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Wheelchair Securement and Occupant Restraint System (WTORS) Practices in Public Transit Buses

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The purpose of this study was to characterize wheelchair tiedown and occupant restraint system (WTORS) usage in public transit buses based on observations of wheelchair and scooter (wheeled mobility device: WhMD) passenger trips. A retrospective review of on-board video surveillance recordings of WhMD trips on fixed-route, large accessible transit vehicles (LATVs) was performed. Two hundred ninety-five video recordings were collected for review and analysis during the period June 2007–February 2009. Results showed that 73.6% of WhMDs were unsecured during transit. Complete use of all four tiedowns was observed more frequently for manual wheelchairs (14.9%) and power wheelchairs (5.5%), compared to scooters (0.0%), and this difference was significant (p = 0.013). Nonuse or misuse (lap belt use only) of the occupant restraint system occurred during 47.5% of WhMD trips. The most frequently observed (52.5%) use of the lap belt consisted of bus operators routing the lap belt around the WhMD seatback in an attempt to secure the WhMD. These findings support the need for development and implementation of WTORS with improved usability and/or WTORS that can be operated independently by WhMD passengers and improved WTORS training for bus operators.

Keywords: wheelchair transportation, public transit buses, wheelchair securement, wheelchair tiedowns, wheelchair occupant restraint systems, WTORS, large accessible transit vehicles, wheelchair safety

Introduction

Four-point, strap-type wheelchair tiedown and occupant restraint systems (WTORS) have been the most common means of securing wheelchairs and restraining occupants in large, accessible transit vehicles (LATVs) for over two decades. During this time the majority of WTORS research has been laboratory based and focused on the capability of tiedowns to secure a wheelchair, and the ability of occupant restraints to retain an occupant in an upright, seated position during a crash. Commercial WTORS are available that comply with the Society of Automotive Engineer’s (SAE) Recommended Practice J2249 Wheelchair Tiedowns and Occupant Restraint Systems for Use in Motor Vehicles (Society of Automotive Engineers, 1996) which provides design guidelines and evaluates the strength and integrity of WTORS under moderately severe crash conditions. However, despite the availability of SAE J2249-compliant WTORS, previous studies suggest that WTORS may not be implemented or used properly in the field (Shaw & Gillispie, 2003; Buning, Getchell, Bertocci, & Fitzgerald, 2007; Fitzgerald, Songer, Rotko, & Karg, 2007; Frost & Bertocci, 2010), potentially placing wheelchair and scooter (wheeled mobility device: WhMD) users at increased risk of injury.

Four-point wheelchair tiedown systems consist of four tiedown straps. Two straps are secured to the front of the WhMD and two secured to the rear of the WhMD. Straps typically have an “S” hook end-fitting used to attach the strap to the WhMD. Proper use of the four-point tiedown system consists of using all four tiedown straps to secure the WhMD to the vehicle floor. Occupant restraint systems are comprised of a shoulder and lap belt assembly used to restrain the passenger’s upper torso and pelvis. Figure 1 illustrates proper use of the complete WTORS in accordance with SAE Recommended Practice J2249.

The majority of fixed route LATVs in the United States are equipped with WTORS in order to meet the accessibility requirements of the American with Disabilities Act (Americans with Disabilities Act: ADA, 1990). However, although the ADA mandates the use of WTORS, the ADA does not mandate the use of WTORS (Americans with Disabilities Act, 1990). The ADA permits individual transit agencies to establish policies regarding the use of WTORS. As a result, disparities may exist across transit agencies with respect to use of WTORS. Buning et al. (2007) surveyed 111 transit agencies on their policies and practices with regard to WTORS. Although the majority of transit agencies (73.9%) required that WhMDs be secured, less than a quarter (19.8%) mandated use of occupant restraints; the rationale being that ambulatory passengers traveling on LATVs are not required to use occupant restraints.

Nonuse of WTORS have been shown to place WhMD users at greater risk of injury (National Highway Traffic Safety Administration, 1997). We previously conducted a pilot study (Frost & Bertocci, 2009) in which video surveillance records of WTORS usage on LATVs were reviewed. Our findings indicated that the majority (76%) of WhMDs were not secured using

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WTORS Practices in Buses

Fig. 1. Wheelchair tiedown and occupant restraint system (Ride Safe®, University of Michigan) consisting of two tiedowns securing the front of the wheelchair, two tiedowns securing the rear of the wheelchair, and including both a lap and shoulder belt for occupant restraint (color figure available online).

four-point, strap-type tiedowns during transport, and that misuse of the lap belt was common (44% of cases). Misuse of the lap belt consisted of the LATV operators attempting to secure the WhMD by routing the lap belt around the WhMD seatback.

With the exception of the pilot study mentioned above, to our knowledge no study has been published describing WTORS practices in LATVs based on real world observations. In our current study, we conducted a detailed retrospective review of video recordings obtained from on-board video surveillance cameras installed in LATVs. We describe the frequency of WTORS use, nonuse, and/or misuse in LATVs, which may have important implications for WhMD passenger safety, bus driver training, and passenger education.

Research Methods

Approval to conduct this study was obtained from the University of Louisville Institutional Review Board (IRB No. 170.07)

Video Recordings and Transit Agency Demographics

Video surveillance footage was obtained from a metropolitan transit agency located in the southeastern region of the United States. The transit agency serves a population of 1.3 million people and operates approximately 285 LATVs. WhMD boardings are estimated at 200–250 per week, averaging 10,400–13,000 annual WhMD trips. All LATVs were equipped with four-point, strap-type, tiedown systems, and occupant restraint systems consisting of both lap and shoulder belts. Signs are posted in each camera-equipped LATV notifying passengers that activities within the vehicle are monitored and recorded for public safety.

At the time of the study, the transit agency operated 57 LATVs that were equipped with the GE® MobileView III Video Surveillance System® (GE Security, Bradenton, FL). Details regarding this system have been published previously (Frost, Bertocci, & Sison, 2010). Each video surveillance system consists of 4–5 permanently mounted video cameras, including 1 camera focused on the WhMD securement station (Figure 2). Randomly selected DVRs containing video footage were provided to the authors by the transit agency and viewed 2–3 times per month for the 21 month period of June 2007 to February 2009. Video footage of WhMD trips were captured and archived for analysis. Each recording included the WhMD securement process.

All videos were reviewed by two of the authors (K. Frost and Z. Salipur). To ensure consistent data recording of video observations, we first reviewed videos as a team to insure agreement on interpretation and findings. Subsequent videos were reviewed in parallel. In the event either reviewer expressed uncertainty or disagreement regarding an observation, the reviewers concurrently reviewed and discussed the video, and sought the opinion of the remaining author as needed. However, there were no cases for which the data recorded was not based on a unanimous finding.

Data Collection and Analysis

WTORS usage was assessed from captured video footage and was recorded as categorical or continuous data in a customized database (FileMaker Pro 8 Ver. 2, for Mac OS X). General data collected included WhMD passenger gender, WhMD type, number of items (backpacks/bags) attached to the WhMD, and any additional assistive technology used or carried by the WhMD passenger that may have encumbered use of the WTORS. WTORS usage was subdivided into two categories: WhMD tiedown usage and occupant restraint usage. WhMD tiedown data was recorded based on whether or not WhMD tiedowns were used, along with the number and location of the applied tiedowns (as applicable). Three terms were used to categorize tiedown usage: “complete use” was defined as the use of all four tiedowns, “misuse” was defined as the use of between one to three tiedowns, and “nonuse” was defined as situations in which zero tiedowns were applied to the WhMD. Occupant restraint system usage was...
recorded based on whether or not occupant restraint belts were used, and which occupant restraint belts were used (lap or shoulder). The terms complete use, misuse, and nonuse were also used to categorize occupant restraint usage as follows: complete use was defined as the use of both the shoulder and lap belt, misuse was defined as use of only one belt, and nonuse was defined as situations in which neither the shoulder nor lap belt were used to restrain the occupant. Additionally, a fourth category—“wrong use”—was defined as use of the lap belt to secure the WhMD by routing it around the WhMD seatback. The individual who applied the WTORS (LATV operator, caregiver/assistant, other passenger) was also recorded. Descriptive statistics were used to present all data. Post-hoc independent samples chi-square analysis was performed to examine WTORS usage based on WhMD type. All statistical analysis was conducted using SPSS Statistics, Ver 19.

Results

During the 21 month study period, video records of 295 WhMD trips were reviewed and analyzed.

General Passenger and WhMD Findings

Slightly more than half of the WhMD passengers were male (n = 158; 53.6%). The majority of observed trips were taken by passengers using power wheelchairs (n = 201; 68.1%). Passengers using manual wheelchairs (n = 74; 25.1%) were observed less frequently, followed by scooter users (n = 20; 6.8%). Fifteen passengers utilized and/or were equipped with an additional form of assistive technology during travel: five WhMD passengers carried a cane, three traveled with service dogs, two carried walkers in their lap/footrest area, two had augmentative communication devices mounted to their WhMD, one passenger had a tray mounted to his WhMD, one passenger had an oxygen tank attached to their wheelchair, and one passenger had an extended footrest to accommodate a leg cast. Fifty-nine percent (59%) of all passengers had at least one backpack/bag attached to their WhMD (n = 174), and the majority of backpacks/bags were attached to the rear of the WhMD (n = 169; 97.7%). Forty of these passengers (22.9%) had two or more backpacks/bags attached to their WhMD.

WTORS Usage Findings

WhMD tiedown usage

Details of tiedown usage, and the location of applied tiedowns were quantified for each WhMD trip by WhMD type (Figures 4–6). When the WhMD was secured, the individual securing the WhMD was the LATV operator in all but one case (a fellow passenger secured the wheelchair in a single case). Complete use of tiedowns (application of all four tiedowns) to secure the WhMD was observed in 22 of 295 WhMD trips (7.5%), and misuse (application of one to three tiedowns) was observed in 56 of 295 WhMD trips (18.9%). The majority of observed WhMD trips (n = 217; 73.6%) evidenced nonuse (zero tiedowns used) during transit. These results are summarized in Figure 3, and presented in greater detail below.

Figure 4 details tiedown usage observed for 20 scooter trips. Nonuse of tiedowns was observed during the majority (80.0%, n = 16) of scooter trips, followed by observations of misuse of (20.0%, n = 4). Fifty percent (50%, n = 2) of misuse observations consisted of using 3 tiedowns. The remaining 50% of observations consisted of using only 1 or 2 tiedowns (n = 1 for each tiedown scenario). The combination of front and rear tiedown usage per trip (e.g., 0 rear tiedowns +2 front tiedowns) is shown in Figure 4. There were no scooter trips in which complete use of all four tiedowns was observed.

Tiedown usage for 74 observed manual wheelchair trips is detailed in Figure 5. Nonuse of tiedowns was observed during the majority of trips (59.5%, n = 44), followed by observations of misuse (25.6%, n = 19). Complete use of all four tiedowns was observed during 14.9% (n = 11) of manual wheelchair trips (14.9%). The majority of misuse observations (56%) consisted of using of 2 tiedowns. Use of only 1 tiedown was observed for 33.3% of trips, and the use of 3 tiedowns was observed during 11.1% of manual wheelchair trips. The use of rear tiedowns only was the most frequent observation. Detailed results of front and rear tiedown use per trip are included in Figure 5.

Tiedown usage for power wheelchair trips followed the trend observed for scooter and manual wheelchair trips (Figure 6). Nonuse of tiedowns was observed during 78.1% of power wheelchair trips (n = 157). Misuse accounted for 15.4% of observations (n = 31), and complete use of all four tiedowns was observed during 5.5% of trips (n = 11). The majority of misuse observations (46.7%) involved the use of 2 tiedowns. Only 1 tiedown was used during 33.3% of trips and the use of 3 tiedowns occurred during 20% of power wheelchair trips. Use of rear tiedowns only was the most frequently observed scenario for power wheelchairs. Detailed results of front and rear tiedown use per trip are shown in Figure 6.

Post-hoc Chi-square analysis revealed a significant relationship between WhMD type and complete use (all four) of tiedowns to secure the WhMD ($\chi^2(1) = 6.48, p = .011$), indicating that compared to power wheelchairs, manual wheelchairs were more frequently secured using all four tiedowns (no scooters were secured using all four tiedowns). Passengers riding while seated in a scooter or power wheelchair were also more likely to ride with their WhMD unsecured (80% and 78.1%, respectively) compared to manual wheelchair users (59.5%) and this difference was significant ($p = .006$).
Occupant restraint system usage

There were no trips in which complete use of occupant restraints (both shoulder and lap belt) was observed. Misuse (only one belt used) was observed in 61 of 295 total trips (20.7%), and all observations showed lap belt usage only. Nonuse (zero belts) occurred more frequently, accounting for 26.8% (n = 79) of observations. However, the predominant use of occupant restraints was wrong use of the lap belt to secure the WhMD, observed as routing the lap belt around the WhMD seatback (n = 155, 52.5%). Occupant restraint usage according to WhMD type is summarized in Figure 7. The LATV operator applied the occupant restraint(s) during all but four trips. In three trips a personal assistant applied the lap belt, and in one trip the WhMD passenger applied the lap belt.

Occupant restraint usage during scooter trips is shown in Figure 8. Misuse (lap belt only) was observed in 4 of 20 scooter trips (20.0%), and nonuse accounted for 10% of observations (n = 2). Seventy percent (70%) of observations showed wrong use of the lap belt. During manual wheelchair trips (Figure 9), misuse was observed in 23 of 74 cases (31.1%), followed by observations of wrong use (n = 24; 32.4%) and nonuse (n = 27; 36.5%). For power wheelchairs (Figure 10), misuse was observed in 34 of 201 power wheelchair trips (16.9%). Nonuse was observed more frequently (n = 50; 24.9%), and wrong use of the lap belt to secure the power wheelchair was observed in the majority of cases (n = 117; 58.2%).

Post-hoc Chi-square analysis was used to examine the relationship between WhMD type and occupant restraint usage. There was a significant relationship between WhMD type and misuse of occupant restraints (χ²(2) = 6.62, p = .036), indicating that compared to manual wheelchairs users, power wheelchair and scooter users were less likely to be observed using only the
Fig. 6. Tiedown usage for power wheelchairs.

∗Whether or not front and/or rear tiedowns were used was indeterminate in two cases. In the first case, 1 front tiedown was used, but it could not be determined whether or not a rear tiedown(s) was used. In the second case, it could not be determined whether front or rear tiedown(s) were used.

Fig. 7. Summary of occupant restraint usage by WhMD type.

lap belt as an occupant restraint. There was also a significant relationship between WhMD type and wrong use of the lap belt to secure the WhMD ($\chi^2(2) = 17.03, p > .001$). Compared to manual wheelchair users, significantly more power wheelchair and scooter users were observed traveling with the lap belt routed around the seatback as a means to secure the wheelchair.

Fig. 8. Occupant restraint system usage for scooters.

∗Wrong use consisted of routing the lap belt around the seatback.

Discussion

This study provides detailed information about observed WTORS usage in fixed route LATVs in a metropolitan setting. Despite the transit agency’s policy mandating “no securement, no ride” and bus operator training on the proper use of four-point tiedown straps, the majority of observations (92.5%; $n = 273$) indicate widespread nonuse and misuse of tiedowns within the transit agency’s service region. Although these findings are limited to a single transit agency, results of web-based surveys conducted by Easter Seals Project ACTION (2008) and Buning et al. (2007) report similar nonuse. Thirty-two percent (32%) of respondents to an Easter Seals Project ACTION survey stated their WhMD was either never secured, or secured less than half of the time they traveled on a public transit bus (Easter Seals Project Action, 2008). Buning et al. reported that 39%
of WhMD users never requested to have their WhMD secured during transit (Buning et al., 2007). When asked why they did not request their WhMD to be secured, the majority of WhMD users (82.2%) participating in Buning et al.’s survey stated one of three reasons: (1) the bus driver was unwilling (32.5%), (2) the equipment did not fit comfortably (25.4%), or (3) the bus operator did not know how to use the equipment properly (24.3%). These reasons, though based on individual perceptions of situations, support concerns regarding proper implementation of four-point tiedowns.

The current ADA Accessibility Guidelines for Transportation Vehicles (36 CFR Parts 1192) state that WhMD securement spaces shall be a minimum of 30 inches wide by a minimum of 48 inches in length to accommodate a “common wheelchair” of the same dimensions. However, recently published data indicates that 20% of occupied wheelchairs exceed 48 inches in length (Steinfeld, Maisel, Feathers, & D’Souza, 2010). The larger the dimensions of the occupied WhMD, the less space the bus operator has to maneuver in the securement station, resulting in the need to adopt ergonomically challenging postures when attempting to secure a WhMD, and thus increased potential risk of injury to the bus operator. Moreover, these challenges may decrease the likelihood of proper tiedown application.

The use of less than all four tiedowns to secure a wheelchair, and/or failure to properly restrain a wheelchair-seated passenger during transport may increase the risk of injury even under normal driving conditions. Despite modest improvements in WTORS over the past two decades, the incidence rate of injuries for wheelchair-seated passengers using fixed route transportation is estimated at 5.2 injuries per 100,000 miles traveled, compared to an incidence rate of 0.6 injuries per 100,000 miles for wheelchair-seated passengers who transfer to a vehicle seat (Songer, Fitzgerald, & Rotko, 2004). Songer et al. (2004) reported that wheelchair-seated passengers using public transit had higher injury rates as compared to wheelchair-seated passengers traveling in private vehicles (14% vs. 11%, respectively).

Bus operators also report their own functional limitations (e.g., knee, hip, back, and shoulder pain, or range-of-motion limitations), and concerns regarding potential injuries to extremities as reasons for not fully or properly securing WhMDs (Hardin, Foreman, & Callejas, 2002; Ahmed et al., 2012). Injuries sustained by bus operators include back strains, hand, arm and shoulder injuries, and lacerations and bruises (Hardin et al., 2002). In addition to ergonomic issues, violation of passenger personal space is another concern voiced by bus operators when attempting to implement WTORS (Foreman & Hardin, 2001).

We previously reported that 43.6% of WhMD passenger injuries that occurred while accessing or using public transit buses happened at the securement station (Frost & Bertocci, 2010). Unfortunately, no data has been published on the corresponding costs of WhMD passenger injuries incurred during travel in public transit vehicles. These costs may include, but are not...
limited to, medical expenses, equipment repair/replacement, personal assistant costs, lost workdays, and/or opportunity costs (e.g., time required to seek medical care, arrange for equipment repair/replacement, etc.). Future studies are needed to understand the financial impact of injuries related to misuse and nonuse of WTORS.

Nonuse of the four-point tiedown system was observed more frequently when the passenger was a scooter or power wheelchair user (80% and 78.1%, respectively) versus a manual wheelchair user (59.5%) and this difference was significant (p = .006). The observational nature of this study prohibited querying bus operators regarding tiedown practices. However, anecdotal evidence based on conversations with bus operators indicates a perception that turning off the power to scooters and power wheelchairs adequately prohibits movement during transit. Additionally, many power wheelchair and scooter frames are enclosed with plastic housings, making their frames inaccessible for securement, and this factor may also result in decreased securement. Participants in wheelchair transportation safety training programs we have conducted have repeatedly raised concerns and voiced frustration about the inability to access appropriate securement points on such WhMDs. Moreover, it is unknown whether or not bus operators perceive manual wheelchairs to be less stable during transit compared to powered WhMD.

In this study, wrong use of the lap belt to secure the WhMD by routing it around the WhMD seatback was the most frequently observed use of occupant restraints (52.5%). Many of these observations seem to indicate that wrong use of the lap belt was an established behavior between some operators and WhMD passengers. During such observations the WhMD passenger would park his/her WhMD, immediately lean his/her torso forward and away from the seatback; and the operator would route the lap belt between the passenger’s torso and seatback. Once informed of this finding, the transit agency took immediate action to correct this behavior among bus operators.

Another important finding regarding occupant restraint usage was the percentage of nonuse of either the lap or shoulder belt. Nonuse occurrence was observed during 26.8% of trips. Combined with instances of wrong use, a total of 79.3% of WhMD passengers observed in this study travelled without benefit of a lap or shoulder belt to provide occupant protection in the event of an emergency or crash situation. Buning et al. reported that 31.8% of WhMD passengers stated they never used occupant restraints, and 30.4% stated the occupant restraints did not fit comfortably (Buning et al., 2007). The authors projected that 62.2% of WhMD passengers who participated in their nationwide survey did not receive the protection that occupant restraints are designed to provide. The observational nature of this study did not permit follow up with WhMD passengers or bus operators regarding these findings. However, reports indicate that both WhMD passengers and bus operators are frustrated by dirty or twisted occupant restraints and tiedown straps, and may be unaware that wheelchair seatbelts (unless labeled as “transit safe”) are designed as aids to pelvic positioning and do not provide adequate protection in emergency or crash situations (Buning et al., 2007; Easter Seals Project Action, 2008).

Our findings are representative of one transit agency operating in a medium-sized metropolitan city and are not necessarily generalizable to other transit agencies. The DVRs containing video footage were provided by the transit agency on a random basis. The transit agency’s practices include random assignment of LATVs to routes on a daily basis; and the majority of bus operators are also randomly assigned routes for each work shift. Given these practices, we anticipated a random sample of video records depicting representative WhMD trips and made no effort to identify or filter videos for bus operators or WhMD passengers who may have been recorded more than once. As a result, it is possible that the data contain multiple trips of one or more WhMD passengers, and multiple trips involving one or more bus operators. Additionally, we were unable to determine if tiedowns were properly tensioned or attached to appropriate securement points on the WhMD, given the locations of the surveillance cameras and viewing angles. The observational nature of this study also prohibited us from querying bus operators to investigate underlying factors influencing misuse, wrong use, and nonuse of WTORS. These limitations must be taken into account when interpreting and using the findings of this study.

Conclusions

Our findings from one transit agency indicate that misuse and nonuse of WTORS is a prevalent practice among bus operators. These practices affect a substantial majority of WhMD passengers who travel on fixed-route public transit buses. Our objective, video surveillance-based assessment of wheelchair tiedown and occupant restraint usage patterns from 295 WhMD trips on fixed-route public transit vehicles supports previous survey reports of misuse and nonuse of WTORS in public transit vehicles. The use of all four tiedowns was observed during only 7.5% of WhMD trips, and complete use of the occupant restraints (lap and shoulder belt) was not observed during any trips. Scooters were found to be the least likely WhMD to be properly secured.

Four-point wheelchair tiedown and occupant restraint systems have been the most common means of securing WhMDs and restraining occupants in U.S. public transit vehicles for the past two decades. However, mounting evidence indicates these systems are not being properly utilized in the field. Our findings support the need for development and implementation of WTORS with improved usability and/or WTORS that can be operated independently by WhMD passengers and improved WTORS training for bus operators.

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