https://doi.org/ 10.14669/AM/155001

THE SAFETY OF WHEELCHAIR OCCUPANTS IN MOTOR VEHICLES

ZDZISŁAW HRYCIÓW[1]

Abstract

Ensuring the free movement of disabled people, including the use of vehicles, is a fundamental right. Therefore, efforts should be made to draw up standards regulating both organisational and technical aspects related to the construction and testing of wheelchairs. The main purpose of the paper is a review of the literature related to wheelchair transport safety and the current standards for wheelchair crash testing Wheelchair users must securely and safely attach their wheelchair to the vehicle when travelling. The most common methods include securing with a four-belt system or using docking systems. Docking systems allow the disabled person to restrain the wheelchair themselves. Their main limitation is the lack of standardisation. Issues related to in-vehicle wheelchair design and testing are mainly described in the international ISO standards and, in the US, in ANSI standards. Not all wheelchairs are crash tested. Before using wheelchairs, it should be checked if they can be mounted in a car. An important issue is education of wheelchair users and their carers on proper wheelchair securing. Even when wheelchairs are effectively secured, occupants in wheelchairs could be seriously and fatally injured because of improperly used and positioned belt restraints.

Keywords: occupants safety; wheelchair securement systems; impact testing

1. Introduction

In developed societies, increasing attention is being paid to meeting the needs of a wide range of citizens with a variety of needs, including persons with different disabilities. They have the right to have good conditions in the workplace, to live independently, to have equal opportunities, to participate fully in the life of their community. All have a right to a life without barriers [4].

The EU legislator has defined the terms "disabled person" and "person with reduced mobility" in various regulations. These are persons whose mobility when using transport is reduced due to any physical, sensory or motor disability, permanent or temporary, intellectual disability or impairment, or any other cause of disability or age [1]. The European Disability Strategy 2010–2025 paved the way to a barrier-free Europe, fostering actions supported also by EU

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https://doi.org/ 10.14669/AM/155001

funds to make a difference for the life of approximately 87 million persons having some form of disability in the EU. Statistics [6] show that 24.7% of EU population over 16 years of age are limited in their activities, 17.7% having moderate, 7% severe limitations. For people over 65, the rate is as high as 48.9%.

Among the people with reduced mobility, wheelchair users are those who have more problems accessing road vehicles. They can do in two ways: transferring from wheelchair to a vehicle seat or travelling seated in their own wheelchair [16]. A best-practice travel recommendation for individuals who use wheelchairs and travel in passenger vehicles is to transfer to original seats and make use of vehicle's occupants protection systems [3, 10, 12]. Persons for whom transfer from a wheelchair is impractical may use adapted vehicles, which are configured to allow the use of a wheelchair as a seat on the vehicle. However, they should be aware that a wheelchair secured in a vehicle does not offer the same level of safety as the bolted-in seating system of a vehicle. Many wheeled mobility devices are not designed with safety features that are implemented to protect occupants in original motor vehicle seat [2].

People with disabilities can often drive safely by making modifications or adding adaptive equipment to their vehicles to meet their specific needs. As the technology has gotten better and has increased in availability, the number of people using adapted vehicles has also increased. At the same time, the variety of solutions available on the market may make it difficult for potential customers to choose the right solution. In order to help people with disabilities to get advice on the appropriate choice of adaptive devices, a number of centres, organisations and support programmes have been set up in developed countries. They support people with disabilities by offering tips on modifying or purchasing a vehicle to accommodate their driving needs. For example, in the United States there is the National Mobility Equipment Dealers Association, and in Europe the best developed include The Motability Scheme or BraunAbility. In Poland, the Automotive Service Centre for the Disabled Persons was established at the Motor Transport Institute in 2015 [17], and in 2021 the Information and Consultation Point has been created at Military University of Technology.

In Europe and the US, wheelchairs are considered a medical device regulated by European Medicines Agency (EMA) or the Food and Drug Administration (FDA) in order to meet specific usage standards. Many of the wheelchairs designed for low-resource settings have not gone through the FDA/EMA regulatory process due to the high cost and long timeline, and, it is not required for distribution in the markets in which they are operating.

This paper reviews the literature related to wheelchair transport safety, focusing on wheelchair securement systems in motor vehicles and a review of current standards for wheelchair crash testing.

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2. Wheelchair Securement Systems

Wheelchair users must securely and safely attach their wheelchair to the vehicle when travelling. If the user is seated in the wheelchair it must be located in a forward facing position in the direction of travel. Side facing seating orientation is not permitted. The most common method of securing the wheelchair to the vehicle is a four-point, strap-type wheelchair tiedown and occupant restraint systems (WTORS). WTORS consist of two tiedowns securing the front of the wheelchair, two tiedowns securing the rear of the wheelchair, and include both a lap and shoulder belt for occupant restraint [5] (Figure 1). Front and rear tie-downs must be fitted to provide a stable seat for the wheelchair occupant. The lap belt must be routed under arm supports and side guards to achieve close contact with the pelvis of the wheelchair seated passenger. The shoulder belt should lay across the sternum and over the mid-shoulder to effectively restrain the upper torso of the occupant. This system allows to secure a wide range of wheelchair types.

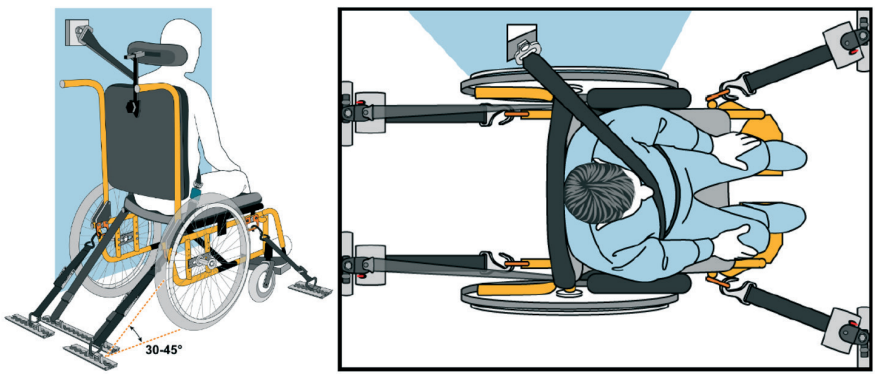

Fig. 1. Wheelchair Tie-down and Occupant Restraint System [18]

However, this system usually requires a third party to assist with the application of the seatbelt and its routing around wheelchair features. Often this means that a person the wheelchair user is unfamiliar with must enter personal space and physically contact them to apply the seatbelt. This can be uncomfortable for wheelchair users [12].

These disadvantages are not present in wheelchair docking systems. The wheelchair docking system is commonly used in Drive from Wheelchair Cars (DWC) but is also very popular for passengers travelling in their wheelchairs as it allows the user to be secured into the car safely and swiftly. Very often, the system can release the wheelchair by pushing an electrical release button. Usually, it consists of a bracket mounted in the floor of the vehicle and a docking pin attached to the wheelchair [22]. The pin is guided into the "V" shaped structure at the opening of the docking base. Once in position, just pull a little forward and the wheelchair engages the docking system. Systems offer secure fixing through its mechanical or electronic docking mechanism and also include a mechanical emergency release device. Examples of this type of docking system are shown in Figure 2 and Figure 3.

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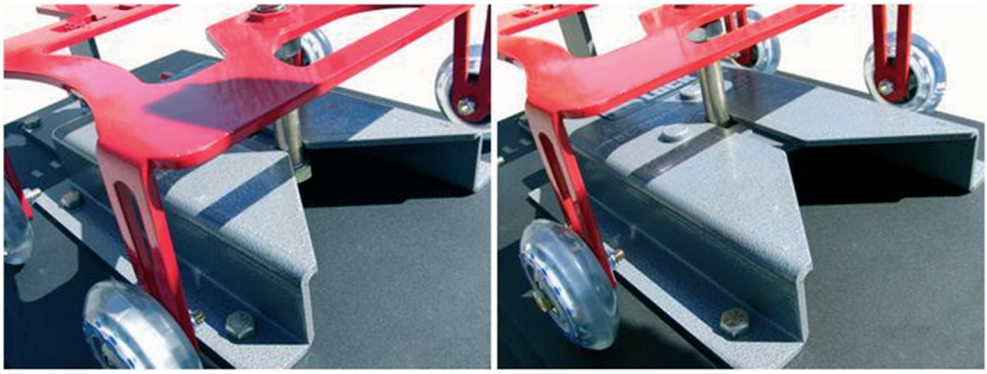

Fig. 2. The EZ Lock Wheelchair Docking System [7]

Despite the undoubted advantages of wheelchair docking systems, their main problem and limitation is the lack of standardisation. The mounting system in the vehicle must correspond to that used in the wheelchair. For this reason, docking systems are in general limited to individual use. When purchasing a wheelchair, an important factor to consider is if it is compatible to be used inside a vehicle.

Fig. 3. Dahl Docking Station [9]

It is important to educate wheelchair users and their carers on proper wheelchair securing as well as Proper Lap-Belt Positioning. Even when wheelchairs are effectively secured, occupants in wheelchairs are being seriously and fatally injured because of improperly used and positioned belt restraints. The paper [23] reports the results of research on the correctness of fixing the wheelchair. It showed that 90% of users used four-point tie-down systems to secure the wheelchairs. A total of 88% of drivers tied the wheelchairs down correctly; only 20% used a separate lap–shoulder belts to secure the occupants. Twenty-five percent used lap trays, which are not recommended. Fifteen participants travelled with medical equipment secured inappropriately. Many deviations from best practice were observed and they highlighted areas for increased awareness, education, and resources for caregivers. The author [19] points out that the lack of use of wheelchair securement systems or their incor-

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rect using has been attributed to the fact that many wheelchairs are difficult to secure. 50 percent wheelchair users reported that they have difficulty securing their wheelchairs. Lack of securement use also can be attributed to a lack of bus driver training in the proper use of wheelchair securement systems and a lack of compatible wheelchair securement hardware and wheelchair securement systems [21].

3. Wheelchairs impact testing

Issues related to in-vehicle wheelchair design and testing are described in international ISO standards and, in the US, in ANSI standards. Wheelchair testing standards are intended to reduce the risk faced by people who remain seated in their wheelchairs while in motor vehicles. One of the main methods of testing wheelchairs is impact testing.

Various standards of impact tests have been developed, and the basic ones include:

- ISO 10542-1 Technical systems and aids for disabled or handicapped persons –Wheelchair tie-down and occupant-restraint systems. Part 1: Requirements and test methods for all systems. This part specifies design and performance requirements and associated test methods for WTORS, as well as requirements for product marking and labelling and manufacturers' instructions and warnings to installers and consumers.

- ISO/DIS 16840-3 Wheelchair seating — Part 3: Determination of static, impact and repetitive load strengths for postural support devices. This document specifies requirements for repetitive, static, impact, and repetitive load strengths for postural support devices with associated attachment hardware intended for use with an undefined wheelchair seating system. It specifies the test methods for determining whether the minimum performance requirements have been met to release a product into use. It also specifies requirements for disclosure of the test results.

- ISO 7176-19 Wheelchairs – Part 19: Wheelchairs for use as seats in motor vehicle. This document specifies test methods, requirements and recommendations for wheelchairs intended for use as seats in motor vehicles related to design, performance, labelling, user instructions and user warnings.

- ANSI/RESNA WC-4 Wheelchairs Volume 4: Wheelchairs and Transportation. The standard includes the following sections:
  - Section 18: Wheelchair tiedowns and occupant restraint systems for use in motor vehicles.
  - Section 19: Wheelchairs used as seats in motor vehicles.
  - Section 20: Wheelchair seating systems for use in motor vehicles.

These section are often referred to as "WC18", "WC19" and "WC20".

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The WC18 test methods and performance criteria are very similar to those of ISO 10542-1, however, an additional test of tiedown/securement systems in WC18 requires the Anthropomorphic Test Devices (ATD) to be restrained by a pelvic belt anchored to the surrogate wheelchair, thereby increasing the frontal-impact loads on the rear tiedown straps of four-point, strap-type tiedown, or on other types of securement devices. Surrogate wheelchair means rigid, reusable device and that is used to simulate a wheelchair for the purpose of testing wheelchair tie-down and occupant-restraint systems (Figure 4a). Tests are conducted using an 85 kg surrogate wheelchair to dynamically load the wheelchair tiedown/securement system in a 48 km/h, 20-g frontal-impact test.

WC 19 establishes design and performance requirements, and associated test methods, for wheelchairs related to their use as seats in motor vehicles (Figure 4b). This standard employs basic principles of occupant protection and accepted procedures for dynamic testing. It is very similar to ISO 7176-19. A wheelchair that complies with RESNA WC19 meets all of the key requirements of ISO 7176-19 but the reverse is not true.

WC 20 provides for the independent testing of wheelchair seating systems (seats and back support with attachment hardware) on a surrogate wheelchair base.

The above standards define similar test methods. A test wheelchair is mounted in a forward-facing configuration on the impact sled of an impact simulator and is loaded with an anthropomorphic test device (ATD). The WTORS is installed to secure the test wheelchair and restrain the ATD (Figure 4). The sled platform is subjected to a defined acceleration/deceleration-time pulse in order to achieve a defined velocity change. Observations and measurements are made to determine whether the strength and performance of the WTORS are satisfactory under the test conditions. As in other types of crash tests, forces and accelerations are recorded at selected points and high-speed cameras are used [11, 13, 14].

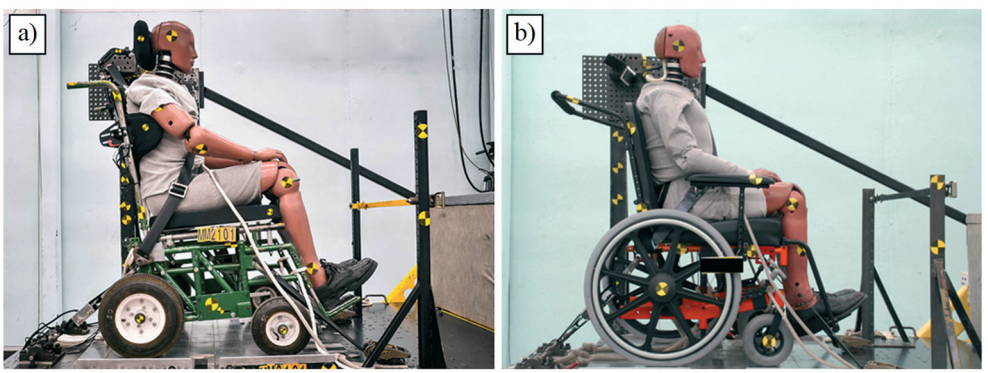

Fig. 4. Example of tiedown/securement system testing; (a) surrogate wheelchair [15], (b) wheelchair frontal-impact testing [8]

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At Figure 5 typical 30-mph (48 km/h) sled deceleration pulse compared to corridor required by SAE, ANSI/RESNA, and ISO standards (grey area) is presented. The pulse must exceed 20 g for a continuous 15 ms and 15 g for a cumulative 40 ms.

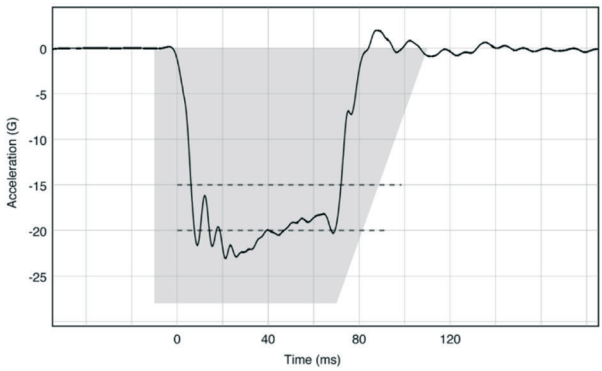

Fig. 5. Typical 30-mph sled deceleration pulse [20]

It should be stressed that not all wheelchairs are crash tested. Before using wheelchairs, it should be checked if they can be mounted in a car. If a manufacturer refers to a wheelchair as "Crash Tested" it means that the wheelchair is safe to be pushed inside a suitable vehicle and secured during travel. The crash tested wheelchair will have anchor points, allowing the wheelchair to be secured into place with the occupant seated within the wheelchair. The anchor points on the wheelchair are used by attaching straps to the anchor points on the wheelchair. These straps are then tightened to ensure the wheelchair will not move in the event of an accident and therefore protecting the wheelchair user from harm when travelling. Wheelchairs that have been manufactured and adequately tested for safe use in a suitable vehicle are clearly marked on the wheelchair with anchor symbols featured on the frame of the wheelchair. The icon is usually located on the front frame of the wheelchair.

4. Conclusions

Presented in article literature review provides background information on wheelchair transportation safety. Among the people with reduced mobility, wheelchair users are those who have more problems accessing motor vehicles. They can do in two ways: transferring from wheelchair to a vehicle seat or travelling seated in their own wheelchair. Wheelchair users must securely and safely attach their wheelchair to the vehicle when travelling. If the user is seated in the wheelchair it must be located in a forward facing position in the direction of travel. Side facing seating orientation is not permitted.

The most common method of securing the wheelchair to the vehicle is a four-point, strap-type wheelchair tiedown and occupant restraint systems. The wheelchair docking system

is commonly used in Drive from Wheelchair Cars. Their main limitation is the lack of standardisation. The mounting system in the vehicle must correspond to that used in the wheelchair.

The ANSI/RESNA test methods and performance criteria are very similar to those of ISO. However, there are some differences between them.

Not all wheelchairs are crash tested. Before using wheelchairs, it should be checked if they can be mounted in a car. The crash tested wheelchair will have anchor points, allowing the wheelchair to be secured into place with the occupant seated within the wheelchair.

An important factor is education of wheelchair users and their carers on proper wheelchair securing Wheelchair users can suffer serious and fatal injuries due to improperly used and adjusted seat belts.

In a further stage of the work, a numerical experiment is planned to evaluate an influence of restraints system on wheelchair occupant safety.

5. Acknowledgement

The article was prepared as part of the project no. POWR.03.05.00-00-CW07/20-00 entitled: "Knowledge Centre on Accessibility to Transport and Mobility of People with Special Needs" co-financed by the European Social Fund under the Operational Program Knowledge Education Development 2014-2020.

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