle speeding-related casualties subsequent to the introduction of Ontario's street racing/stunt driving legislation (Leigh, 1996; Peak and Glensor, 2004; Leal, 2010; Vingilis et al., 2011). An ideal comparison group to control for possible temporal changes in casualty trends over the pre- and post-new legislation time frame would be males who drove in the same jurisdiction but were not subject to the new legislation. However, as this law was a "full-coverage program", it was not possible to find such a comparison group (Rossi et al., 1999). Females have been shown to be the least likely to engage in street racing and stunt driving. Thus young (aged 16–25) and mature (aged 26–65) female drivers were used to serve as comparison groups for possible extraneous temporal changes in casualties; we hypothesized no change in their casualties subsequent to Ontario's street racing/stunt driving legislation. To control for general casualty trends we included in all speeding-related casualty analyses, non-speeding-related casualties as a covariate.

2. Methods

2.1. Variables

The data for the study were provided by the MTO. The goal of the MTO is to improve Ontario road safety. The MTO maintains various administrative databases, including Accident Data System (ADS). The ADS contains data on all reportable motor vehicle collisions in Ontario. In the case of reportable collisions, an investigating police officer completes a comprehensive motor vehicle collision report. The report is transferred to the Road Safety Research Office at the MTO, which maintains the database. The data were provided by the MTO to the research team for the period of 2002–2011. This study received approval from the Office of Research Ethics for Human Subject Use of the University of Western Ontario.

2.1.1. Roadside suspension data (process measure)

Monthly time series of the roadside suspensions for street racing/stunt driving were provided by the MTO for the period of September 30, 2007 till December 31, 2011. Roadside suspensions were used as a surrogate measure of enforcement of the new law. Prior to September 30, 2007, no administrative suspensions were meted out for street racing/stunt driving as these constituted new penalties and thus any suspensions for street racing/stunt driving were evidence of charges being laid under the new law. Suspension codes included 85 and 86; both are used for administrative licence suspensions for racing/stunts (Section 172 of Highway Traffic Act). Code 85 is used for roadside administrative 7-day licence suspension and code 86 is used for court-ordered licence suspensions. The suspensions data were plotted to assess whether this new licence suspension provision was actually being meted out (process evaluation) subsequent to the enactment of the new street racing/stunt driving legislation.

2.1.2. Highway speed data (intermediate outcome measure)

Three sections of major provincial highways have permanent counting stations installed, which collect data on the volume and speed of traffic. The hourly data were provided by MTO for these three counting stations: two of them operated on different locations on highway 401, the major east–west highway in Ontario (Putman and Port Hope) and one station collected data on highway 11, a major north–south highway in central Ontario (Medonte). The hourly data were averaged to produce daily time series. The data were collected on consecutive days over varying periods of time with the stations being periodically out of service, so the resulting time series has many gaps or equivalently since the gaps are large enough we may assume the data for each station are comprised of several independent time series or subseries.

2.1.3. Collision casualty data (criterion outcome)

Individual-level collision data were aggregated by month of collision to monthly counts of casualties (injuries and fatalities) of drivers, accompanying passengers in the motor vehicles as well as pedestrians and cyclists killed or injured by a speeding driver to produce time series for the period of January 1, 2002–December 31, 2010. The street racing/stunt driving legislation came into effect on September 30, 2007 so this corresponds to 69 months and 39 months for the pre-intervention and post-intervention subseries, respectively. Injury was defined in accordance with the Motor Vehicle Collision Report Manual as "any bodily harm visible or complained of resulting from the collision" (Ministry of Transportation of Ontario, 2012). Fatality was defined as an injury resulting in a death within 30 days from the day of collision.

The Accident Data System specified driver's action which contributed to a collision. No data element on the collision form was assigned to street racing and stunt driving. Nor is information available on the speed of travel of vehicles before they crashed. Therefore, we used a 'proxy' measure to capture motor vehicle casualties relevant to street racing and stunt driving by restricting the driver's action field to the Accident Data System's two speed-related categories: speed exceed limit and speed too fast for condition. This measure is to some extent consistent with the main stunt driving offence laid, namely speeding 50 km/h and higher over the posted speed limit.

Earlier studies reported that street racing was predominantly a male activity and the prevalence of street racing among females was relatively low (Leigh, 1996; Vaananen and Wieloch, 2002; Peak and Glensor, 2004; Warn et al., 2004; Vingilis and Smart, 2009; Leal, 2010). Therefore, the casualties were analyzed separately by sex based on the assumption that a greater potential for deterrence would occur for males than for females because of the higher prevalence of street racing behaviour among males than among females. Our previous study indicated that per licensed driver, 1.21% of 16- to 24-year-old male drivers and 0.37% of 25- to 64-year-old male drivers had their licences suspended under the new law between September 2007 and December 2011. This is in contrast to females where 0.21% of 16- to 24-year-old female drivers and 0.07% of 25- to 64-year-old female drivers had their licences suspended under the new law during the same time period (Mireambayeva et al., 2014). Analyses were performed for speeding-related casualties for the following four groups of drivers: young males (aged 16–25), mature males (aged 26–65), young females (aged 16–25) and mature females (aged 26–65). The age division between young and mature drivers was based on previous studies that street racing was more prevalent for young drivers (Leigh, 1996; Knight et al., 2004; Peak and Glensor, 2004; Armstrong and Steinhardt, 2006).

Stable structure of the driver's population exists in terms of sex distribution during the study period. The number of observations before and after the intervention is sufficient to have the power to detect the effect at the chosen level of significance (5%), according to the method by McLeod and Vingilis (2008). Assuming a step intervention model and a moderate lag-one autocorrelation ($\varphi = 0.5$), with $n = 108$ months in total and intervention occurring at time $T = 70$, the probability of detecting a change of one standard deviation equals 87%. An online power computation program (McLeod, 2007) was used to compute the power for a two-sided test at 5% significance level.

2.1.4. Non-speeding-related casualties

To control for general trends in casualties, the time series of monthly counts for all non-speeding-related casualties (injuries and fatalities) for the period of January 1, 2002–December 31, 2010, were used as a covariate in all analyses of speeding-related casualties time series analyses.

2.2. Statistical analysis

Interrupted time series modelling was used to evaluate the effect of an intervention on a time series and to account for the feature of time series data that the error terms associated with each observation are not independent (Katz, 2010). Traffic-related time series data often exhibit not only autocorrelations but also seasonal patterns due to weather effects on driving practices. An intervention analysis was carried out for each of the speeding casualties time series groups including the non-speeding casualties as a covariate. Denote the casualties for the j-th group at time t by $Y_t^{(j)}$, where $j = 1, 2, 3, 4$ corresponds respectively to young males, mature males, young females and mature females and $t = 1, \ldots, 108$ corresponding to the observation number for the monthly time series from January 2002 to December 2010. The general dynamic intervention analysis time series model used in our study may be written as,

$$Y_t^{(j)} = \mu + \beta(X_t - \bar{X}) + \frac{\omega}{1 - \delta B} I_t^{(T)} + \frac{\Phi(B^s)\phi(B)}{\Theta(B^s)\theta(B)} a_t. \quad (1)$$

where μ is the expected mean of the pre-intervention time series, β is the regression coefficient for the non-speeding casualties, X_t is the non-speeding casualties corresponding to observation t, $\bar{X}$ is the sample mean of the non-speeding casualties, ω and δ are the intervention model parameters, B is the backshift operator on t, $I_t^{(T)}$ is an indicator series, and $T = 0$ corresponds to the start of the intervention, October 2007. The final term in the model corresponds to the autocorrelated time series error and may be denoted by N_t, so

$$N_t = \frac{\Phi(B^s)\phi(B)}{\Theta(B^s)\theta(B)} a_t,$$

where $\Phi(\cdot)$, $\phi(\cdot)$, $\Theta(\cdot)$, and $\theta(\cdot)$ denote operator polynomials of degrees p_s, p, q_s and q, respectively, $S = 12$ is the seasonal period and a_t is a sequence of normal independent random innovations with mean zero and variance σ_a^2, In other words N_t is a multiplicative seasonal ARMA model (Box et al., 2008; Cryer and Chan, 2008). The ARMA model for N_t assumes that it is a stationary time series. More general ARIMA models with differencing were also fit in some cases and shown to give equivalent statistical inferences about the intervention but the interpretation is slightly simpler in the stationary case. See Supplement Data for details.

Two types of indicator series were examined in our modelling corresponding to a step intervention when $I_t^{(T)} = S_t^{(T)}$ where,

$$S_t^{(T)} = \begin{matrix} 1 & t \geq T \\ 0 & t < T \end{matrix} \quad (2)$$

or a pulse intervention when $I_t^{(T)} = P_t^{(T)}$

$$P_t^{(T)} = \begin{matrix} 1 & t = T \\ 0 & t \neq T \end{matrix} \quad (3)$$

When $\delta = 1$, the model contains a simple step intervention since we can write,

$$\frac{\omega}{1 - \delta B} I_t^{(T)} = \omega S_t^{(T)} \quad (4)$$

and so in this case the intervention is modelled as simply a change to a new level. This means that the expected mean before the intervention is μ and the post-intervention series mean is $\mu + \omega$.

Building intervention models that include a covariate time series is discussed by Hipel and McLeod (1994). The first step is to estimate the noise term using least squares and then using the estimated noise term we identify a suitable seasonal ARIMA model. After selecting p, q, p_s and q_s, the full model specified in Eq. (1) is fit using exact maximum likelihood. This is followed by rigorous testing of the statistical assumptions. The intervention analysis model in Eq. (1) assumes that the only change that occurs after the intervention is a change in the mean or level of the time series. As a first approximation this is often reasonable. Major violations of this assumption may also be detected by examining the residual time series plot of variance changes and/or autocorrelation after the intervention. For time series models, one of the important assumptions is the independence of the estimated innovations, $\hat{a}_t$, or residuals. Outliers may also be a concern. Graphical methods along with significance tests are used to check these assumptions. When significant autocorrelation is detected, re-specifying the ARIMA model usually produces an adequate fit. When outliers are present, a first approach is to re-fit the model treating the corresponding observation as missing. The R function arima() is used since it provides exact maximum likelihood estimation with missing values. A minor adjustment to R arima() function for the model in Eq. (1) is implemented in our Supplement Data package. All intervention analysis computations were carried using R (R Development Core Team, 2013). Complete details with graphs and computer scripts in R of the modelling steps are provided in the Supplement Data.

3. Results

3.1. Roadside licence suspensions

The implementation of the new law, which included a new provision of licence suspensions, was shown to occur with over 1000 suspensions laid in the first month of the new law. A decreasing trend was found for the number of monthly roadside licence suspensions for street racing/stunt driving, starting from September 2007, when the law was implemented, until the end of 2011 (Fig. 2).

3.2. Highway speed data

Time series plots for each of the stations are shown in Fig. 3. From this plot we see the time series have many large outliers towards the left tail and so the usual type of power transformation does not help to reduce the outliers or make the distribution more symmetrical. For this reason, we use medians rather than means.

As shown in Table 1, the median average speed decreased by 2.26, 2.08, and 1.32 for Medonte, Port Hope and Putnam, respectively and this difference was significant at less than 0.1%

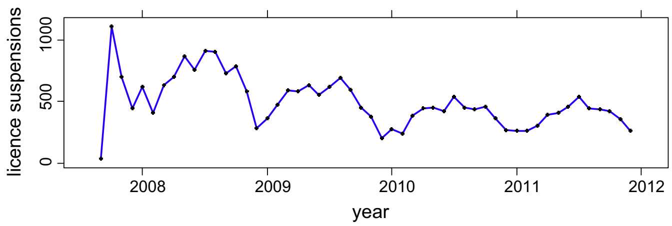

Fig. 2. Plot of roadside suspensions for racing/stunts for the period of September 2007–December 2011.

on a two-sided Wilcoxon test. The 95% confidence intervals using the Wilcoxon test as well as those obtained using a non-parametric time series moving-block time series bootstrap (Efron and Tibshirani, 1994; Davison and Hinkley, 1997) are also shown in Table 1. These two methods give very similar results. The Wilcoxon test method for difference in medians assumes statistical independence as well assuming the underlying distributions are symmetric whereas the moving-block bootstrap relaxes both of these assumptions. The computations were performed using R (R Development

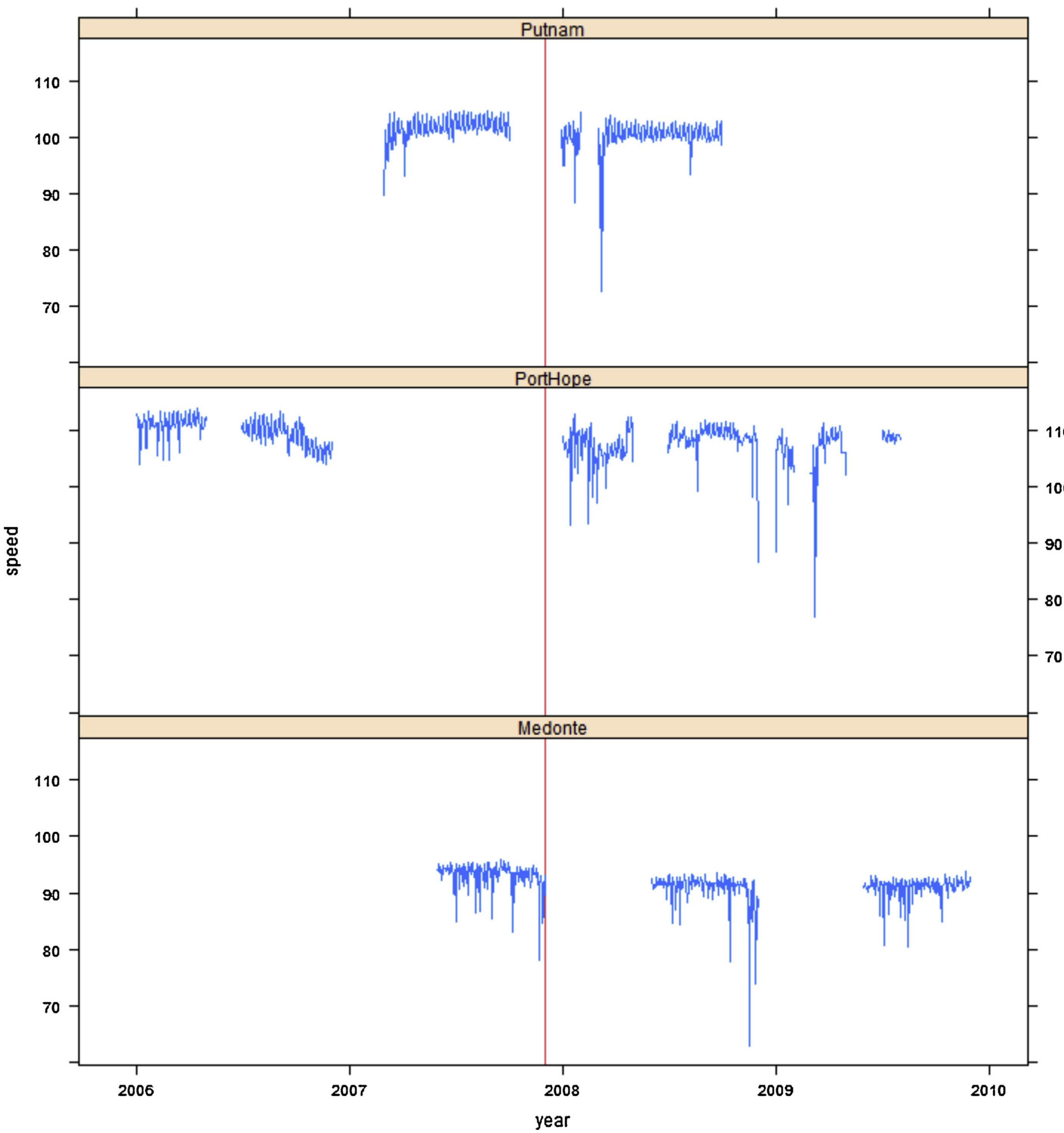

Fig. 3. Average daily speeds from three stations on major highways in Ontario. The vertical line marks the start of the intervention, October 2007.

Table 1
Medians and confidence intervals for median differences for three speed counting stations.

Counting stations	Median	*n*	Difference[a]	95% CI Bootstrap	95% CI Wilcoxon
Medonte					
Pre-intervention	93.97	122	2.26	(2.12, 2.62)	(2.18, 2.59)
Post-intervention	91.59	430			
Port Hope					
Pre-intervention	110.56	275	2.08	(1.50, 2.46)	(1.69, 2.30)
Post-intervention	108.48	400			
Putnam					
Pre-intervention	101.56	214	1.32	(1.06, 1.54)	(1.04, 1.51)
Post-intervention	100.24	248			

[a] Median pre-intervention speed minus median post-intervention speed.

Core and Team, 2005) and all details are included in the online Supplement Data.

3.3. Analyses of speeding-related casualties

As discussed in Section 2.2, for each analysis, model fitting involved the iterative procedure of identifying a suitable ARMA model for the error term followed by exact maximum likelihood estimation and model diagnostic checking. Details of all our analyses are available in the Supplement Data.

In our univariate analysis we used the simple step intervention, that is, Eq. (1) with δ set to 1. For the simple step intervention the effect of the intervention may be visualized from the time series plots shown in Fig. 4. The horizontal line in the pre-intervention period corresponds to the term μ in Eq. (1) and the horizontal line in the post-intervention period corresponds to the term $\mu + \omega$. In this case, the step change, estimated parameter ω, was not statistically significant on a two-sided test for either young females or mature females. For both young and mature males, the step intervention was statistically significant with a two-sided *P*-value of less than 0.1%. In our next analysis, the non-speeding casualties time series was used as a covariate and once again a step intervention was used. In all cases the covariate was highly significant with a two-sided *P*-value less than 0.1%. This indicates that the covariate was helpful in removing common contemporaneous changes in the casualties time series for each of the four groups not related to the intervention. In this case, as with the univariate analysis, the step intervention was not significant at 5% for either young or mature females. On the other hand, the two-sided *P*-value for the step intervention for mature males was 6.5% and a 95% confidence interval for the estimated monthly reduction in casualties was (−1.4, 42.3). For young males, the step intervention was again significant at less than 0.1% and the 95% confidence interval for the reduction in monthly casualties was (18.3, 50.1).

For the young male casualties group, further analyses were done using the dynamic response intervention model. Although we found the step intervention as highly significant, it could be that the effect of the intervention diminishes. To test this hypothesis the pulse intervention model was fit. A likelihood-ratio test of the null hypothesis $H_0 : \delta < 1$ vs. the alternative $H_0 : \delta = 1$ was rejected at less than 0.1%, indicating the effect did not diminish over the post-intervention period. This intervention was also highly significant with a two-sided *P*-value less than 0.1%. A visualization comparing the fitted simple step intervention and the fitted dynamic step intervention for the young male casualties is shown in Fig. 5. This model suggests that the intervention is steadily increasing up to a new level, sometimes referred to as the gain and estimated by $\omega/(1 - \delta)$. The estimated gain for the model in Fig. 5 is 58.3. This means that in the long run, the average decrease in casualties on a per month basis is about 58.3.

4. Discussion

This study presents a formal process and outcome evaluation of the impact of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation. This study suggests that the new legislation had an effect on reducing speeding-related casualties of young male drivers, the cohort with the highest per licensed driver rate of speeding-related casualties in Ontario. As hypothesized, we found that the casualties from speeding-related collisions involving young male drivers, the primary intervention group, decreased in the post-intervention period compared to pre-intervention period, even after controlling for non-speeding related casualties. However, for the secondary intervention group, mature male drivers, the intervention effect was found to be negative but did not reach statistical significance when the non-speeding-related covariate was added to the analysis. No effect was found for both comparison groups, young female drivers and mature female drivers.

Deterrence theory suggests that in order for new legislation to be effective in deterring the offenders, it has to be publicized and well enforced to affect perception of detection and punishment (Vingilis et al., 1988). We found evidence of law enforcement, using the monthly counts of administrative licence suspensions as the measure of implementation as prior to the new law, suspensions were not meted out. A month after the law came into effect, more than 1000 suspensions occurred under Bill 203. The monthly suspensions were exhibiting gradual decrease over time, with the elements of seasonal patterns – higher number during warm seasons. Assuming a constant level of law enforcement over months, it was possible that the decrease in suspensions resulted from the deterrent effect of the legal intervention, although it is important to point out that the gradual reduction could also reflect a decrease in enforcement activities.

Finally, our findings on the average daily highway traffic speeds (excluding peak hours) on two major highways are consistent with the causal model presented in Fig. 1. The median average speed decreased at each station after September 30, 2007. As shown in Table 1, the 95% confidence interval for the decrease in median speed for the three counting stations indicated a statistically significant decrease at 5% in all cases. Although the speed reduction seems numerically small, it is important to point out that according to the European Transport Safety Council (1999), for every 1 km/h decrease in average speed, a 4% reduction in crashes is estimated to occur.

The different datasets triangulate to show consistent results supportive of deterrence theory that certain, swift and severe sanctions of administrative licence suspensions and vehicle impoundment can deter risky driving behaviour. The results are also supported by our previous study on the new legislation that found a statistically significant decrease in extreme speeding convictions (over 50 km/h over posted speed limit) for males but not for females (Meirambayeva et al., 2014). Moreover, these findings are congruent with other studies that examined the effects of

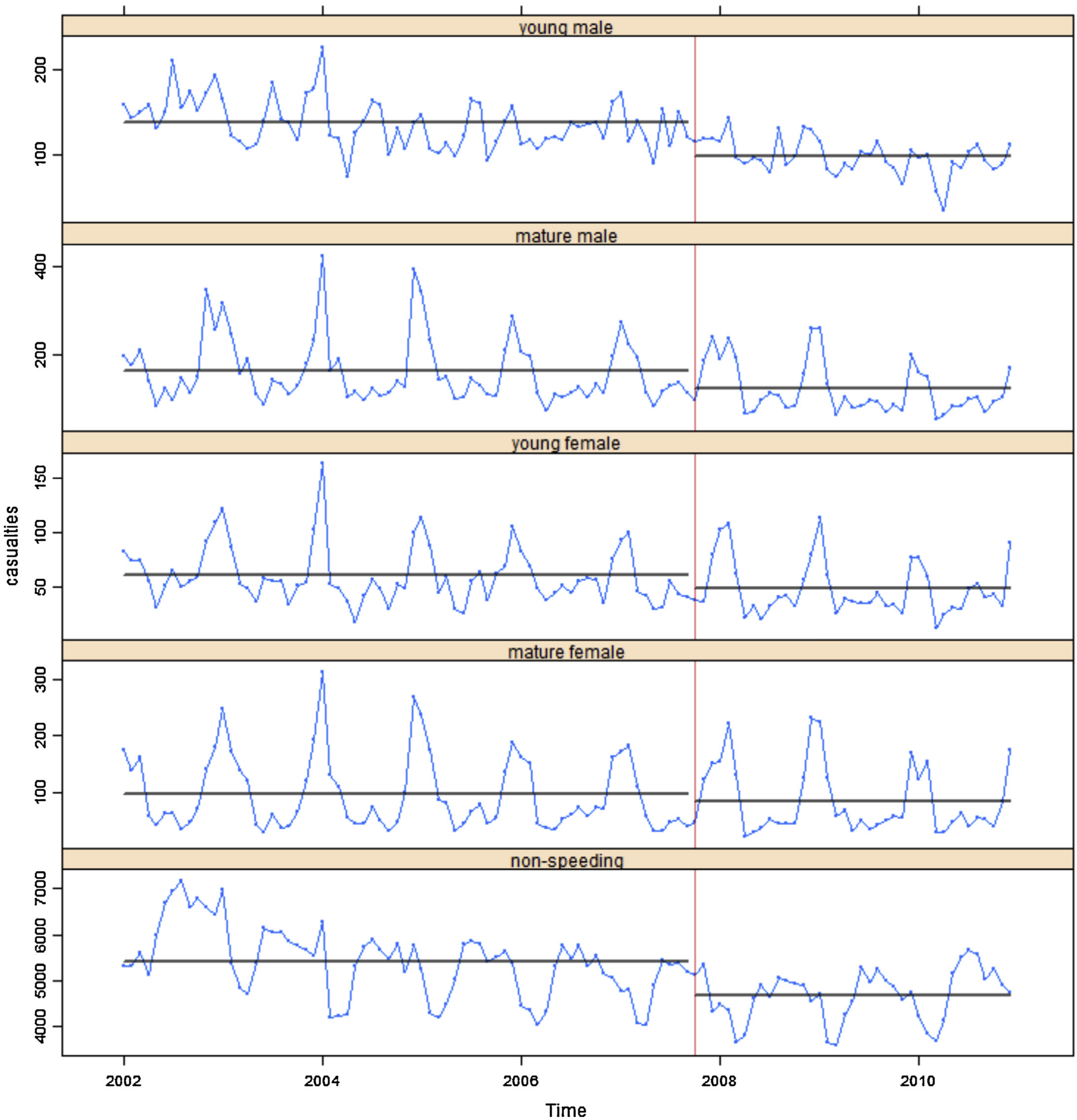

Fig. 4. Casualties time series. The vertical line marks the start of the intervention, October 2007.

administrative sanctions on casualties or fatalities for other offences, such as impaired driving (Asbridge et al., 2009; Beirness et al., 1997; Eisenberg, 2003; Henderson and Kedjidjan, 1992; Legge and Park, 1994; Mann et al., 2002; Rogers, 1995; Villaveces et al., 2003).

Importantly this study found an average decrease of about 58 casualties per month involving young male drivers. Young male drivers are at a particularly high risk of motor vehicle casualties because of their increased propensity to risky driving, as evidenced by their higher self-reported speeding, street racing, drinking and driving and not using safety belts compared to older male and female drivers (Vingilis and Wilk, 2010; Vingilis et al., 2011). Recent research indicates that there is a complex interaction among neurological, cognitive and psychosocial processes leading to greater risk-taking and sensation seeking at onset of puberty offset by development of self-regulatory competence which only fully matures in young males in their mid to late twenties (Casey et al., 2008; Glendon, 2011; Johnson and Jones, 2011; Spear, 2013; Steinberg, 2010). An overlapping influence is aggression and competitiveness commonly found in young males and known as “the young male syndrome”, perhaps representing an evolutionary, developmental process (Wiesenthal and Singhal, 2012; Wilson

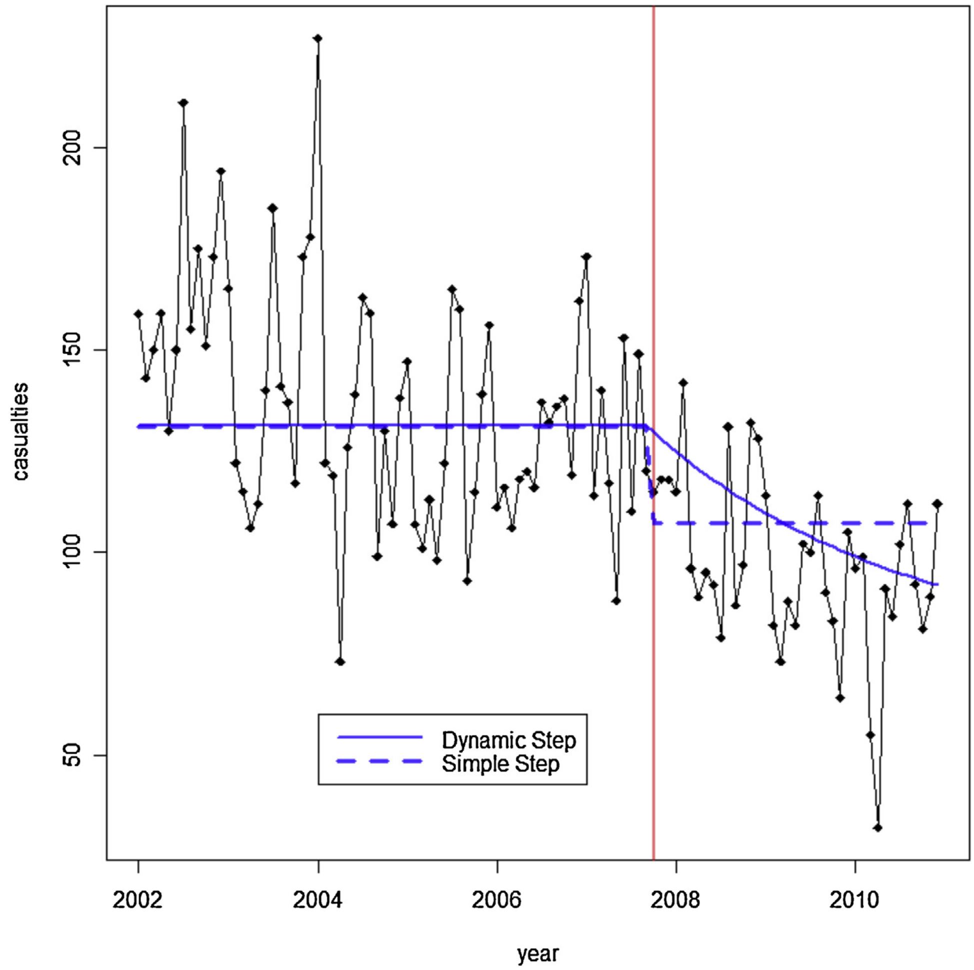

Fig. 5. Dynamic Step Intervention Model for young male casualties with covariate adjustment. The vertical line marks the start of the intervention, October 2007.

and Daly, 1985). Thus, despite the potentially neurodevelopmental component to young male risk taking, this study suggests that young males may be responsive to the effects of new laws with heavy penalties.

Our study has a number of strengths and limitations. This study was the first to examine formally the effectiveness of Ontario's street racing/stunt driving law on reducing casualties from speeding-related collisions. A very comprehensive and complete data source of collisions originating from the MTO was used. We employed quasi-experimental interrupted time series design as it was not possible to randomly assign violators to different sanctions. The findings of quasi-experimental designs are more vulnerable to alternative explanations than experimental designs, but they can offer fairly strong findings if comparison groups are used and biases are explored (Voas and Deyoung, 2002). Additionally theory and methods triangulation were used to examine whether the results were congruent with the causal model and the results of the different datasets were congruent with each other.

Use of a comparison group in the study allows for the control of history effects. 'History' refers to the possibility that other external events, occurring during the time period of the intervention, might have explained the observed outcomes (Grembowski, 2001). Although we used non-equivalent comparison groups due to the comprehensive policy change of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation, the use of young and mature females as comparison groups was our best available choice. Additionally, non-speeding-related casualties were used as a covariate in the time series analyses to control for general collision casualty trends.

We are aware of another legislative change which could have affected speeding casualties – mandatory truck speed limiter regulation, which was introduced starting January 1, 2009 and fully enforced 6 months after its implementation. However, this intervention was unlikely to have produced the results similar to the observed street racing/stunt driving intervention effect because truck speed limiter regulation was applied only to trucks, not to all vehicles and truck drivers are mainly mature male drivers (estimated age between 44 and 51) (Gill, 2013; Gill and Mcdonald, 2013) due to fewer young people entering the industry. Thus the reduction in casualties in our primary intervention group (young male drivers) relative to mature males and the comparison groups (young or mature female drivers) is most likely not due to the truck speed limiters regulation, although we cannot rule out its possible effect on highway speed.

The use of a proxy variable for identifying street racing/stunt driving casualties was an additional point of limitation. The collision database did not have a special code assigned for racing/stunt driving, and speeding-related codes was the best possible option; we could only examine a general deterrent effect on speeding-related casualties and not specifically on street racing or driving 50 km/h over the speed limit. Thus, this study was not able to measure extreme speeding casualties but rather speeding-related casualties. Other types of collision casualties that could be due to stunt driving activities could not be examined, although the vast majority of charges laid under the new law were for extreme speeding of over 50 km/h over the speed limit. An additional limitation is our assumption that a constant level of law enforcement of the new law had occurred, although it is quite possible that enforcement over time decreased as policing priorities may have changed. Additionally the MTO only has three permanent sites with traffic count data which also had breakdowns leading to a serious missing data problem; these three sites may not be representative of traffic speeds for the entire province of Ontario. Finally, no comparison region without the intervention could use used because neighbouring provinces either had extremely low casualty rates or were different in culture, although general trends in casualties were accounted for by using non-speeding-related casualties as a covariate. Given that the intervention coincided with the economic recession, it is not surprising that a decrease was found in general casualty trends.

Keeping in mind all the limitations, this study has some important implications. First, our findings provide additional evidence in support of the general deterrent effect of administrative vehicle and drivers' licence sanctions. Second, this study points to the possibility of behavioural change in response to a legislative intervention. As predicted by our causal model, the implementation of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation may have led to safer driving practices of Ontario drivers, resulting in fewer young male casualties.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.aap.2014.05.009.

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