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Effects of excessive speeding and falling asleep while driving on crash injury severity in Ethiopia: A generalized ordered logit model analysis

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ABSTRACT

The severity of injury from vehicle crash is a result of a complex interaction of factors related to drivers' behavior, vehicle characteristics, road geometric and environmental conditions. Knowing to what extent each factor contributes to the severity of an injury is very important. The objective of the study was to assess factors that contribute to crash injury severity in Ethiopia. Data was collected from June 2012 to July 2013 on one of the main and busiest highway of Ethiopia, which extends from the capital Addis Ababa to Hawassa. During the study period a total of 819 road crashes was recorded and investigated by trained crash detectors. A generalized ordered logit/partial proportional odds model was used to examine factors that might influence the severity of crash injury. Model estimation result suggested that, alcohol use (Coef. = 0.5565; *p*-value = 0.017), falling asleep while driving (Coef. = 1.3102; *p*-value = 0.000), driving at night time in the absence of street light (Coef. = 0.3920; *p*-value = 0.033), rainfall (Coef. = 0.9164; *p*-value = 0.000) and being a minibus or vans (Coef. = 0.5065; *p*-value = 0.013) were found to be increased crash injury severity. On the other hand, speeding was identified to have varying coefficients for different injury levels, its highest effects on sever and fatal crashes. In this study risky driving behaviors (speeding, alcohol use and sleep/fatigue) were a powerful predictor of crash injury severity. Therefore, better driver licensing and road safety awareness campaign complimented with strict police enforcement can play a pivotal role to improve road safety. Further effort needed as well to monitor speed control strategies like; using the radar control and physical speed restraint measures (i.e., rumble strips).

1. Introduction

Severity of an injury is the result of a complex interaction between several factors representing driver and other road users, road characteristics, vehicle defect and design, and environmental characteristics including weather condition and light (Mondal et al., 2011; Thompson et al., 2013). Understanding to what extent each factor contributes to the severity of crash related injury is one of the most effective means to improve highway safety.

The human factor appears in the literature as being the most common determinants of road safety. Demographic characteristics: male, younger and older drivers are more likely to be involved in death and severe injury crashes (Dissanayake and Lu, 2002; Helai et al., 2008; Shope and Bingham, 2008; Haleem and Gan, 2013). As indicated by many researchers the strongest association of crash injury severity are related to behavioral factors, including: alcohol/drug use (Kuruc et al., 2009; Tsui et al., 2010; Ponce et al., 2011; Hels et al., 2013); speeding (Dissanayake and Lu, 2002; Afukaar, 2003); failure to wear seat belts (Munk et al., 2008; Siskinda et al., 2011; Kashani et al., 2012); using mobile phone while driving (Violanti, 1998) and sleep/fatigue (Radun and Summala, 2004). Speeding is a critical safety concern, especially for developing countries, where fatalities are more common among pedestrians and users of two- and three-wheelers (Mohan, 2002). Fatigue crashes are usually severe, as the driver makes no attempt to limit the consequence (Radun and Summala, 2004). Such types of crashes are linked with the nature of the road alignment; good condition of the road network make the driver task easy and

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monotonous, which demanded little effort as a result sleep/fatigue will be induced (Summala, 1996; Rossi et al., 2011).

Studies have also suggest that road alignment (Hosseinpour et al., 2014), street light condition (Wanvik, 2009; Mogaka et al., 2011) and adverse weather conditions (Mondal et al., 2011) are important predictors that affect the severity of vehicle crashes. As stated by various researchers, rainy weather significantly affect crash injury severity (Mogaka et al., 2011; Mondal et al., 2011), wet road reduce the tire traction efficiency, leading to poor braking performance (Cho et al., 2006). In addition, visibility obstruction due to fog resulted a higher severity crashes (Abdel-Aty et al., 2011).

Vehicle type and traffic mix as well found to be important factors and significantly associated with injury severity (Chang and Wang, 2006). Commercial and public transportation operated in developing countries are influenced by the owners to work excessively long hours when exhausted (Mock et al., 1999). On the other hand, in multi-vehicle crashes, heavy truck have better resistance to crash impact and protect its occupants; however, results in more serious injuries to the other vehicle(s) involved in the crash (Kockelman and Kweon, 2002). Empirical evidence also showed, motorcycles are a more dangerous mode of transportation than automobiles due to the absence of structure that protect the riders during a crash (Schlundt et al., 2004).

Most of these facts on crash related injury severity and associated factors are obtained from developed countries. Evidence is scarce from developing countries, especially in Africa (Lagarde, 2007). Thus, this study was conducted to explore the potential factors related to crash injury severity in Ethiopia.

2. Methods

2.1. Study setting

This study was conducted from June 2012 to July 2013, on one of the main and busiest roads of Ethiopia, which extends South from the capital Addis Ababa to Hawassa (Hawassa is the capital city of Southern Nations Nationality and Peoples Regional State, located at 275 km South of Addis Ababa). This two-way and two-lane road has an average width of 8 m and covers a total distance of 264 km. It is part of the main route of the country's import and export corridor from the port of Djibouti and part of the Trans-African Highway (an international road that stretched from Cairo to Cape Town). Moreover, the road has a significant economic importance since many of the cash crops, floriculture farms, recreational areas and tourist centers are located across the stretches of the road. Due to these reasons, the road is considered as the most vital route in terms of economy and traffic volume. The traffic mix on this road is very diverse, shared by high speed vehicles, heavy trucks, animal drowns carts, two-and three-wheelers and pedestrians. According to the Ethiopian Road Authority report more than 20,000 vehicles used the road daily (38.8% trucks, 24.3% cars, 21.4% buses and 15.5% truck trailers) (ERA, 2012). Compared to other road networks in the country, the Addis Ababa-Hawassa road has good features with regard to its alignment (i.e., straight and less curved). Map of Addis Ababa-Hawassa highway is illustrated in Fig. 1.

2.2. Statistical analysis

Crash injury severity often categorized universally as discrete ordered categories such as: fatal injury, incapacitating injury, non-incapacitating injury, possible injury, and property damage only. However, this classification may slightly vary from place to place. For example, in Ethiopia crash injury severity is classified into four categories: fatal injury (death at the scene or up to one month following an incident); serious injury (victim hospitalized at least for 24 h); minor injury (victim treated at an outpatient service or hospitalized for less than 24 h), and property damage only (crash without any human injury). Severity of the crash was determined according to the level of injury to the worst injured road users. Accordingly, we coded as: 1 = no injury, 2 = minor injury, 3 = serious injury and 4 = death. The contribution of driver characteristics (i.e., age and vehicle ownership) and driver behavior (i.e., speeding, alcohol use, phoning and sleep), collision type, infrastructure characteristics (i.e., road alignment, posted traffic sign, speed limit, and section type), vehicle type and environmental conditions (i.e., lighting and weather) were assessed by the crash injury severity model.

Previously, numerous researchers implemented ordered discrete outcome models; ordered logit and probit in injury severity research (O'donnell and Connor, 1996; Abdel-Aty, 2003; Gray et al., 2008; Pai and Saleh, 2008). However, these two models assume the parameter estimates are constant across the severity levels, which is not always fulfilled. This condition is said to be the proportional odds or parallel-regression assumption. Violation of this assumption leads to the formulation of an incorrect or mis-specified model. It can be checked by using Brant test (Brant, 1990), a significant test statistic provides evidence that the parallel regression assumption has been violated. Generalized ordered logit model relax the proportional odds or parallel-regression assumption for some or all variables. Eluru (2013) recommended generalized ordered logit model as a best alternative of multinomial logit model for ordinal response data. In recent years, this model adopted in the field of road safety (Wang and Abdel-Aty, 2008; Kaplan and Prato, 2012; Mooradian et al., 2013). Generalized ordered logit model has the form described below

$$p\left(y_i > j\right) = g\left(X_i \beta_j\right) = \frac{\exp\left(\alpha_j - X_i' \beta_j\right)}{1 + \exp\left(\alpha_j - X_i' \beta_j\right)}, \quad j = 1,\ 2,\ 3 \tag{1}$$

where X_i is a $p \times 1$ vector containing the values of crash i on the full set of p explanatory variables, β_j is a $p \times 1$vector of regression coefficients, α_j represents a cutoff point for the jth cumulative logit. This model relaxes the parallel-line assumption for all of the covariates which is not always true, and hence, increases the number of parameters unnecessarily.

By assuming only few covariates violate the parallel-line assumption, the unconstrained partial-proportional odds model developed by (Peterson and Harrell, 1990) was applied. A gamma parameterization of unconstrained partial-proportional odds model with logit function can be specified as

$$P\left(Y_i > j\right) = g\left(X_i \beta_j\right) = \frac{\exp\left[\alpha_j - \left(X_i' \beta_j + T_i' \gamma_j\right)\right]}{1 - \exp\left[\alpha_j - \left(X_i' \beta_j + T_i' \gamma_j\right)\right]} \tag{2}$$

where T' is a $q \times 1$ vector, $q \le p$ containing the values of crash i on that subset of the p predictor variables for which the proportional odds assumption not fulfilled. γ_j is a $q \times 1$ vector of regression coefficient associated with q covariate in T', so that, $T' \gamma_j$ is the increment associated with the jth cumulative logit. Covered with a non-proportional odds have one, k-2γ and k-1α coefficients, where k is the number of alternatives (in our case, $k = 4$). The overall contribution of these variables on different injury severity category can be computed by adding the gamma coefficients of the respected equation and the beta coefficients.

Generalized ordered logit model can be fitted by user-written program geologit2 in Stata (Williams, 2006). Interpreting the coefficients of intermediate categories for those unconstrained variables requires special care, since the direction of the effect not always determined by the sign of the estimate. Usually marginal values are considered for interpretation. Model fitness can be assessed by using Pseudo R^2 and Akaike's information criteria (AIC), best-fitted models has a smaller value of AIC (Stata, 2005).