The use of seat belt cushion accessories among drivers aged 75 years and older

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Abstract

Chest injuries are the most common crash injuries among elderly occupants. While seatbelts are highly successful in reducing risk of death and injury in crashes, the seatbelt is the most common source of chest injuries in older occupants. Seatbelt effectiveness may be affected by the use of add-on accessories used to improve occupant comfort. This paper examines the use of seatbelt and seat cushion accessories among drivers aged 75 years and older. Self-reported seatbelt wearing patterns were collected using a survey and accessory use was assessed from observations of older drivers in their own vehicles. Height and weight measurements of drivers were also taken. Logistic regression was used to examine associations between occupant anthropometry, reported comfort and accessory use. Data from 367 participants was collected. Self-reported seatbelt use was high (99%), however, 23% were observed using a belt or cushion accessory. This included 9% using seatbelt comfort pads, and 17% using accessory cushions such as a seat base cushion, seat back cushion, back support or head-rest cushion. Seatbelt pads were more likely to be used by shorter drivers (OR1.07 95%CI 1.02-1.13), and cushion accessories were more likely to be used by drivers who reported belt comfort problems (OR2.5 95%CI 1.1-5.6). It is possible that many of the observed accessories would negatively impact crash protection by inducing slack into the system and the impact on crash protection requires further investigation. In the interim, other solutions, such as the use of adjustable D Rings should be encouraged.

Keywords: older occupants, seat belt accessories, seat cushions, seat belt fit

Introduction

There is widespread consensus that seat belts reduce the risk of injury and death in motor vehicle crashes (Campbell, 1987; Evans, 1986; Malliaris & Digges, 1987), however, seat belts are often the most common cause of chest injuries among older drivers (Martinez, Sharieff, & Hooper, 1994; Morris, Welsh, & Hassan, 2003; Welsh, Morris, Hassan, & Charlton, 2006). Seat belts are engineered to maximise the distance over which an occupant 'slows down' in the event of a crash by tightly securing the occupant to the vehicle, thereby lowering the deceleration forces transferred to the occupant. To minimise crash injury the seat belt must distribute these forces across the strongest parts of the occupant's body, that is, the clavicle, sternum and pelvic bones. Although seat belts are designed to do this, safety is reliant on the fit of the seat belt to the anthropometry of the occupant.

Seat belt fit may be compromised by age-related anthropometric changes to general body shape (Wells, Treleaven, & Cole, 2007), as well as differences in thoracic structure (Kent et al., 2005) and spinal geometry (Hammerberg & Wood, 2003) that occur in later life. Even with optimal seat belt contact across the strongest bony anatomical landmarks, tolerance to seat belt loading decreases with age (Kent et al., 2005) which may contribute to the shift from soft to bony tissue injuries, including rib fractures, that have been seen in older occupants involved in crashes (Ridella, Rupp, & Poland, 2012). Older occupants, not only bear the highest rates of chest injuries amongst all occupants (Koppel, Bohensky, Langford, & Taranto, 2011; Ridella et al., 2012) and higher morbidity and mortality following rib fracture (Bergeron et al., 2003; Stawicki, Grossman, Hoey, Miller, & Reed, 2004), but, overall risk of crash injury is higher (Koppel et al., 2011; Tefft, 2008; Welsh et al., 2006), even in crashes of lower severity, and commonly result in worse outcomes for similar crash severity and injury (Ridella et al., 2012).

Poor outcomes are often linked to the presence of comorbidities (Ridella et al., 2012) and increased fragility associated with ageing (Bergeron et al., 2003; Stawicki et al., 2004). While it is likely that age-related changes, fragility and comorbidities all play a role in the severity of crash outcomes among older occupants, little is known about seat belt fit in older populations and its contribution to crash injury and severity. Despite the call for age-related fragility to be considered in the design of vehicle occupant protection features such as seat belts and airbags (Keall & Frith, 2004), only one study to date has shown changes to seat belt fit with increasing age (Reed, Ebert, & Hallman, 2013), and although it stands to reason that this will impact injury type and severity, more research is required. Reed's study investigated posture and belt fit in 46 men and 51 women, predominantly over 40 years of age and analysed the location of the belt in relation to skeletal structures. This laboratory study permitted detailed evaluation of the belt fit and found that increases in body mass index negatively impacted the lap belt fit by placing it higher and forward of the bony pelvis and also introduced slack into the system.

To further investigate seat belt fit among older drivers we conducted an exploratory study into the seat belt wearing characteristics of a community sample of older drivers aged 75 years and older (Brown, Coxon, Fong, Clarke, & Keay, 2013). Preliminary results indicated that good overall seat belt fit, including correct lap and sash belt positioning, was observed in only 30% of participants (Brown et al., 2013). Unexpectedly, a relatively high proportion of older drivers were observed to use add-on accessories such as seat belt comfort pads and seat cushions, raising the question of the role these accessories play in seat belt fit, crash injury and severity in this population. To date, there are no studies exploring add-on accessory use by older drivers, leaving the underlying reasons for use uncertain. While the manuscript published by Brown in 2013 presented data on seat belt fit and noted the use of accessories by some older drivers, this early work did not examine the use of these accessories in detail. This study aims to explore the scope and predictors of add-on accessory use by drivers aged 75 years and older. Add-on accessories may introduce slack into the seat belt system affecting occupant protection in the event of a crash. In the context of unprecedented rates of population ageing (CEPAR, 2013) and rising rates of licensed older drivers in motorised countries (BITRE, 2014; Cicchino & McCartt, 2014), this study will be an important first step in understanding patterns of accessory use and their predictors, which will in turn inform further investigations into the safety implications of add-on accessory use on occupant protection among older drivers.

Methods

A cross-sectional analysis of observed accessory use, occupant anthropometry, and self-reported seatbelt wearing patterns was conducted to explore predictors of add-on accessory use by older drivers.

Participants

A convenience sample of 380 older drivers were recruited as part of a randomised controlled trial investigating the efficacy of an education program designed to promote safe mobility in later life (Keay et al., 2013). Drivers, 75 years or older, with a valid drivers' license, residing in northwest Sydney were eligible to enrol. Each participant was required to own a vehicle for monitoring and be the primary driver of that vehicle for more than 80% of driving time. All participants provided written consent prior to their involvement and ethics approval was granted by The Human Research Ethics Committee of the University of Sydney.

Data Collection

Trained researchers conducted home-based assessments at baseline. All data was recorded and managed on Research Electronic Data Capture (REDCap) (Harris et al., 2009). Questionnaires were administered via interview to collect demographic information (age, gender, years of education, year of car), health status and seat belt wearing characteristics for each participant. Comorbidities were obtained using the co-morbidity index (Groll, To, Bombardier, & Wright, 2005). Participants were asked if they have or have ever experienced each condition. Arthritis, joint replacement, back pain, osteoporosis and degenerative disc disease were coded as orthopaedic conditions (Table 1). An inventory of prescription medications was also taken.

Several questions were asked regarding seat belt usage, patterns and comfort. In particular, participants were asked if they found their seat belt comfortable, and if they needed to reposition the seat belt to make it more comfortable. Comfort and need to reposition the seatbelt were coded as binary variables (Table 1). Participants were also asked whether their seat belt sash was height adjustable. Participants could respond 'no', 'I don't know' or 'yes', however, 'no' and 'I don't know' were combined for analysis as these participants either did not have the feature or did not actively adjust the D ring to optimise seat belt fit. The reported answer was always recorded, regardless of any inaccuracies found upon vehicle inspection. Anthropometric measurements including standing height and weight were taken, and Body Mass Index (BMI) was calculated after the visit.

During the home-based assessment, a standardised series of electronic photographs were taken of each participant in their vehicle with the seat belt fastened in its usual position for driving. Researchers did not intervene or change the position of the seat belt in any way. Photos were taken in an arc starting on the driver's right hand side, moving around the front and finishing on their left. Four to seven photos were taken of each participant. A series of reference photos were also taken without the participant in the vehicle. Sash angle was measured from the photographs using Capture NX2 (Nikon Corp. Capture NX2 Version 2.4.6, Released 2014, Tokyo Japan; Nikon Corp). The sash angle was measured between the mid-sagittal line, identified by the suprasternal notch, and the medial edge of the sash belt (Figure 1). Seat belt fit was judged visually from the photos. If the sash passed over the mid portion of the shoulder, fit was judged to be 'good'. For 'good' lap belt fit the belt had to pass low over the abdomen with at least the bottom edge of the webbing in contact with the upper thigh. For ‘good’ overall fit to be achieved the criteria for both ‘good’ lap and ‘good’ sash fit needed to be satisfied (Brown et al., 2013).

Figure 1. Diagram showing the measured sash angle (x°) between the sash belt and the midline of the chest

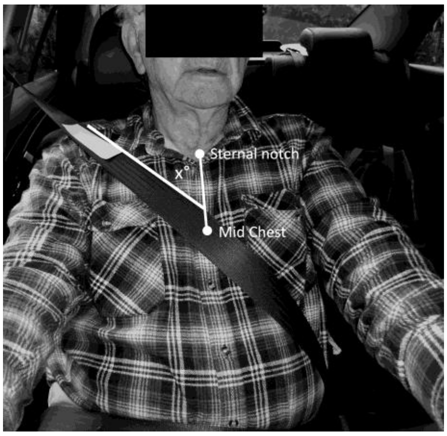


Table 1. Variables included in logistic regression model exploring predictors of seat belt cushion and seat accessory use among older drivers

Variable	**Type of data**	**Units**
Outcome Variables		
Use of a seat belt comfort pad	binary	yes/no
Use of a seat accessory	binary	yes/no
Other variables of interest		
Age	continuous	years
Gender	binary	female/male
Shorter Height	continuous	centimetres
Body Mass Index (BMI)	continuous	kg/m^2
Orthopaedic condition reported	binary	no/yes
Sash angle	continuous	degrees
Sash belt fit	binary	good/poor
Lap belt fit	binary	good/poor
Overall fit	binary	good/poor
Seat belt comfort “Overall, when your seat belt is on, do you find it comfortable?”	binary	yes/no
Reposition seat belt “Do you ever reposition the seatbelt to make it more comfortable?”	binary	no/yes
Sash height adjustable (“D” ring adjuster)	binary	no/yes
Year of vehicle	discrete	year

Outcomes

Two outcomes were selected for investigation; use of seat belt comfort pads (Figure 2) and use of seat accessories (Figure 3). Seat belt comfort pads included any pad or cushion attached to the seat belt sash. All other accessories used on the car seat were classified as seat accessories, including seat base cushions, seat back cushions, back supports and head-rest cushions. The use of add-on seat and/or belt accessories were identified from the vehicle photographs and recorded. Fitted seat covers were not considered an add-on accessory and were ignored.

Figure 2. Examples of seat belt comfort pads

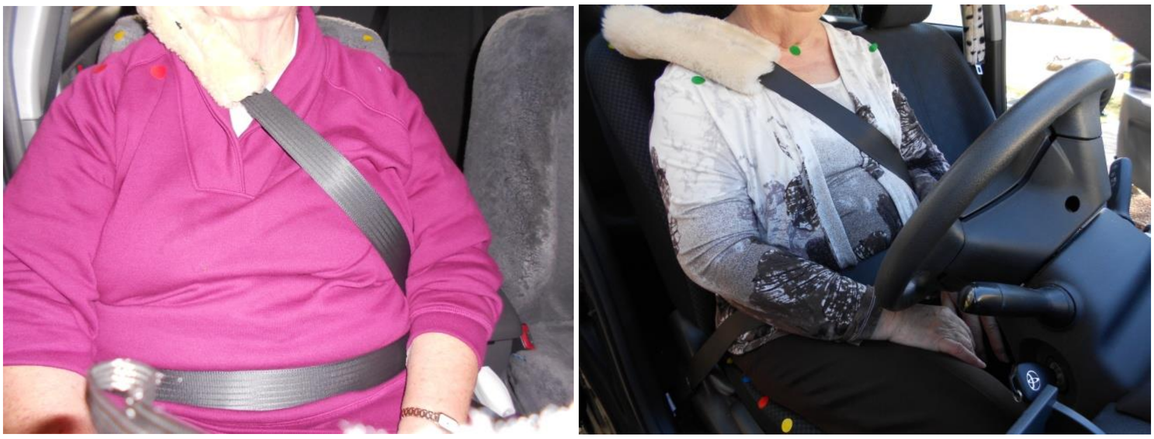
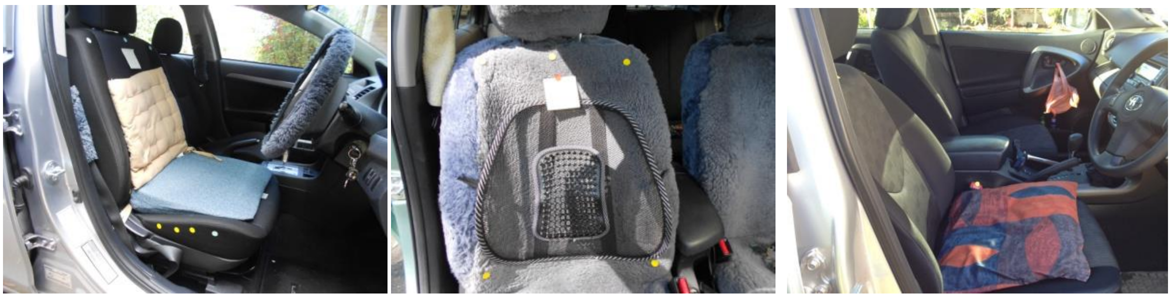


Figure 3. Examples of seat accessories



Data Analysis

Demographic and seat belt wearing characteristics were summarised using descriptive statistics. Chi-square tests were used to compare the proportion of men and women using add-on accessories in this sample. A correlation matrix was used to evaluate possible collinearity of continuous predictive variables. Univariate logistic regression was employed to assess the relationship between predictive variables (Table 1) and each outcome of interest. All possible predictive variables with a univariate association $p<0.25$ were included in an initial logistic multivariate regression model. Plausible interactions were explored before a step-wise process of backwards elimination was used to reveal the final multivariate model predicting each outcome. Significance was set at 0.05 and SAS Enterprise Guide Version 5.1 (SAS Institute Inc, 2012) was used for the analysis. The results are presented in accordance with the STROBE guidelines for reporting observational studies (von Elm et al., 2008).

Results

A total of 380 older drivers were enrolled in the RCT and researchers were able to take photographs of 367 participants. Problems with vehicle access, reduced mobility or adverse weather conditions prevented 13 participants from accessing their vehicle for photographs.

Data from these 13 participants was therefore incomplete and excluded from analysis. The mean age of the sample was 80 years, ranging from 75 to 94 years (Table 2). More males (222/367) than females (145/367) enrolled in the study, with an approximate 60:40 split. On average, participants had 13 years of education, 5.5 comorbidities and 3.8 prescription medications. Orthopaedic conditions were common with approximately three out of four participants (285/367, 78%) reporting a past or present diagnosis. The average BMI (27.5 kg/m^2) fell within the overweight range, with 69% (252/365, missing height data for 2/367) of participants considered to be overweight or obese (BMI>25). The year of vehicle manufacture ranged from 1978 to 2013 (median: year 2005, corresponding to 8 year old vehicles).

Reported seat belt use was high (99%, 362/367) among participants. Seat belt discomfort was reported by 11% (39/367) of participants, however, nearly double (20%, 74/367) reported repositioning the seat belt to improve comfort. The majority of participants either did not know if their sash was height adjustable (32%, 118/367) or reported that they did not have this feature in their vehicle (30%, 110/367). Of the participants who reported having this feature; only 59% (86/145) reported having adjusted the height for better fit or comfort. Seat belt comfort pads and seat accessories were used by 9% (32/367) and 17% (64/367) of participants respectively (Table 2). Photographs revealed a total of 49 seat base cushions, 20 seat back cushions, 6 back supports, 2 head rest cushions and 1 beaded seat overlay. Some participants had a combination of different seat accessories and/or a seat belt comfort pad. Close to one in four participants (23%) were observed to have at least one or more add-on accessories. More women than men used seat belt comfort pads (χ^2_1= 12.54, p=0.0004) and seat accessories (χ^2_1=7.47, p=0.006) in this sample.

Table 2. Characteristics of participants* (n=367)

Characteristic	**Mean (SD)***
Age (years)	80.2 (4.3)
Education (years)	13.3 (3.9)
Number of comorbidities	5.5 (2.7)
Number of prescription medications	3.8 (2.8)
Height (cms)**	167.7 (8.7)
Body Mass Index (BMI)(kg/m^2)**	27.5 (4.2)
Characteristic	**n (%)**
Gender	
Male	222 (60.5)
Female	145 (39.5)
Orthopaedic condition reported	285 (77.7)
Seat belt is uncomfortable	39 (10.6)
Add-on accessories	
Uses a seat belt comfort pad	32 (8.7)
Uses a seat accessory	64 (17.4)
Has at least one or more accessories	85 (23.2)

*Participants with seat belt photographs included in this analysis

**2 participants did not have their height measured

The correlation matrix revealed only weak associations between continuous predictive variables, indicating that collinearity was unlikely to interfere with analysis. Gender, height, orthopaedic conditions and sash angle predicted use of seat belt comfort pads in the univariate analysis (Table 3). Gender and orthopaedic conditions were eliminated from the multivariate analysis, leaving height (χ^2_1=7.85, p=0.005) and sash angle (χ^2_1=3.85, p=0.0498) as independent predictors. After controlling for sash angle, for every one centimetre decrease in height, the likelihood of using a seat belt comfort pad increased by 7% (95% CI: 2-13%) on average. Sash angle just reached significance in the multivariate model. After controlling for height, for every degree increase in sash angle away from the neck, the likelihood of using a seat belt comfort pad decreased by 6% (95% CI: 0-12%) on average.

Table 3. Predictors of seat belt cushion and seat accessory use by older drivers

		Univariate model		Multivariate model		
Outcome variable	**Explanatory Variable**	**Odds ratio**	***p*-Value**	**Odds ratio**	***p*-Value**	**95% CI**
Use of seat belt comfort pad	Age	1.04	0.29	-	-	-
	Gender	**0.26**	**0.0008**	-	-	-
	Shorter height	**1.09**	**0.0003**	**1.07**	**0.005**	**1.02-1.13**
	Body Mass Index (BMI)	1.01	0.85	-	-	-
	Orthopaedic condition	**4.71**	**0.04**	-	-	-
	Sash angle	**0.91**	**0.004**	**0.94**	**0.0498**	**0.88-1.00**
	Sash belt fit	0.85	0.66	-	-	-
	Lap belt fit	0.83	0.63	-	-	-
	Overall seat belt fit	0.76	0.48	-	-	-
	Seat belt comfort	1.6	0.34	-	-	-
	Reposition seat belt	0.91	0.83	-	-	-
	Sash height adjustable	0.62	0.24	-	-	-
	Year of vehicle	1.00	0.84	-	-	-
Use of seat accessory	Age	**1.09**	**0.006**	**1.07**	**0.04**	**1.003-1.14**
	Gender	**0.47**	**0.007**	-	-	-
	Shorter height	**1.05**	**0.003**	**1.04**	**0.02**	**1.01-1.08**
	Body Mass Index (BMI)	**0.89**	**0.003**	**0.89**	**0.004**	**0.83-0.97**
	Orthopaedic condition	1.68	0.16	-	-	-
	Sash angle	0.96	0.10	-	-	-
	Sash Belt fit	1.05	0.86	-	-	-
	Lap belt fit	1.12	0.69	-	-	-
	Overall belt fit	1.12	0.70	-	-	-
	Seat belt comfort	**2.7**	**0.007**	**2.5**	**0.03**	**1.1-5.6**
	Reposition seat belt	1.7	0.08	-	-	-
	Sash height adjustable	0.90	0.73	-	-	-
	Year of vehicle	1.02	0.42	-	-	-

Univariate analysis revealed five predictors of seat accessory use (Table3). Only gender was eliminated in the multivariate analysis. Age (χ^2_1=4.26, p=0.04), height (χ^2_1=5.53, p=0.02), BMI (χ^2_1=8.22, p=0.004) and seat belt comfort (χ^2_1=4.99, p=0.03) were all found to be independent predictors of seat accessory use. For every one year increase in age, the likelihood of using a seat accessory increased by 7% (95% CI: 0.3-14%) on average. For every one centimetre decrease in height, the likelihood of using a seat accessory increased by 4% (95% CI: 1-8%) and for every one kilogram/metre^2 increase in BMI, the likelihood of using a seat accessory decreased by 11% (95% CI: 3-17%) on average. People who reported seat belt discomfort were 2.5 times more likely, on average, to use a seat accessory than people who found their seat belt comfortable (95% CI: 1.1-5.6). All estimates were calculated after controlling for all covariates in the model.

Discussion

This study represents the first investigation into add-on accessory use by older drivers. The use of add-on accessories was found to be high among older drivers, with close to one in four participants observed to use at least one add-on accessory in their vehicle. Shorter drivers and those with more acute sash belt angles (where the sash is often close to the neck) were more likely to use a seat belt comfort pad. A large set of factors; older age, shorter height, lower BMI and self-reported seat belt discomfort, independently predicted the use of seat accessories. These results indicate that seat belt comfort pads and seat accessories are employed by older drivers for different reasons. Sash angle, which is an interaction between inherent seat belt geometry and anthropometry, appears to motivate use of seat belt comfort pads, while body shape and comfort, possibly related to occupant postural issues, appear to motivate seat accessory use. Gender and orthopaedic conditions were not predictive of accessory use in multivariate models. Orthopaedic conditions and pain were only investigated using the comorbidity index and should be graded and explored in more detail to fully investigate this relationship in future research.

As sash angle decreases, the likelihood of using a seat belt comfort pad increases. It is likely that height, although independently predictive of comfort pad use, is also associated with sash angle. In a laboratory study by Reed et al. (2013) stature was found to change seat belt fit. In particular, increases in height were shown to correspond with outboard movement of the shoulder belt relative to the body centreline (Reed et al., 2013) and as a result shorter people are more likely than taller people to have acute sash angles. As sash angles decrease, seat belts are positioned closer to the occupant's neck, which may cause the belt to touch or rub (as seen in Figure 2), leading to discomfort. This is likely to explain the use of seat belt comfort pads in some participants. Alternatively, adjustment of the D ring may ameliorate this issue without the need for an accessory.

Although only a small proportion of older drivers were found to have good overall seat belt fit in our preliminary analysis in this cohort (Brown et al., 2013), no association was found between seat belt fit (including sash angle) and seat accessory use. It appears that the decision to use seat accessories is less about the fit of the seat belt, than the influence of body shape (BMI), stature (height) and seat belt comfort. Body shape and stature may influence driving posture and function. A person with a shorter stature may use a cushion for better vision of the environment while driving, supporting the association that we found between height and seat accessory use. Occupational therapists or driving rehabilitation specialists may also prescribe seating cushions, arm rests or other adaptive equipment for comfort, postural support or function while driving (Bouman & Pellerito, 2006; Steinfeld, Tomita, Mann, & DeGlopper, 1999). Add-on accessories may be self-selected or prescribed, however, determining this was beyond the scope of investigation in this study. Although occupational therapists commonly recommend and prescribe adaptive equipment for driving, the impact of these accessories on occupant safety in the event of a crash is not known (Arbesman & Pellerito, 2008).

Older drivers who reported seat belt discomfort were 2.5 times more likely to use a seat accessory. A link between seat belt discomfort and seat accessories suggests these add-ons may be employed in an attempt to remediate seat belt comfort issues. This is an important finding for two reasons. Firstly, the use of seat accessories may be a symptom of a more systemic problem with the comfort of seat belt fit in older drivers. Secondly, the safety implications of using add-on devices are unknown. Drivers may be introducing slack into the seat belt system compromising occupant safety.

The safety of add-on accessories warrants further investigation. Given the high risk (Koppel et al., 2011; Tefft, 2008; Welsh et al., 2006) and rates of injuries (Koppel et al., 2011; Ridella et al., 2012) among crash involved older drivers, along with the high proportion of older drivers found to use accessories, the possibility that add-on accessories contribute to these injuries must not be ignored. The effect of seat belt comfort pads and seat accessories on occupant safety is likely to be different. It is unlikely that comfort pads will introduce slack into the system; however, their use may signify incorrect sash belt fit or positioning which has inherent safety and injury risks in itself. Ideally the seat belt sash should cross the mid-clavicle region. Any mis-positioning of the sash may result in changes to the distribution of forces in the event of a crash compromising occupant protection. On the other hand, seat accessories may introduce slack into the system, reducing the effectiveness of the seat belt system in the event of a crash.

Adjustable D ring positions are one way to counteract poor sash positioning, which may eliminate the need for a seat belt comfort accessory. However, results from our survey revealed that 32% of participants did not know if they had this feature and only 59% of the participants who reported having this feature had adjusted the seat belt height for better fit or comfort. Although newer cars are likely to have this feature, vehicle age was not predictive of either seat belt comfort pad or seat accessories use. These results suggest that participants may be unaware of the available adjustments to seat belt fit in their vehicle. Further to this, many recent model vehicles have seat adjustments including seat base height, seat back angle and lumbar support. It is unknown whether participants are using these adjustments to their full potential to optimise function and comfort. Education programs designed to help fit the person to the vehicle such as CarFit (American Automobile Association & American Occupational Therapy Association, 2008) may increase awareness and use of all available adjustments to maximise their fit and comfort in their vehicle.

Observation of older drivers in their own vehicle was a key strength of this study, however, we acknowledge several limitations that should to be taken into account when interpreting these results. Although researchers did not interfere with seat belt positioning or use of accessories in any way, it must be acknowledged that the presence of an observer itself may have influenced the way the participant donned their seat belt or the accessories they used. Social desirability bias may have come into play, whereby observed participants respond in a manner that will be viewed favourably by others. Given the high proportion of participants using add-on accessories, any social desirability bias would likely underestimate the true rate of accessory use in this population. Photographs were taken by trained researchers using standardised procedures, however, there is potential for some error in measurement of sash angle due to parallax. Judgements about seat belt fit are unlikely to have been affected.

Convenience sampling was employed to recruit participants into the study, and therefore, the sample is not generalisable to all drivers in the target population or other age groups. People who volunteer for driving studies are also likely to be healthier and have higher levels of function than those who do not (Molnar & Eby, 2008).

Conclusion

The results of this study suggest that a significant proportion of older drivers attempt to remedy a poor match between user anthropometry and seat belt fit with seat belt comfort pads and seat belt discomfort by employing seat accessories when driving. It is also possible that seat accessories are prescribed or self-selected to promote functional ability in the task of driving. Many of the observed accessories might negatively impact crash protection by inducing slack into the system but this remains to be tested. Given the high proportion of older drivers using add-on accessories, further investigation of their impact on crash protection is required to ensure occupational therapists prescribing their use are provided with guidelines on the types of accessories that can be used and information is provided to older drivers for independent purchase of such accessories. In the interim, other solutions, such as the use of adjustable D rings and/or seat base, back or lumbar support adjustments to the vehicle seat should be encouraged. Seat belt fit should be considered by older adults when purchasing new or used vehicles.

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