frontiers in Sustainable Cities

REVIEW
published: 14 July 2020
doi: 10.3389/frsc.2020.00033

Aging, Obesity, and Motor Vehicle Collisions

Martin Lavallière[1]*, Mathieu Tremblay[2], Frédéric Lefebvre[1], Maxime Billot[3] and Grant A. Handrigan[4]

[1] Laboratoire de Recherche Biomécanique & Neurophysiologique en Réadaptation Neuro-Musculo-Squelettique-Lab BioNR, Department of Health Sciences, Centre Intersectoriel en Santé Durable (CISD), Module de Kinésiologie, Université du Québec à Chicoutimi, Saguenay, QC, Canada, [2] Module de Kinésiologie, Département des Sciences de la Santé, Université du Québec à Rimouski, Rimouski, QC, Canada, [3] Laboratory PRISMATICS Lab (Predictive Research in Spine/Neuromodulation Management and Thoracic Innovation/Cardiac Surgery), CHU de Poitiers, Poitiers, France, [4] École de Kinésiologie et de Loisir, Faculté des Sciences de la Santé et des Services Communautaires, Université de Moncton, Moncton, NB, Canada

Aging and obesity are two key areas of research as risk factors leading to motor vehicle collisions (MVCs). However, only a few studies identified obese older drivers as an at-risk population of MVC (i.e., older than 65 years old with Body Mass Index >30 kg/m^2). This paper aims to review the literature related to aging, obesity, and MVCs. Extensive literature searches were conducted, and the results are presented in a narrative review of the literature, in order to discuss the risk for involvement in MVC as well as the solutions for this population. Extrinsic factors are components of the "built environment" that decrease road safety for this population and poor fit of the vehicle through their inappropriate design for this population. The intrinsic factors are the autonomy and the health status of the driver. Health status are challenges associated with obesity and aging that increase the prevalence of being part in a MVC and that increase risk of morbidity and mortality during or following a collision. Finally, some prevention strategies are presented for consideration. There is a need to inform public policy makers on the additional risk factors associated with aging and obesity for MVCs.

Keywords: aging, obesity, motor vehicle collision, car design, prevention, mobility

Edited by:
Dorota Lasota, Medical University of Warsaw, Poland

Reviewed by:
Caio Assuncao Torres, Federal University of Ceara, Brazil
Dominik Olejniczak, Medical University of Warsaw, Poland
Liliana Alvarez, University of Western Ontario, Canada

***Correspondence:**
Martin Lavallière
martin_lavalliere@uqac.ca

Specialty section:
This article was submitted to Health and Cities, a section of the journal Frontiers in Sustainable Cities

Received: *15 March 2020*
Accepted: *08 June 2020*
Published: *14 July 2020*

Citation:
Lavallière M, Tremblay M, Lefebvre F, Billot M and Handrigan GA (2020) Aging, Obesity, and Motor Vehicle Collisions. Front. Sustain. Cities 2:33. doi: 10.3389/frsc.2020.00033

INTRODUCTION

Despite many safety improvements (e.g., air bags, electronic stability control) in the past decades, motor vehicle collisions (MVC) continue to be a large source of mortality worldwide (World Health Organization, 2013). Numerous studies identify major risk factors related to fatal and non-fatal MVC, including distracted driving (Fitch et al., 2014) and driving under the influence of drugs or alcohol (Ogden and Moskowitz, 2004). With much of the focus in the literature on these two intrinsic risk factors, the role of personal characteristics seems overlooked. While there is relatively little information about aging and obesity, they have been separately identified as risk factors of MVC (Eby et al., 2009; Desapriya et al., 2011).

Older individuals are the fastest growing segment of the driving population. According to the National Highway Traffic Safety Administration report (NHTSA, 2017), there were 40 million licensed drivers 65 and older in the United States which was a 33% increase compared to the statistics of 2006. Also, by the year 2030, 70 million individuals in the U.S.A. will be over age 65 and 90% of them will be licensed to drive. Considering that it is well-known that some aspects of normal aging affect driving capacity (e.g., slower reaction time, reduction of visual acuity), pathological aging represents a higher incidence of MVC (Turcotte, 2012; Desapriya et al., 2014). However, a lack of consensus persists in the available literature regarding whether older drivers are involved in increased numbers of MVC because of factors related to aging, or if the difference might be due to a low driving distance bias (Langford et al., 2008). Although low driving distances may mitigate that older drivers may pose to other road users, a large body of literature supports the increased MVC risk for older drivers.

As a population, we are not just aging, but we are also getting heavier. As of 2014, the World Health Organization (WHO) estimated that at least 600 million adults worldwide are obese (World Health Organization, 2018a). The prevalence of obesity throughout the world is well-documented and, it is universally recognized as an important issue that has an impact on several areas of our daily lives (Finucane et al., 2011). Sedentary behaviors, poor dietary habits, and genetic predisposition are among some of the factors associated with this increase in obesity (Chaput et al., 2014). Obesity is a well-established risk factor for a number of common chronic diseases (e.g., diabetes, and obstructive sleep apnea). As pathological aging is, health issues related to the obesity have negative consequences by increasing the driver's risks of MVC (Zhu et al., 2010; Jehle et al., 2012).

A novel hypothesis, and one that is central to the current article, is that obesity and aging have a synergistic effect on risk for MVC and severity of outcomes. That is, it is our contention that older obese drivers are a population at an increased risk for MVCs when compared to obese only or elderly only drivers. This paper focuses on the synergistic aspects of aging and obesity and how this leads to a potential increased risk for involvement in a MVC as well as the consequences following the MVC. The aim of this paper is to provide a narrative review of the current literature on the combined effect of aging and obesity on road safety. Through this review, it is our intention to provide a summary of the evidence of the concurrent issues of aging and obesity as a contribution toward evidence-based public policy decisions, to increase awareness and to initiate a discussion to identify possible solutions.

METHODS

For this narrative review, searches were conducted on Pubmed, ISI Web of Knowledge and Google scholar as they encompass a wide array of scientific areas as well as the most relevant peer-reviewed publications (Falagas et al., 2008). This methodology is scientifically transparent, replicable, and useful to generate an in-depth analysis of the scientific literature (Sackett et al., 1997). To select the most relevant scientific articles to include in this narrative review, the inclusion and exclusion criteria were defined prior to the search:

- Original articles written in English or in French and published in peer-reviewed journals;
- Published or in press between January 1990 and December 2017.
- Search terms were aging AND obesity AND driving.
- Articles were excluded if the sample presented drivers with no specific mentions of their age (ex. Mean age, age distribution) or their weight and/or body mass index.

Titles and abstracts of papers were scanned independently by two of the authors to identify relevant articles to retrieve for full text analysis. In cases where the papers seemed potentially eligible, but no abstract was available, the full text of the paper was retrieved. Disagreements between authors led to a deeper joint analysis of the paper; and a decision was then made regarding its inclusion. Full texts were independently reviewed for inclusion by the same two authors. Twelve articles were found ($N = 12$), but only one was directly related to aging, obesity and driving ($N = 1$) (Frank et al., 2010). The list of retrieved articles was then reviewed to identify additional published papers.

By using an approach adapted from Sackett et al. (1997), identified papers were also categorized using a standardized value system to grade biomedical practices according to the following system: Level I: Systematic reviews, meta-analyses, randomized controlled trials; Level II: Two groups, non-randomized studies (e.g., cohort, case control); Level III: One group, non-randomized (e.g., before and after, pre-test and post-test); Level IV: Descriptive studies including analysis of outcomes (e.g., single-subject design, case series); and Level V: Case reports and expert opinions including narrative literature reviews and consensus statements. In this case, the paper identified was classified as a Level II. Using such an approach while conducting a review provides a scheme of references for the practitioners interested in using these results in their practicum. Evidence-based practices are built on the assumption that scientific evidence of the effectiveness of an intervention can be deemed more or less strong and valid according to a hierarchy of research designs, the assessment of the quality of the research, or both.

Reference measurements standards were used to characterize the evaluated population. Elderly individuals were characterized as age 65 and older since it is "the golden age." Other articles made associations between the evolution of a particular phenomenon and advancing age even if <65. The measure for obesity is the body mass index (BMI) as described by WHO (World Health Organization, 2018a). BMI is calculated as weight in kilograms divided by height in meters squared. A BMI $\geq$ 30 kg/m^2 is considered obesity.

The presentation of the information will be based on the approach of Wang and Carr (2004) where they have identified three factors for collisions related to optimizing solutions in road safety: the environment, the vehicle and the driver. In this case, the extrinsic factors are the environment and the vehicle since they heighten indirectly the risk of MVC. The intrinsic factor is the driver that is considered as the proximal element that contributes to MVC (**Figure 1**). Finally, prevention strategies and research directions are presented for each factor mentioned.

DISCUSSION

Extrinsic Risk Factors

Environment

Prior to discussing the consequences of aging and obesity on driving, a brief discussion of our modern environment [some

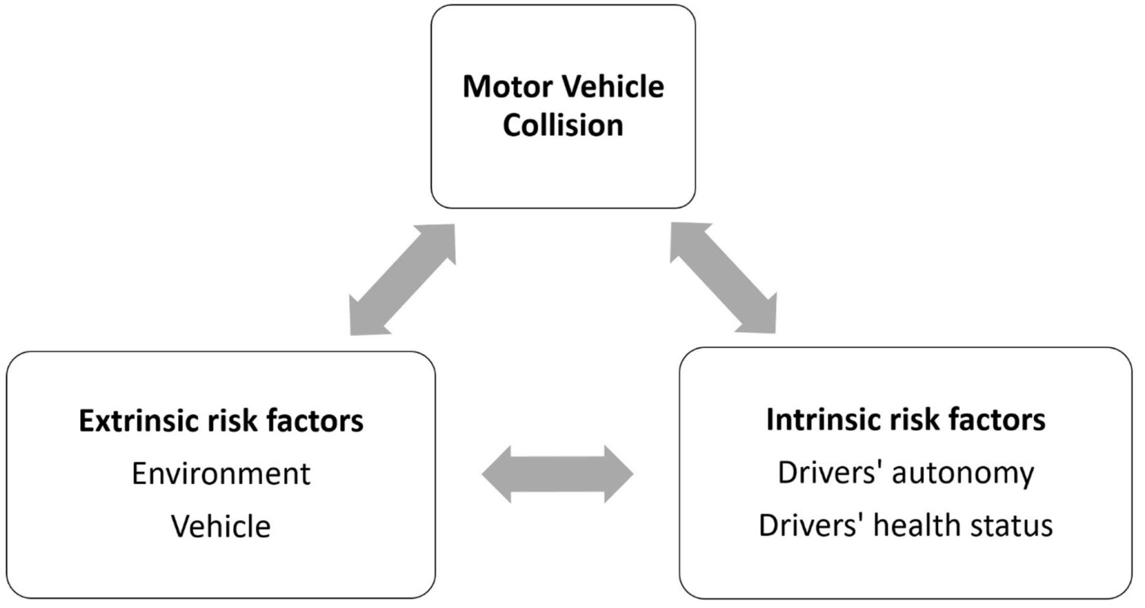

FIGURE 1 | Mapping of the association between MVC (motor vehicle collision), extrinsic (environment, vehicle), and intrinsic (drivers' autonomy and health status: pre, during and post-MVC) risk factors found in the literature.

have termed it an obesogenic environment (Kirk et al., 2010)] and how it contributes in a manner that the elderly population tend to use passive mode of transportation, and subsequently how it favors obesity. Tackling the complexities of urban design is beyond the scope of this literature review.

Worldwide, there is increasing urbanization and a typical characteristic of any larger city is that the center is often the economic hub of the region and a major site of employment. Despite the attempt to increase sustainable living quarters in cities (Cooper et al., 2009) many individuals purchase homes on the outskirts of the urban center and commit to a daily commute (Coughlin, 2009), therefore producing a "built environment" favoring longer distances to travel and less physical activity. These are barriers for an aging population who could use active mode of transportation and thus promote passive transportation (Zhao and Kaestner, 2010). Driving is considered as a light physical activity (Ainsworth et al., 2011) reducing the energy expenditure contributory to obesity with more time spent in the vehicle (Hill and Peters, 1998). There exist a relationship between time spent driving and obesity. Each hour spent in a car has been associated with a 6% increase in the likelihood of obesity and each 0.8 km (half-mile) walked (daily) reduced the odds of obesity by 5% (Frank et al., 2004).

Urban and suburban sprawl was measured in most studies and whatever the sample used, people in more sprawled neighborhoods are heavier than those in neighborhoods that are concentrated. Consequently we spent more time behind the wheel and certainly not creating an optimal environment to diminish the impact of the obesity (Maibach et al., 2009; Guo and Gandavarapu, 2010; Tranter, 2010).

Vehicles

This section is dedicated to view the characteristics of a vehicle which has an impact on the aging obese population. It is in the interest of researchers to explore the design elements of a car in order to adapt or modify it to several type of population to decrease the risk of injury during MVC. The major constraints of the present car design and fit will be discussed.

With the population getting older and heavier, several studies were completed in order to see the effectiveness of the seat belt for obese occupants on the road (Lamielle et al., 2006). The seat belt, composed of a lap belt crossing the hip bone and a belt crossing from the hip to the center of the chest to the shoulder appears problematic for them. For the older drivers, there is an elevated percentage of non-seatbelt users as for obese and overweight drivers. For the aging population, the seat belt seems to be effective but in certain body regions, there are higher risks of injuries for these individuals compared to younger adults due to the position of the restraint system on more fragile structures of the older adult's anatomy. It has also been reported that an increase in body weight was related to a decrease in seat belt usage when compared to normal weight individuals (Schlundt et al., 2007) as well as seatbelt use has been found to be lowest in morbidly obese occupants (i.e., BMI > 40 kg/m^2) (Moran et al., 2001; Viano et al., 2008). This trend was present for all age groups except in the 18–24 years old group. Unfortunately, no information is provided to explain these associations.

Furthermore, the seat belt design seems to be effective but have certain risk due to the seat belt positioning issues. Reed et al. (2012) evaluated the belt fit of 54 men and women, forty-eight percent of whom were obese. Their results showed that an increase in BMI of 10 kg/m^2 was associated with a lap belt positioned further forward and higher relative to the anterior-superior iliac spines of the pelvis (of 43 mm and of 21 mm, respectively). Each 10 kg/m^2 increase in BMI was associated with an increase in lap belt webbing length (of 130 mm). This increased length of seatbelt introduces slack in the seat belt system by routing the belt further away from the skeleton and might increase body excursions and contacts with the binnacle of the car. Taking both aging and obese population in consideration, the seat belt design is a risk factor since it is not adapted their anatomy, which subsequently elevates their injury and mortality risk.

Furthermore, current car design follow national standards, such as the Canadian Motor Vehicle Safety Standards or the US Federal Motor Vehicle Safety regulations and New Car Assessment Program. Yet, the 50th percentile male Hybrid III crash test dummy has a mass of ∼78 kg and a stature of ∼1.75 m (corresponding to a BMI of ∼25.4 kg/m^2). The Hybrid III 95th large male crash test dummy weighs 101.15 kg and measures 1.88 m (corresponding to a BMI of ∼28.6 kg/m^2). Despite of differences between dummies' weights and heights (50th−95th percentile male), it is very hard to extend the behavior of these dummies to heavier individuals since the two dummies do not represent obese individuals at all (Moran et al., 2002). If the regulations do not take into account the different needs for the obese population, current car design standards might be causing more injuries for this population.

Taking both aging and obese population in consideration, the seat belt design is an important risk factor since it is not adapted to the fragile anatomy of old and the excess weight of obese individuals, which subsequently elevates their injury risk.

Intrinsic Risk Factors

Driver

This section is dedicated to examine the MVC components of older obese drivers. Two elements will be discussed here, the way of thinking of the driver' autonomy and their health issues related to MVC.

Autonomy

In general, it appears that older people are infrequent public transportation users, and they rely mainly on their privately owned vehicles (Dobbs, 2008). With aging, this is problematic, as shifting from an independent source of transportation to a dependent source of transportation can be challenging for ones sense of autonomy (Edwards et al., 2009). This is recognized as one of the significant factors that prevent older adults to acknowledge when should be the correct time to change from an independent to a dependent mode of transportation. Drivers' autonomy contributes to the use of automobile as the primary method of transportation which does not promote active transportation methods that are positively associated with better health status (Edwards et al., 2009).

Health status

Numerous health problems associated with aging related illness or conditions have been traditionally linked to MVC. The premise of this section is that the aging and obese driver has increased risk of involvement in an MVC. We will dissect the potential causes or associations for this assumption by using a model inspired by the Haddon's matrix (Haddon, 1972; Runyan, 1998). This matrix provides a framework to structure the presentation of the impact of aging and obesity on MVC. This section will be presented as follows: initial health status (pre-MVC), risk of injury (during-MVC) and injury recovery (post-MVC).

Initial health status (pre-MVC). Changes in vision, cognitive processing and physical function associated to aging are thought to be partially responsible for the high rates of MVC among older drivers. Decline in visual function is part of the normal aging process. Reading signs, judging the speed of vehicles and adjusting to darkness are common problems for older drivers (Kline et al., 1992). The reduction of the useful field of view seems to be one of the best predictor of MVCs among older drivers (Owsley et al., 1998; Wood and Owsley, 2014). Cognitive functions important for driving have been identified as attention, memory, perceptual abilities and information processing speed (Colsher and Wallace, 1991), all of which frequently pose problems for older adults. Due to the types of MVC in which older drivers are usually involved [i.e., MVCs with other vehicles at intersections (Preusser et al., 1998)] it is suggested that these events are primarily linked to a decline in cognitive functions (Anstey et al., 2005). Also, it is reported that older people are more prone to having excessive daytime sleepiness independently of having sleep apnea (Bixler et al., 2005). Reduction in grip and muscle strength and endurance, flexibility and motor speed are also age-related factors that may impair driving (Anstey et al., 2005). For example, reduced neck rotation diminishes the driver's ability to turn its head to detect possible peripheral obstacles in complex driving situations.

Obesity is often associated with increased prevalence of obstructive sleep apnea and hypopnea (OSAH) (Smith and Phillips, 2011; Xie et al., 2011), which is in turn, is associated with increased daytime sleepiness (Braeckman et al., 2011) and thought to be a major risk factor for MVC (Papadakaki et al., 2008). Mulgrew et al. (2008) showed that compared to a control group, patients with mild, moderate and severe OSAH had a higher rate of MVC with personal injury. These results are similar to those of other studies that linked OSAH and the risk of being involved in a MVC (Cummings et al., 2001; Ellen et al., 2006; Tregear et al., 2009). OSAH is under recognized by most primary care physicians in the United States; an estimated 80% of Americans with OSAH are not diagnosed (Young et al., 1997). Studies have showed that even obese persons without OSAH can still show signs of daytime sleepiness (Magee et al., 2010). There is even a stronger relationship that people with obesity (independently of having apnea) had excessive daytime sleepiness compared to people with sleep disordered breathing (Bixler et al., 2005).

Furthermore, eye diseases (ex. Glaucoma and cataracts) are related to greater incidence in aging and obese populations (Cheung and Wong, 2007). These alterations compromise vision and thus, safe driving. Diabetes is another comorbidity commonly seen within aging and obese individuals that can increase risk in driving impairment (Winer and Sowers, 2004). Variations in blood sugar may increase the following symptoms that can increase risk of MVC: sleepiness, confusion, diminished alertness, alteration of vision (blurred vision, vision loss, or diabetic retinopathy) and nerve damage that may cause pain or sensory loss in the hands, legs and feet (Canadian Association of Occupational Therapists, 2009). Cox et al. (2000) advance that diabetes can heighten the risk of driving impairment, mostly with hypoglycemia.

Risk of injury (during-MVC). It is important to make the distinction between fragility (i.e., increased risk of injury) and frailty (i.e., reduced capacity to recover from an injury). Regarding aging, one of the biggest issues for older drivers involved in a collision is their increased fragility in comparison with younger drivers (Rockwood and Mitnitski, 2007; Kent, 2010). When considering all body regions, injuries to the thoracic cavity are greatest for older drivers (Kent et al., 2005; Jingwen et al., 2012). There is also an increased risk of thoracic injuries for obese individuals (Boulanger et al., 1992; Cormier, 2008). Risks of incurring a serious or fatal injury are also higher in older individuals (Lyman et al., 2002); after 65 years old the fatality risk increases by ∼3% per year (Frampton et al., 2012).

The possible reasons for this increased fragility are the natural changes in the musculoskeletal system related to aging (i.e., sarcopenia, osteoporosis). The loss of muscle mass and strength (Brooks and Faulkner, 1994) decrease the traction force provided by the tendon on the bone and therefore, reducing the bone mineral density (Hannan et al., 2000). This reduces the capacity to absorb the kinetic energy during the impact (i.e., MVC), and potentially producing more severe injuries. In addition, some studies came to the conclusion that aging with obesity is a risk factor for diminished bone density and the mechanisms for the regulation of bone density could be altered (Villareal et al., 2004). This could elevate the risk of fractures during MVC.

As for obesity, several studies, using different guidelines, have come to similar conclusions concerning the risk of serious and fatal injuries during MVC for obese individuals. Viano et al. (2008) concluded that obesity influences the risk of serious and fatal injury in MVC by conducting a matched paired analysis carried out between normal weight and obese individuals taken from a National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) field data set (1993–2004). Their results showed that obese occupants (drivers and/or passengers) had 54–61% higher risk of injury compared to a normal weight occupant. Moreover, the matched pairs' analysis showed that obese drivers had higher risk of fatality and serious injury than drivers with normal BMI (97 and 17%, respectively) as well as obese passengers (32 and 40%, respectively). Using NASS-CDS data from 2003 to 2007, Ma et al. (2011) looked at the association between non-fatal MVC injuries and obesity. Their results showed that obese male drivers were at greater risk for non-fatal injuries than non-obese male drivers. This effect was not observed for female drivers, perhaps due to differences in body weight distribution as hypothesized by the authors. This difference has also been presented as the "cushion effect" (Arbabi et al., 2003; Wang et al., 2003). However, there is currently no way of characterizing body weight distribution in any road safety data set. Possibly showing the influence of the cushion effect, Jehle et al. (2012) evaluated 155,584 fatalities from the Fatality Analysis Reporting System's (FARS) database for the year 2000–2005. Results showed that the adjusted risk of mortality from the lowest to the highest in comparison with normal BMI was: 1st overweight, 2nd obese class I, 3rd normal BMI, 4th underweight, 5th obese class II obese, and 6th obese class III. This result shows that perhaps overweight and obese class I individuals could be advantaged by the "cushion effect."

Other studies observed the body region impairs by injury as well as the pattern of injury among obese individuals. Zhu et al. (2010) created computer models based on 10,941 individuals from a NASS-CDS field data set (2001–2005) implied in frontal collisions, and created MVC simulations. According to their modelization, obese men had a higher risk of serious injury and more particularly to the upper body, such as the head, neck, thorax, and spine (i.e., cervical, thoracic, and lumbar) compared to normal weight individuals. Overall, men were more at risk of serious injury than women in every region (except for extremities and abdominal region). Similarly, Rupp et al. (2013) used the Abbreviated Injury Scale (AIS) to evaluate the effects of BMI on the risk of serious-to-fatal injury (≥3 or AIS 3+) to different body regions for adults in frontal, nearside, far side, and rollover MVCs. Their results showed that increased BMI increased the risk of lower-extremity injury in frontal MVCs, increased risk of upper-extremity injury in frontal and nearside MVCs, and increased risk of spine injury in frontal MVCs. Interestingly, there was a decreased risk of lower-extremity injury in nearside impacts for that same group. It was estimated that if no occupants in frontal collision were obese, 7% fewer occupants would sustain AIS 3+ upper-extremity injuries, 8% fewer occupants would sustain AIS 3+ lower-extremity injuries, and 28% fewer occupants would sustain AIS 3+ spine injuries. Recent literature reviews on the impact of obesity on driving came to the same conclusion (Desapriya et al., 2011; Lavallière et al., 2012).

Injury recovery (post-MVC)

In addition to their increased fragility, older people tend to take longer to recover from an injury than their younger counterparts. Nagy et al. (2000) compared data from 85 older trauma patients (≥65 years old) to younger patients (15–40 years old) with similar injuries. Their results showed that older patients had a longer hospital stay (6.9 ± 9.1 vs. 4.3 ± 5.7 days) and spent more days at the intensive care unit (7.3 ± 9.2 vs. 3.4 ± 3.2 days) than younger patients. Older individuals also have increased mortality from complications in the hospital (i.e., days following the surgery) than their younger counterparts (Perdue et al., 1998). Occupants aged over 80 years old were more likely to die from their injuries after an MVC than 65–79 years old occupants (Bansal et al., 2009).

Obesity has also been associated with mortality and complications following surgical procedures in trauma settings (Glance et al., 2014). As an example, following knee arthroplasty of 15,321 patients, age and diabetes were showed as independent predictors of mortality whereas a BMI greater than ≥40 kg/m^2 was an independent predictor of post-operative complications

(OR = 1.47; 95% CI = 1.09–1.98) (Belmont et al., 2014). However, it is impossible to identify whether it's the accident or the surgery that caused mortality or complications because no information concerning the cause is mentioned in the FARS database.

Newell et al. (2007) investigated the relationship between BMI and outcomes in blunt injured patients. Their results showed that, when compared to normal BMI, morbid obesity was associated with increased morbidity (e.g., acute respiratory failure, multisystem organ failure) but not with increase mortality (OR 0.81, 95% CI, 0.35–1.86). Neville et al. (2004) also reported that obesity is an independent predictor of mortality following severe blunt trauma. It appears that following a MVC, it is possible that both surgery and post-surgery recovery are affected by aging and obesity (and their related co-morbidities). One comorbidity, commonly seen in aging obese, that can create complications is diabetes. Diabetes can compromise many steps of the wound healing process that increases the healing time and can contribute to ulcer formation (Blakytny and Jude, 2006).

PREVENTION STRATEGIES: WHAT ARE THE SOLUTIONS

This section is dedicated to possible interventions proposed by the literature and public organizations to decrease the risks of the aging and obese populations to be involved in a MVC. Considering that the driver has a direct impact on the prevalence and risks during and post-MVC, the presented paper identify strategies to improve the health issues of the driver (intrinsic factor), their vehicle and its environment by optimizing the extrinsic factors for safety.

Environment

There are several characteristics of the built environment that could be improved in order to satisfy the needs for the aging obese individuals. It is important to promote "age-friendly" environment and several organizations have responded to the present issues for the elderly population. Recent initiatives by the WHO have put forward "Age-friendly Cities and Communities" (World Health Organization, 2018b). Two of the main concerns of this network are 1) outdoor spaces and buildings, and 2) transportation. This initiative aims to help cities and communities make changes to best suit the needs of older people and promote active aging. Similarly, the Beverly Foundation (Beverly Foundation, 2001) identified the "5 A's" to senior-friendly transportation: availability (transportation services are provided to seniors when required), acceptability (service quality acceptable and adapted to seniors; clean and well-maintained vehicles), accessibility (provide "door-to-door" and "door-through-door" transportation), adaptability (can make multiple stops or different routes, better crossing signs for pedestrians and accommodate wheelchairs and walkers) and affordability (cost of transportation is affordable). The 5 A's reflect the general needs of the elderly population and these solution paths should be considered with close attention.

For obese individuals as of for older, an optimal environment should be designed and constructed in such a way as to promote physical activity, healthy habits and active modes of transportation (ex. access to bicycles and docking stations) to facilitate prevention. These types of strategies appear to be successful at encouraging individuals to adopt more active lifestyles which have been shown to decrease obesity rates and improve health status. While conducting the literature review, only one reference addressed the topics of neighborhood design, physical activity, obesity and older individuals. This study, conducted by Frank et al. (2010), found that an increased walkability score in a neighborhood was associated with increased levels of walking, although the amount of walking was less than the daily minimum requirements of physical activity guidelines (Garber et al., 2011). This suggests that a neighborhood design that only focuses on improving walkability is insufficient as a strategy to promote activity levels to those suggested in national guidelines. Despite the small quantity of physical activity through walking, there exist positive associations between walkability distance and beneficial health outcomes.

After looking at the issues raised by aging and obesity, there are two ways of responding to optimize the environment 1) adapt the road infrastructure 2) promote active transportation. For the first point, there are several recommendations, such as increasing the visibility of the road signs (bigger size, and elevated luminance) and decrease speed limits in strategic places could be possible measures (Cooper et al., 2009). For the second point, safe walking paths (lit and with minimal risk of fall elements), better road crossing systems, are some of the possible changes that could be proposed (Spence et al., 2009). Considering both population's characteristics and needs more carefully, promoting active transportation is possibly the best solution due to the increased risk of MVC for these people (even with environmental changes) and promoting a healthy lifestyle to aging obese individuals.

Vehicle

Considering the increasing worldwide prevalence of aging and obesity for the next decades, better adapted vehicle designs are needed shortly. Some components of the vehicle fit can improve comfort of the occupants, but also decrease the risk of injuries during MVC. The designs that can be adjusted to the individual's anthropometric measures can facilitate the ingress/egress and the comfort while driving (Wang and Carr, 2004). Additional handles to ease ingress and egress of vehicle, belt extension options, steering wheel size options, and telescopic steering column are all options that car dealerships should offer to their clients. For a decreased risk of injury during a MVC, there is a need for new intelligent safety restraining systems that can adjust to heavy weights and integrated seat belt systems that improve the fit. Also, new protection elements, such as dual-stage airbags to decrease the initial impact of the air-bag, increase protection near the feet by putting additional airbags and have active head restraint system in order to prevent injuries to the neck (Wang et al., 2003).

Although new technology is being developed or emerged progressively in order to give the driver feedback on driving capabilities (physical and cognitive). For example, advanced state detection systems can detect state of under-arousal (e.g., drowsiness) and over-arousal (e.g., detecting overload in compromised individuals) through physiological measures (i.e., reduced visual scanning, and percent of eye closure). This feedback system would particularly be helpful among individual with sleepiness symptoms (Reimer et al., 2009). On top of these technologies aimed at the state of the driver, other developments have been made in order to alert the driver of incoming risky/adverse event (i.e., forward collision warning) or mitigate (i.e., autonomous emergency braking). Reports from the Insurance Institute for Highway Safety (IIHS) (IIHS, 2012) have shown that these technologies are effective at reducing the number of MVC and the severity of them.

However, when it comes to vehicle selection, most of the auto industry is focused on selling cars to young drivers. Strangely, people aged 25 are less prone to buy a new car than the one aged 65 and older. Manufacturers know that not a single driver will buy a vehicle if it is advertised as the "older drivers' vehicle" or model (Yoon et al., 2009). Other studies have looked at the vehicle selection of older drivers. Vrkljan and Anaby (2011) asked drivers of 18 years and older, to rank the importance of eight vehicle features (storage, mileage, safety, price, comfort, performance, design, and reliability). Indifferently of age, safety, and reliability were the most highly rated and seemed to be even more important among older drivers (Koppel et al., 2013). Although older drivers seem to rank safety as number one feature, this might not be their priority when they are at the car dealership (Zhan et al., 2013). While drivers rely on technologies (e.g., braking systems and air bags) rather than collision test and collision worthiness to ask about vehicle safety, it might be important to emphasis on all safety characteristics by increasing the vulgarization of: "what are the safety characteristics and why are they important for my own safety" (Koppel et al., 2013).

Nothing is known about the vehicle buying decisions of people with greater BMI's, it is suggested that they are buying bigger vehicles for their increased interior space. It would be interesting to investigate the factors that lead to purchase of a certain type of vehicle in more detail. For example, the security issue as well as "comfort." If a vehicle is perceived as being more comfortable, what are some of the specific characteristics that lead the driver to describe the vehicle as comfortable? Moreover, these bigger vehicles are also recognized for their higher safety in MVC mitigation, which might underestimate the actual implication of obesity in the mortality rate.

Driver

Concerning the possible prevention programs, there should be a combination of better screenings and interventions in order to decrease risk of MVC for certain populations, such as aging and obese individuals (Viamonte et al., 2006). Tests should be administered regularly in order to detect the drivers that do not have the abilities to drive. Another efficient method was used by Ontario (Canada), where drivers who had medical issues, such as alcoholism, dementia, sleep disorders, diabetes, and epilepsy were given medical warnings on a 3 years period to. This prevention program reduced by 45% annual collision rates for this population and 41% annual collision rates for people with diabetes compared to the statistics of the period before medical warnings were implemented (Redelmeier et al., 2012).

After having detected these individuals, interventions can be made in order to regain the right to drive. For instance, seeing a health specialist in order to improve the health issues that influence the driving skills is the first step to take. They could suggest different alternative solutions like specific medical treatments, specific trainings, and educate aging obese to regain the license. To improve one's ability to drive safely, specific training seems to be an effective strategy to develop certain qualities of aging obese individuals to decrease the risk on the road.

Finally, education toward some medical conditions commonly associated with aging and obesity, like diabetes, could prevent driving impairment by recognizing the signs of a possible risk of driving mishap and how to deal with the medical issue in certain situations (Craik, 2011). Furthermore, older obese individuals should be educated concerning their behavior toward the definition of autonomy. It has been shown that healthy aging is associated with the adaptability of the person to accomplish daily activities and to be aware of its limitations (Hansen-Kyle, 2005). This means that older obese individuals who take the road with poor fitness to drive would be considered less autonomous than using alternative methods of transportation. It is important to expose the danger of this attitude for their health and safety and the one of other road users.

LIMITATIONS

It is often mentioned as being difficult for researchers to differentiate between lean and fat mass for individuals in database usage as well as making sure BMI is a clear indicator of obesity. Another approach, suggested in cardiovascular diseases prevention, indicates that the best way of diagnosing the risk would be with a waistline measurement (Despres, 2009). Therefore, it is suggested that waist circumference might be a better alternative when evaluating the impact of weight in car collisions (Arbabi et al., 2003). Unfortunately, there is no dataset, to our knowledge, that includes such information. As a result, most of the literature uses a surrogate measure, BMI, and this is a limitation in the research. Additionally, many studies adjust for age in their statistical analysis thus removing any age indicators in statistical results. Moreover, most of the studies used age as a confounding factor and therefore diluted the results that were of interest for the current review. Furthermore, a limitation of this study is the lack of studies conducted on obese and aging individuals as one type of population. Most of the literature used in this article is conducted on only obese or aging individuals. With this limitation, it is difficult to document the impact of the interaction of both conditions on the risk of MVC. Moreover, often associated with aging and obesity, there is a multitude of health conditions and medications usage associated to them that could alter driving capacities and therefore increases risk of being involved in a MVC. These health conditions and their associated medications could not be covered in the current narrative review. Finally, a probable limitation of this narrative review includes the search process itself, which may not have allowed the identification of all studies showing the effects of age and obesity on motor vehicle collisions. The use of additional databases, such as CINAHL, PsychInfo, and ERIC might have led to slightly different results (Falagas et al., 2008) as well as other search terms.

CONCLUSION

The baby boomers represent a new generation on its own as consumers (Coughlin, 2009). They have experienced mobility, new technology and a growing trend in improvement in every field. While aging, they expect to continue this type of lifestyle and they will ask more from the industries. Also, many of them are aging, and not necessarily in a healthy way, while others are aging obese. Aging obese individuals are facing many challenges, and one of them is that their vehicle are not properly designed for them. Certainly, an approach of interest for car manufacturers would be to aim a universal design, it is a moving target however and that will be hard to fulfill, since the discrepancy in the anthropometry of drivers is getting more spread out. Therefore, we do have to raise awareness of manufacturers and designers to develop adapted vehicle in the future.

AUTHOR CONTRIBUTIONS

ML, MT, FL, MB, and GH contributed equally to this manuscript. All authors contributed to the article and approved the submitted version.

REFERENCES

Ainsworth, B. E., Haskell, W. L., Hermann, S. D., Meckes, N., Basset, D. R. Jr., Tudor-Locke, C., et al. (2011). Compendium of physical activities: a second update of codes and MET values. *Med. Sci. Sports Exerc.* 43, 1575–1581. doi: 10.1249/MSS.0b013e31821ece12

Anstey, K. J., Wood, J., Lord, S., and Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clin. Psychol. Rev.* 25, 45–65. doi: 10.1016/j.cpr.2004.07.008

Arbabi, S., Wahl, W. L., Hemmila, M. R., Kohoyda-Inglis, C., Taheri, P. A., and Wang, S. C. (2003). The cushion effect. *J. Trauma* 54, 1090–1093. doi: 10.1097/01.TA.0000064449.11809.48

Bansal, V., Conroy, C., Lee, J., Schwartz, A., Tominaga, G., and Coimbra, R. (2009). Is bigger better? The effect of obesity on pelvic fractures after side impact motor vehicle crashes. *J. Trauma* 67, 709–714. doi: 10.1097/TA.0b013e3181af6cc1

Belmont, P. J. Jr., Goodman, G. P., Waterman, B. R., Bader, J. O., and Schoenfeld, A. J. (2014). Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. *J. Bone Joint Surg. Am.* 96, 20–26. doi: 10.2106/JBJS.M.00018

Beverly Foundation (2001). *On the Road to Senior Friendly Transportation: The 5 A's*. Pasadena, CA: Beverly Foundation.

Bixler, E., Vgontzas, A., Lin, H.-M., Calhoun, S., Vela-Bueno, A., and Kales, A. (2005). Excessive daytime sleepiness in a general population sample: the role of sleep apnea, age, obesity, diabetes, and depression. *J. Clin. Endocrinol. Metab.* 90, 4510–4515. doi: 10.1210/jc.2005-0035

Blakytny, R., and Jude, E. (2006). The molecular biology of chronic wounds and delayed healing in diabetes. *Diabet. Med.* 23, 594–608. doi: 10.1111/j.1464-5491.2006.01773.x

Boulanger, B. R., Milzman, D., Mitchell, K., and Rodriguez, A. (1992). Body habitus as a predictor of injury pattern after blunt trauma. *J. Trauma* 33, 228–232. doi: 10.1097/00005373-199208000-00011

Braeckman, L., Verpraet, R., Van Risseghem, M., Pevernagie, D., and De Bacquer, D. (2011). Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drivers. *Chronobiol. Int.* 28, 126–134. doi: 10.3109/07420528.2010.540363

Brooks, S. V., and Faulkner, J. A. (1994). Skeletal muscle weakness in old age: underlying mechanisms. *Med. Sci. Sports Exerc.* 26, 432–439. doi: 10.1249/00005768-199404000-00006

Canadian Association of Occupational Therapists (2009). *National Blueprint for Injury Prevention in Older Drivers*. Ottawa, ON: Canadian Association of Occupational Therapists.

Chaput, J. P., Perusse, L., Despres, J. P., Tremblay, A., and Bouchard, C. (2014). Findings from the Quebec family study on the etiology of obesity: genetics and environmental highlights. *Curr. Obes. Rep.* 3, 54–66. doi: 10.1007/s13679-013-0086-3

Cheung, N., and Wong, T. Y. (2007). Obesity and eye diseases. *Surv. Ophthalmol.* 52, 180–195. doi: 10.1016/j.survophthal.2006.12.003

Colsher, P. L., and Wallace, R. B. (1991). Longitudinal application of cognition function measures in a defined population of community-dwelling elders. *Ann. Epidemiol.* 1, 215–230. doi: 10.1016/1047-2797(91)90001-S

Cooper, R., Evans, G., and Boyko, C. (2009). *Designing Sustainable Cities*. Lancaster, PA, Wiley-Blackwell.

Cormier, J. M. (2008). The influence of body mass index on thoracic injuries in frontal impacts. *Accid. Anal. Prev.* 40, 610–615. doi: 10.1016/j.aap.2007.08.016

Coughlin, J. F. (2009). Longevity, lifestyle, and anticipating the new demands of aging on the transportation system. *Public Works Manag. Policy* 13, 301–311. doi: 10.1177/1087724X09335609

Cox, D. J., Gonder-Frederick, L. A., Kovatchev, B. P., Julian, D. M., and Clarke, W. L. (2000). Progressive hypoglycemia's impact on driving simulation performance. Occurrence, awareness and correction. *Diabetes Care* 23, 163–170. doi: 10.2337/diacare.23.2.163

Craik, J. M. (2011). Occupational therapists lead a national injury prevention strategy to help older drivers. *Can. J. Occup. Ther.* 78, 137–140. doi: 10.2182/cjot.2011.78.2.9

Cummings, P., Koepsell, T. D., Moffat, J. M., and Rivara, F. P. (2001). Drowsiness, counter-measures to drowsiness, and the risk of a motor vehicle crash. *Inj. Prev.* 7, 194–199. doi: 10.1136/ip.7.3.194

Desapriya, E., Giulia, S., Subzwari, S., Peiris, D. C., Turcotte, K., Pike, I., et al. (2011). Does obesity increase the risk of injury or mortality in motor vehicle crashes? A systematic review and meta-analysis. *Asia. Pac. J. Public Health* 26, 447–460. doi: 10.1177/1010539511430720

Desapriya, E., Harjee, R., Brubacher, J., Chan, H., Hewapathirane, D. S., Subzwari, S., et al. (2014). Vision screening of older drivers for preventing road traffic injuries and fatalities. *Cochrane Database Syst. Rev.* 2014:CD006252. doi: 10.1002/14651858.CD006252.pub4

Despres, J. P. (2009). Targeting abdominal obesity and the metabolic syndrome to manage cardiovascular disease risk. *Heart* 95, 1118–1124. doi: 10.1136/hrt.2008.151274

Dobbs, B. M. (2008). Aging baby boomers—a blessing or challenge for driver licensing authorities. *Traffic Inj. Prev.* 9, 379–386. doi: 10.1080/15389580802045823

Eby, D. W., Molnar, L. J., and Kartje, P. S. (2009). "*Maintaining safe mobility in an aging society*," in ed B. H. Kantowitz (Boca Raton, FL: CRC Press), 225. doi: 10.1201/9781420064544

Edwards, J. D., Lunsman, M., Perkins, M., Rebok, G. W., and Roth, D. L. (2009). Driving cessation and health trajectories in older adults. *J. Gerontol. A Biol. Sci. Med. Sci.* 64, 1290–1295. doi: 10.1093/gerona/glp114

Ellen, R. L., Marshall, S. C., Palayew, M., Molnar, F. J., Wilson, K. G., and Man-Son-Hing, M. (2006). Systematic review of motor vehicle crash risk in persons with sleep apnea. *J. Clin. Sleep Med.* 2, 193–200.

Falagas, M., Pitsouni, E., Malietzis, G., and Pappas, G. (2008). Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. *FASEB J*. 22, 338–342. doi: 10.1096/fj.07-9492LSF

Finucane, M. M., Stevens, G. A., Cowan, M. J., Danaei, G., Lin, J. K., Paciorek, C. J., et al. (2011). National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *Lancet* 377, 557–567. doi: 10.1016/S0140-6736(10)62037-5

Fitch, G. M., Grove, K., Hanowski, R. J., and Perez, M. A. (2014). "Investigating light vehicle and commercial motor vehicle driver compensatory behavior when conversing on a cell phone using naturalistic driving data," in *TRB 2014 Annual Meeting* (Washington, DC: EDS). doi: 10.3141/2434-01

Frampton, R., Lenard, J., and Compigne, S. (2012). "An in-depth study of abdominal injuries sustained by car occupants in frontal crashes," in *Annals of Advances in Automotive Medicine/Annual Scientific Conference, Vol. 56* (Seattle, WA: Association for the Advancement of Automotive Medicine; EDS), 137–149.

Frank, L., Kerr, J., Rosenberg, D., and King, A. (2010). Healthy aging and where you live: community design relationships with physical activity and body weight in older Americans. *J. Phys. Act. Health* 7, S82–90. doi: 10.1123/jpah.7.s1.s82

Frank, L. D., Andresen, M. A., and Schmid, T. L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *Am. J. Prev. Med*. 27, 87–96. doi: 10.1016/j.amepre.2004.04.011

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., et al. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med. Sci. Sports Exerc*. 43, 1334–1359. doi: 10.1249/MSS.0b013e318213fefb

Glance, L. G., Li, Y., Osler, T. M., Mukamel, D. B., and Dick, A. W. (2014). Impact of obesity on mortality and complications in trauma patients. *Ann. Surg*. 259, 576–581. doi: 10.1097/SLA.0000000000000330

Guo, J. Y., and Gandavarapu, S. (2010). An economic evaluation of health-promotive built environment changes. *Prev. Med*. 50, S44–S49. doi: 10.1016/j.ypmed.2009.08.019

Haddon, W. Jr. (1972). A logical framework for categorizing highway safety phenomena and activity. *J. Trauma* 12, 193–207. doi: 10.1097/00005373-197203000-00002

Hannan, M. T., Felson, D. T., Dawson-Hughes, B., Tucker, K. L., Cupples, L. A., Wilson, P. W., et al. (2000). Risk factors for longitudinal bone loss in elderly men and women: the Framingham Osteoporosis Study. *J. Bone Miner. Res*. 15, 710–720. doi: 10.1359/jbmr.2000.15.4.710

Hansen-Kyle, L. (2005). A concept analysis of healthy aging. *Nurs. Forum*. 40, 45–57. doi: 10.1111/j.1744-6198.2005.00009.x

Hill, J. O., and Peters, J. C. (1998). Environmental contributions to the obesity epidemic. *Science* 280, 1371–1374. doi: 10.1126/science.280.5368.1371

IIHS (2012). They're working: insurance claims data show which new technologies are preventing crashes. *Status Rep*. 47, 1–7.

Jehle, D., Gemme, S., and Jehle, C. (2012). Influence of obesity on mortality of drivers in severe motor vehicle crashes. *Am. J. Emerg. Med*. 30, 191–195. doi: 10.1016/j.ajem.2010.10.017

Jingwen, H. U., Rupp, J. D., and Reed, M. P. (2012). Focusing on vulnerable populations in crashes: recent advances in finite element human models for injury biomechanics research. *J. Autom. Saf. Energy* 3, 295–307.

Kent, R. (2010). *The Biomechanics of Aging. NTSB Forum on Safety, Mobility, and Aging Drivers*. Washington, DC: Transportation Research Board.

Kent, R., Henary, B., and Matsuoka, F. (2005). On the fatal crash experience of older drivers. *Annu. Proc. Assoc. Adv. Autom. Med*. 49, 371–391.

Kirk, S. F., Penney, T. L., and McHugh, T. L. (2010). Characterizing the obesogenic environment: the state of the evidence with directions for future research. *Obes. Rev*. 11, 109–117. doi: 10.1111/j.1467-789X.2009.00611.x

Kline, D. W., Kline, T. J. B., Fozard, J. L., Kosnik, W., Schieber, F., and Sekuler, R. (1992). Vision, aging, and driving: the problems of older drivers. *J. Gerontol*. 47, 27–34. doi: 10.1093/geronj/47.1.P27

Koppel, S., Clark, B., Hoareau, E., Charlton, J. L., and Newstead, S. V. (2013). How important is vehicle safety for older consumers in the vehicle purchase process? *Traffic Inj. Prev*. 14, 592–601. doi: 10.1080/15389588.2012.740642

Lamielle, S., Cuny, S., Foret-Bruno, J., Petit, P., Vezin, P., Verriest, J., et al. (2006). Abdominal injury patterns in real frontal crashes: influence of crash conditions, occupant seat and restraint systems. *Annu. Proc. Assoc. Adv. Autom. Med*. 50, 109–124.

Langford, J., Bohensky, M., Koppel, S., and Newstead, S. (2008). Do older drivers pose a risk to other road users? *Traffic Inj. Prev*. 9, 181–189. doi: 10.1080/15389580801975632

Lavallière, M., Handrigan, G. A., Teasdale, N., and Corbeil, P. (2012). Obesity, where is it driving us? *J. Transport. Saf. Sec*. 4, 83–93. doi: 10.1080/19439962.2011.646386

Lyman, S., Ferguson, S. A., Braver, E. R., and Williams, A. F. (2002). Older driver involvements in police reported crashes and fatal crashes: trends and projections. *Inj. Prev*. 8, 116–120. doi: 10.1136/ip.8.2.116

Ma, X., Laud, P. W., Pintar, F., Kim, J. E., Shih, A., Shen, W., et al. (2011). Obesity and non-fatal motor vehicle crash injuries: sex difference effects. *Int. J. Obes. (Lond)*. 35, 1216–1224. doi: 10.1038/ijo.2010.270

Magee, C. A., Huang, X. F., Iverson, D. C., and Caputi, P. (2010). Examining the pathways linking chronic sleep restriction to obesity. *J. Obes*. 2010:821710. doi: 10.1155/2010/821710

Maibach, E., Steg, L., and Anable, J. (2009). Promoting physical activity and reducing climate change: opportunities to replace short car trips with active transportation. *Prev. Med*. 49, 326–327. doi: 10.1016/j.ypmed.2009.06.028

Moran, S. G., McGwin, G. J., Reiff, D. A., and Rue, L. W. III. (2001). The association between body habitus, restraint use, and fatality in motor vehicle collisions. *Annu. Proc. Assoc. Adv. Autom. Med*. 45, 107–123.

Moran, S. G., McGwin, G. Jr., Metzger, J. S., Windham, S. T., Reiff, D. A., and Rue, L. W. III. (2002). Injury rates among restrained drivers in motor vehicle collisions: the role of body habitus. *J. Trauma* 52, 1116–1120. doi: 10.1097/00005373-200206000-00015

Mulgrew, A. T., Nasvadi, G., Butt, A., Cheema, R., Fox, N., Fleethman, J. A., et al. (2008). Risk and severity of motor vehicle crashes in patients with obstructive sleep apnoea/hypopnoea. *Thorax* 63, 536–541. doi: 10.1136/thx.2007.085464

Nagy, K. K., Smith, R. F., Roberts, R. R., Joseph, K. T., An, G. C., Bokhari, F., et al. (2000). Prognosis of penetrating trauma in elderly patients: a comparison with younger patients. *J. Trauma* 49, 190–193; discussion 3–4. doi: 10.1097/00005373-200008000-00003

Neville, A. L., Brown, C. V., Weng, J., Demetriades, D., and Velmahos, G. C. (2004). Obesity is an independent risk factor of mortality in severely injured blunt trauma patients. *Arch. Surg*. 139, 983–987. doi: 10.1001/archsurg.139.9.983

Newell, M. A., Bard, M. R., Goettler, C. E., Toschlog, E. A., Schenarts, P. J., Sagraves, S. G., et al. (2007). Body mass index and outcomes in critically injured blunt trauma patients: weighing the impact. *J. Am. Coll. Surg*. 204, 1056–1061; discussion 62–64. doi: 10.1016/j.jamcollsurg.2006.12.042

NHTSA (2017). *Traffic Safety Facts Older Population*. Contract No.: 12803-022417-v2a. Washington, DC: NHTSA's National Center for Statistics and Analysis.

Ogden, E. J., and Moskowitz, H. (2004). Effects of alcohol and other drugs on driver performance. *Traffic Inj. Prev*. 5, 185–198. doi: 10.1080/15389580490465201

Owsley, C., McGwin, G. Jr., and Ball, K. (1998). Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. *Ophthal. Epidemiol*. 5, 101–113. doi: 10.1076/opep.5.2.101.1574

Papadakaki, M., Kontogiannis, T., Tzamalouka, G., Darviri, C., and Chliaoutakis, J. (2008). Exploring the effects of lifestyle, sleep factors and driving behaviors on sleep-related road risk: a study of Greek drivers. *Accid. Anal. Prev*. 40, 2029–2036. doi: 10.1016/j.aap.2008.08.019

Perdue, P. W., Watts, D. D., Kaufmann, C. R., and Trask, A. L. (1998). Differences in mortality between elderly and younger adult trauma patients: geriatric status increases risk of delayed death. *J. Trauma Acute Care Surg*. 45, 805–810. doi: 10.1097/00005373-199810000-00034

Preusser, D. F., Williams, A. F., Ferguson, S. A., Ulmer, R. G., and Weinstein, H. B. (1998). Fatal crash risk for older drivers at intersections. *Accid. Anal. Prev*. 30, 151–159. doi: 10.1016/S0001-4575(97)00090-0

Redelmeier, D. A., Yarnell, C. J., Thiruchelvam, D., and Tibshirani, R. J. (2012). Physicians' warnings for unfit drivers and the risk of trauma from road crashes. *N. Engl. J. Med*. 367, 1228–1236. doi: 10.1056/NEJMsa1114310

Reed, M. P., Ebert-Hamilton, S. M., and Rupp, J. D. (2012). Effects of obesity on seat belt fit. *Traffic Inj. Prev*. 13, 364–372. doi: 10.1080/15389588.2012.659363

Reimer, B., Coughlin, J. F., and Mehler, B. (2009). *Development of a Driver Aware Vehicle for Monitoring, Managing & Motivating Older Operator Behavior*. Washington, DC: ITS-America.

Rockwood, K., and Mitnitski, A. B. (2007). Frailty in relation to the accumulation of deficits. *J. Gerontol. Biol. Sci. Med. Sci.* 62A, 722–727. doi: 10.1093/gerona/62.7.722

Runyan, C. W. (1998). Using the Haddon matrix: introducing the third dimension. *Inj. Prev*. 4, 302–307. doi: 10.1136/ip.4.4.302

Rupp, J. D., Flannagan, C. A., Leslie, A. J., Hoff, C. N., Reed, M. P., and Cunningham, R. M. (2013). Effects of BMI on the risk and frequency of AIS 3+ injuries in motor-vehicle crashes. *Obesity (Silver Spring)* 21, E88–E97. doi: 10.1002/oby.20079

Sackett, D., Richardson, W. J., Rosenberg, W., and Haynes, R. (1997). *How to Practice and Teach Evidence-Based Medicine*. New York, NY: Churchill Livingstone.

Schlundt, D. G., Briggs, N. C., Miller, S. T., Arthur, C. M., and Goldzweig, I. A. (2007). BMI and seatbelt use. *Obesity* 15, 2541–2545. doi: 10.1038/oby.2007.303

Smith, B., and Phillips, B. A. (2011). Truckers drive their own assessment for obstructive sleep apnea: a collaborative approach to online self-assessment for obstructive sleep apnea. *J. Clin. Sleep Med*. 7, 241–245. doi: 10.5664/JCSM.1060

Spence, J. C., Cutumisu, N., Edwards, J., Raine, K. D., and Smoyer-Tomic, K. (2009). Relation between local food environments and obesity among adults. *BMC Public Health*. 9:192. doi: 10.1186/1471-2458-9-192

Tranter, P. J. (2010). Speed kills: the complex links between transport, lack of time and urban health. *J. Urban Health* 87, 155–166. doi: 10.1007/s11524-009-9433-9

Tregear, S., Reston, J., Schoelles, K., and Phillips, B. (2009). Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis. *J. Clin. Sleep Med*. 5, 573–581. doi: 10.5664/jcsm.27662

Turcotte, M. (2012). *Profile of Seniors' Transportation Habits*. Ottawa, ON, Statistics Canada.

Viamonte, S. M., Ball, K. K., and Kilgore, M. (2006). A cost-benefit analysis of risk-reduction strategies targeted at older drivers. *Traffic Inj. Prev*. 7, 352–359. doi: 10.1080/15389580600791362

Viano, D. C., Parenteau, C. S., and Edwards, M. L. (2008). Crash injury risks for obese occupants using a matched-pair analysis. *Traffic Inj. Prev*. 9, 59–64. doi: 10.1080/15389580701737645

Villareal, D. T., Banks, M., Siener, C., Sinacore, D. R., and Klein, S. (2004). Physical frailty and body composition in obese elderly men and women. *Obes. Res*. 12, 913–920. doi: 10.1038/oby.2004.111

Vrkljan, B. H., and Anaby, D. (2011). What vehicle features are considered important when buying an automobile? An examination of driver preferences by age and gender. *J. Saf. Res*. 42, 61–65. doi: 10.1016/j.jsr.2010.11.006

Wang, C. C., and Carr, D. B. (2004). Older driver safety: a report from the older drivers project. *J. Am. Geriatr. Soc*. 52, 143–149. doi: 10.1111/j.1532-5415.2004.52025.x

Wang, S. C., Bednarski, B., Patel, S., Yan, A., Kohoyda-Inglis, C., Kennedy, T., et al. (2003). Increased depth of subcutaneous fat is protective against abdominal injuries in motor vehicle collisions. *Annu. Proc. Assoc. Adv. Autom. Med.* 47, 545–559.

Winer, N., and Sowers, J. R. (2004). Epidemiology of diabetes. *J. Clin. Pharmacol*. 44, 397–405. doi: 10.1177/0091270004263017

Wood, J. M., and Owsley, C. (2014). Useful field of view test. *Gerontology* 60, 315–318. doi: 10.1159/000356753

World Health Organization (2013). *Global Status Report on Road Safety 2013: Supporting a Decade of Action*. Geneva: WHO.

World Health Organization (2018a). *Obesity and Overweight Fact Sheet 2018*. Available online at: http://www.who.int/mediacentre/factsheets/fs311/en/ (accessed March 6, 2018).

World Health Organization (2018b). *Towards an Age-Friendly World.* Available online at: www.who.int/ageing/age_friendly_cities_network/ (accessed February 5, 2018).

Xie, W., Chakrabarty, S., Levine, R., Johnson, R., and Talmage, J. B. (2011). Factors associated with obstructive sleep apnea among commercial motor vehicle drivers. *J. Occup. Environ. Med*. 53, 169–173. doi: 10.1097/JOM.0b013e3182068ceb

Yoon, C., Cole, C. A., and Lee, M. P. (2009). Consumer decision making and aging: current knowledge and future directions. *J. Consum. Psychol*. 19, 2–16. doi: 10.1016/j.jcps.2008.12.002

Young, T., Evans, L., Finn, L., and Palta, M. (1997). Estimation of the clinically diagnosed proportion of sleep apnea syndrome in middle-aged men and women. *Sleep* 20, 705–706. doi: 10.1093/sleep/20.9.705

Zhan, J., Porter, M. M., Polgar, J., and Vrkljan, B. (2013). Older drivers' opinions of criteria that inform the cars they buy: a focus group study. *Accid. Anal. Prev*. 61, 281–287. doi: 10.1016/j.aap.2013.02.029

Zhao, Z., and Kaestner, R. (2010). Effects of urban sprawl on obesity. *J. Health Econ*. 29, 779–787. doi: 10.1016/j.jhealeco.2010.07.006

Zhu, S., Kim, J. E., Ma, X., Shih, A., Laud, P. W., Pintar, F., et al. (2010). BMI and risk of serious upper body injury following motor vehicle crashes: concordance of real-world and computer-simulated observations. *PLoS Med*. 7:e1000250. doi: 10.1371/journal.pmed.1000250

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.