Guidelines for Use of Secondary Postural Support Devices by Wheelchair Users During Travel in Motor Vehicles

RERC on Wheelchair Transportation Safety

Many individuals who use wheelchairs for mobility require the use of postural support or control devices to enhance their ability to function. The addition of secondary postural support devices (PSDs) to wheelchairs improves the individual's comfort and motor control during activities of daily living. These PSDs may include pelvic positioning belts, headrests, anterior chest supports and lateral thoracic supports, as well as less frequently prescribed PSDs such as lateral upper leg supports, medial upper leg supports, anterior head restraints and subASIS bars. [1]

Because PSDs contact and provide support for different regions of the body, questions are often raised about the potential benefit or harm from their use while remaining seated in a wheelchair during travel in a motor vehicle. This is of particular concern in the event of a motor vehicle crash or emergency maneuver. The benefits or harm are generally unknown as current crash-test dummies are not designed or instrumented to assess for the potential hazards or benefits of PSDs, and there are little to no real-world injury data on PSDs in the motor-vehicle environment. Despite these limitations, guidelines and best practices can be developed for use of PSDs during travel in a motor vehicle using basic principles of occupant protection and knowledge about the biomechanics of injuries.

This document presents guidelines and recommendations for using PSDs on wheelchairs used as a seat in a motor vehicle. It is written primarily for clinicians, prescribers and individuals who use wheelchairs.

This document is organized into two main sections:

- **Section 1:** review of basic principles for safe transportation of wheelchair-seated occupants and resources for additional information, and
- **Section 2:** guidelines and recommendations for using specific PSDs during transportation.

The information in this document should not be used as justification to prohibit wheelchair users from having access to vehicle transportation.

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Section 1: Basic principles of transportation safety

This section summarizes the basic principles of transportation safety and occupant protection that a wheelchair-seated occupant should follow. It also provides references for additional information on this topic and voluntary industry standards that apply to wheelchair transportation safety products.

1.1 Wheelchair users should transfer to the vehicle seat and use the vehicle seatbelt system or a child safety seat when they can both transfer and ride safely.

It is generally recommended that wheelchair users transfer from their wheelchair to the vehicle seat when feasible. This is especially advisable if the vehicle seat allows the individual to use a belt restraint system that complies with federal motor vehicle safety standards, and if the wheelchair user does not have a wheelchair that complies with ANSI/RESNA WC19 [2] (see 1.3 below).

In determining if transfer is feasible, it is important to consider the difficulty and risks involved in making the transfer. It is also important to consider the particular seating and postural support needs of the wheelchair user, as well as other medical and behavioral issues, that may be compromised if the wheelchair user transfers to the vehicle seat. These issues may increase health risks beyond those of occupant crash protection.

1.2 When there is an option, travel in a larger vehicle.

It is a well-established fact of transportation safety that riding in larger vehicles is safer than riding in smaller vehicles, all other things being equal. This is primarily because, due to their larger size and weight, large vehicles are less likely to be involved in higher severity crashes than small vehicles.

For people who cannot feasibly transfer from their wheelchair to the vehicle seat, it is preferable to travel in larger vehicles when there is an option to do so. This is especially true for those seated in heavy wheelchairs or other mobility devices that do not comply with WC19. For example, children in wheelchairs who are being transported to and from school would be much safer traveling in large school buses than in small school buses or van-sized vehicles.

1.3 Use a wheelchair that complies with ANSI/RESNA WC19.

If a wheelchair user does not transfer to the vehicle seat, a comparable level of safety can be achieved by traveling in a properly secured wheelchair that complies with ANSI/RESNA WC19 [2].

An increasing number of WC19 wheelchairs are available for purchase. A list of currently available WC19 wheelchairs can be found at: http://www.rercwts.org/WC19.html

WC19 wheelchairs have four crash-tested securement points for attachment of wheelchair tiedown straps or hooks. The securement points are clearly labeled, easily accessible, and enable attachment of tiedown hooks using a one-hand maneuver. These designated securement points greatly increase the ease and reliability of effectively securing wheelchairs occupied by passengers in motor vehicles.

WC19 wheelchairs provide improved seat and back support in a crash, increasing the likelihood that the vehicle-anchored belt restraints remain correctly positioned over skeletal parts of the body to reduce injury risk and allow for optimal performance.

WC19 wheelchairs are rated for their ease of optimally positioning vehicle-anchored belt restraints on the wheelchair occupant. It is best to choose a wheelchair with an “A” rating, though a “B” rating is acceptable.

WC19 wheelchairs feature crash-tested anchor points on the wheelchair frame, which can be used to attach crash-tested pelvic belts that are available from the wheelchair manufacturer. Since this requirement was phased in two years after the standard was published, not all crash-tested wheelchairs have this feature. Using a wheelchair-anchored pelvic belt generally improves belt fit and performance, as well as reduces interference with personal space by a driver or attendant.

1.4 Orient wheelchair-seated travelers facing toward the front of the vehicle.

Frontal crashes account for more than half of all disabling injuries and fatalities and are, therefore, the first priority in occupant crash protection.

It is very difficult to provide effective belt restraint in frontal collisions for occupants who are facing sideways in the vehicle.

During a frontal impact, a side-facing occupant will twist as they move toward the front of the vehicle, thereby increasing injury risk.

1.5 Properly secure the wheelchair to the vehicle using a crash-tested tiedown system or a docking system that complies with SAE J2249, Wheelchair Tiedowns and Occupant Restraint Systems for Use in Motor Vehicles [3] or ISO 10542-3, Docking Type Tiedown Systems [4].

It is critical to effectively secure the wheelchair to the vehicle. This limits the movement of the wheelchair, allowing vehicle-anchored occupant restraints to remain properly positioned. It also prevents the wheelchair from adding additional weight and forces to the occupant during driving maneuvers or an accident.

Wheelchair securement is currently most effectively accomplished using a WC19 wheelchair and a four-point, strap-type tiedown. Other methods of wheelchair securement, such as docking-type securement, are necessary for wheelchair-seated drivers. The wheelchair model being used needs to be crash tested with the docking system to ensure crash protection.

1.6 Use a correctly positioned and crash-tested occupant restraint system with both upper (shoulder) and lower-torso (pelvic) belts.

Most serious and fatal injuries are caused by the “human collision”, which is contact of the occupant with the vehicle interior, with other occupants, or with objects outside of the vehicle.

A crash-tested 3-point (pelvic and shoulder) restraint or a 5-point child-restraint harness is needed to limit occupant movement during a crash, and thereby minimize or prevent the human collision.

Improperly positioned occupant restraint belts pose an injury risk in severe crashes. Proper positioning of the pelvic portion of the occupant restraints is low on the pelvis near the upper thighs. The pelvic belt should not be placed over the soft tissue of the abdomen.

The shoulder portion of the restraint should cross the middle of the region between the neck and shoulder, cross the center of the chest, and then connect to the pelvic belt near the hip of the occupant. It should remain in good contact with the shoulder and chest during travel.

Design and performance requirements for occupant restraints for wheelchair-seated riders are specified in SAE J2249 [3] and ANSI/RESNA WC19.

Most PSDs are not crash-tested occupant restraints and, therefore, may not provide adequate crash protection when used alone. They should be used in conjunction with crash-tested occupant restraints.

1.7 It is best to ride with the wheelchair backrest positioned at an angle of 30 degrees or less from the vertical.

For upper-torso belt restraints to be most effective in a frontal crash, it is best if the seat-to-back angle of the torso is relatively upright and the vehicle-mounted upper-anchor point is located behind the shoulder. This allows the belt to have good contact with the chest and shoulder prior to the collision, and for the shoulder to take most of the load as the torso rotates forward.

Reclining the backrest of a wheelchair seating system more than 30 degrees increases the potential for the wheelchair-seated occupant to slide under the pelvic belt and sustain abdominal injuries during an accident.

For those individuals for whom the seatback angle must be reclined more than 30 degrees, moving the upper shoulder belt anchor point rearward in the vehicle will help maintain contact of the shoulder belt with the torso and shoulder and will help improve restraint system performance.

Use of both upper- and lower-torso belts is strongly recommended, even when the backrest must be reclined beyond 30 degrees.

1.8 Firmly attach or tether PSDs and other rigid components, parts, equipment or accessories weighing more than 100g (about 3.5 oz) to the wheelchair or seating system so they won’t break free during a crash and injure vehicle occupants.

1.9 Parts that are likely to come in contact and injure the occupant during vehicle movement or to cut or damage occupant restraint webbing should be covered with high-density padding.

1.10 During travel in a motor vehicle, continue to use the PSDs needed to maintain clear airways and meet other critical positioning and medical needs.

Never compromise breathing or health needs for purposes of travel in a motor vehicle. No wheelchair user can be safe in a motor vehicle if breathing or health becomes impaired or compromised due to inadequate postural support.

The proper and appropriate use of PSDs may be critical to respiratory and other basic functions for some wheelchair users, and should continue to be used during travel in a motor vehicle.

1.11 Use PSDs needed to achieve and maintain proper positioning of the wheelchair user to enable effective use of occupant restraint systems.

PSDs are used to position individuals to maximize function and mobility. The postural control PSDs provide may help limit forward and lateral motion and, in general, enhance the fit of the occupant restraint system.

PSDs and their attachment hardware should not interfere with the proper positioning of occupant restraints.

For additional information on these topics, please see the information provided at the following URLs:

- *Ride Safe at:*

  www.travelsafer.org

  Basic how-to information to help you travel more safely in motor vehicles while seated in your wheelchair

- *WC19 - Your ticket to Ride at:*

  www.rercwts.org/WC19.html

  Information on the voluntary standard, ANSI/RESNA WC19 - Wheelchairs Used as Seats in Motor Vehicles, along with a list of commercial products that comply with the standard

- *Rehabilitation Engineering Research Center (RERC) on Wheelchair Transportation Safety at:*

  www.rercwts.org

  Extensive information on all aspects of wheelchair transportation safety

- *Wheelchair Transportation Frequently Asked Questions (FAQs) at:*

  http://www.rercwts.org/RERC_WTS2_FAQ/RERC_WTS_FAQ.html

Section 2: Recommendations for postural support devices

This section provides specific recommendations regarding the use of different types of postural support devices (PSDs) during transportation, and describes the rationale for these guidelines. PSDs have the potential to provide benefit and to injure the wheelchair-seated passenger, depending upon their design and interaction with the passenger during travel or an accident.

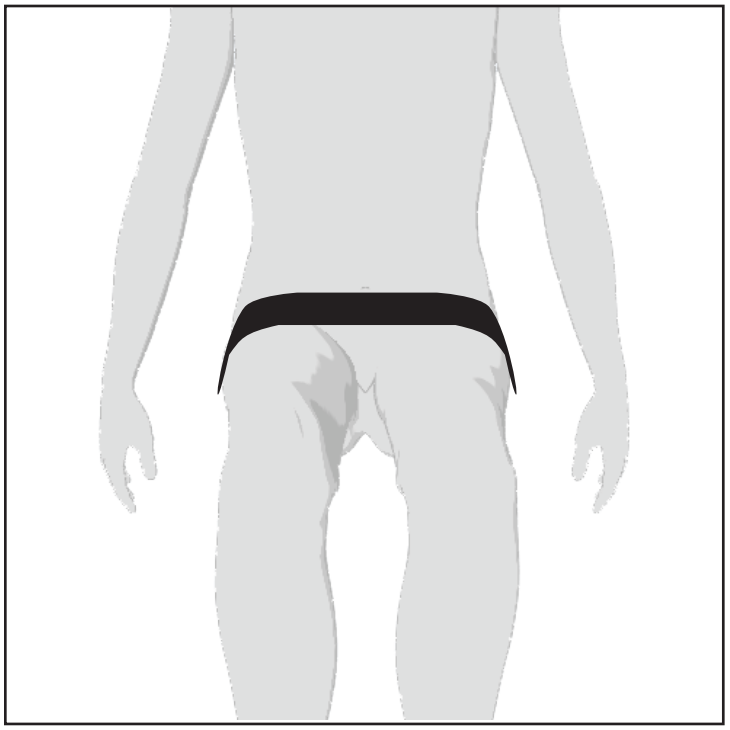
In general, the concerns about PSDs causing injuries to the wheelchair user or other occupants stem from three issues:

1. The PSD may press and injure a vulnerable body part of the wheelchair occupant,
2. The PSD may break loose from the wheelchair and injure other occupants in the vehicle, and
3. The PSD may interfere with proper positioning of belt restraints that are designed to restrain and protect the occupant in a crash.

When considering the potential benefits and concerns of PSDs, the importance of the PSD to the general health and well being of the wheelchair user must be the overriding concern. For example, some PSDs may be needed to maintain clear airways and meet other critical positioning and medical needs. In these cases, use of the PSD is essential during travel in motor vehicles. A second factor to consider when making decisions about using PSDs during travel is that effective occupant restraint and crash protection is often dependent on the occupant being in a relatively upright-seated position. Thus, to the extent that PSDs help maintain an upright, seated posture, they will generally enhance the fit and effectiveness of occupant restraint systems. When PSDs are used, it may be possible to modify the PSD to reduce injury concerns while maintaining its beneficial function for the user.

2.1 Pelvic positioning belts

Description: Pelvic positioning belts are webbed straps that provide anterior pelvic support and improve pelvic position. [6, 7]



Issues related to use during motor vehicle travel:
The primary safety concern for the pelvic positioning belt is that individuals often assume that it can be used in place of a crash-tested occupant restraint when traveling in a motor vehicle. Postural belts are not designed for crash safety and often do not stay fastened or attached during crash tests. They should not be relied upon to protect an occupant or to provide adequate occupant restraint during a motor vehicle accident. Proper positioning of pelvic positioning belts, low on the pelvis, is critical in preventing abdominal injury in a crash. If the positioning belt is placed over the soft tissue of the abdomen, during an accident it could potentially press into the rider and cause injury.

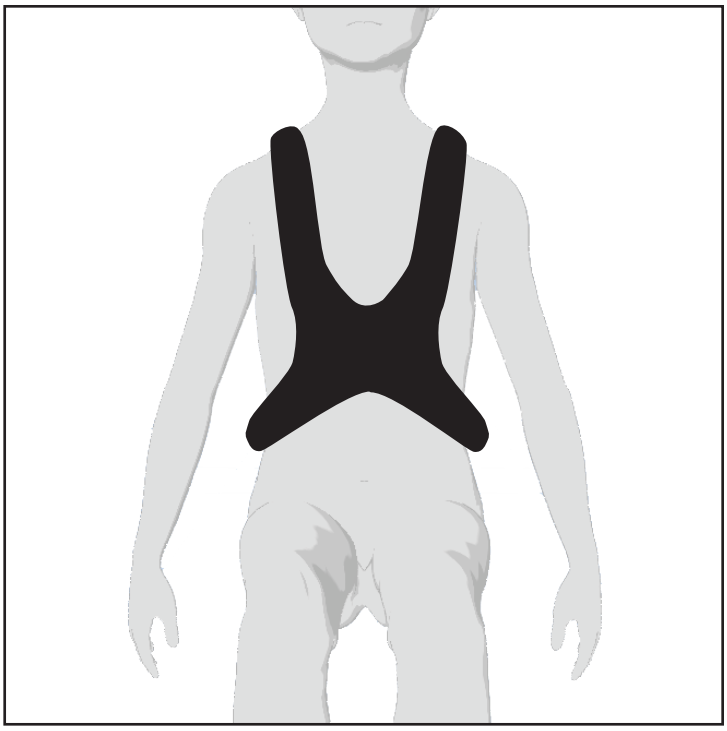
Wheelchairs that comply with ANSI/RESNA WC19 [2] offer the option of a crash-tested pelvic belt that is anchored to the wheelchair frame. This crash-tested pelvic belt can be used both as a pelvic restraint in a motor vehicle and, depending on the individual's postural needs, may also serve as a pelvic positioning belt. Attaching the lower end of a vehicle-anchored shoulder belt to the pelvic belt must be done to complete the 3-point occupant restraint system. Crash-tested wheelchair-anchored pelvic belts will be labeled to indicate that they comply with WC19.

Recommendations for Pelvic positioning belts:

- Place pelvic positioning belt low on the pelvis and at an angle of 45 degrees or greater to the horizontal, to most effectively maintain a seated posture and prevent the wheelchair user from sliding forward.
- Postural belts should not be relied upon to provide effective restraint in a motor vehicle accident. A crash-tested lap and shoulder restraint or child restraint harness should be used.

2.2 Anterior trunk supports (chest harnesses)

Description: Anterior trunk supports typically have a soft component that crosses the trunk or chest and attaches to the wheelchair in four places with straps made of webbing. These are also commonly referred to as chest harnesses or H-straps.[6] They are commonly used to promote trunk extension and/or limit forward trunk movement.[7]



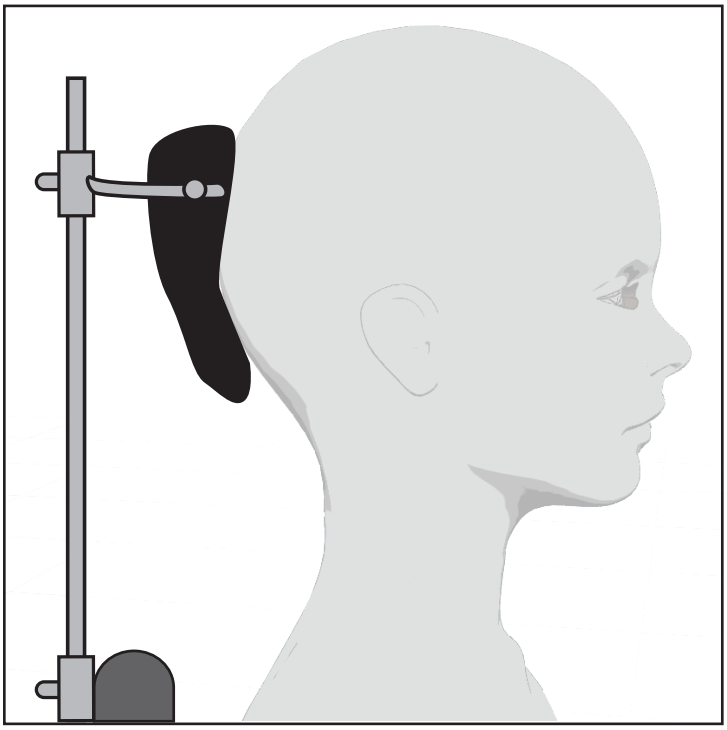
Issues related to use during motor vehicle travel:
Anterior trunk supports control trunk position and help maintain an upright rider position, enhancing the fit and performance of the vehicle shoulder belt. In addition, some wheelchair users who do not typically use trunk supports may find that use during motor vehicle travel affords them increased riding comfort and stability during vehicle operation. Concern for injury occurs if the wheelchair user slides downward in the seat during travel or a motor vehicle incident, allowing the anterior trunk support to press on the neck.

Recommendations for Anterior trunk supports:

- Anterior trunk supports should be used as needed to provide postural support during travel in a motor vehicle.
- Ensure the pelvis is held securely and other postural supports are in place to minimize the likelihood of the user's pelvis sliding forward. This reduces the likelihood of the wheelchair user sliding downward in the wheelchair, allowing the anterior support to press on the neck, potentially causing injury or asphyxiation.

2.3 Headrests

Description: Headrests are postural support devices intended to contact the posterior surface of the head.[6] They are commonly used to improve position of the head. Some individuals use a headrest only part of the time, such as to support the head when seating is tilted or to diminish fatigue during transportation in a motor vehicle. [7]



Issues related to use during motor vehicle travel:
Reduced rearward head and neck movement can reduce whiplash injuries in a rear impact. Headrests can help limit this rearward head/neck movement and thus reduce whiplash injuries. [8, 11, 12] Wheelchair headrests are not designed to provide head restraint in a rear impact and, therefore, may not provide total head and neck protection. However, based on the principles of occupant protection and knowledge about the biomechanics of injuries, the chances for a whiplash injury will be decreased when a headrest is used and positioned behind and close to the back of the head.

Some wheelchair users who do not typically need a headrest may find that a headrest helps stabilize the head and neck during vehicle acceleration and turning. Rarely, head support is provided solely at the base of the skull. When this type of device is used alone, there is an increased risk of neck hyperextension injuries caused by limiting the rearward motion of the upper neck but not the head.

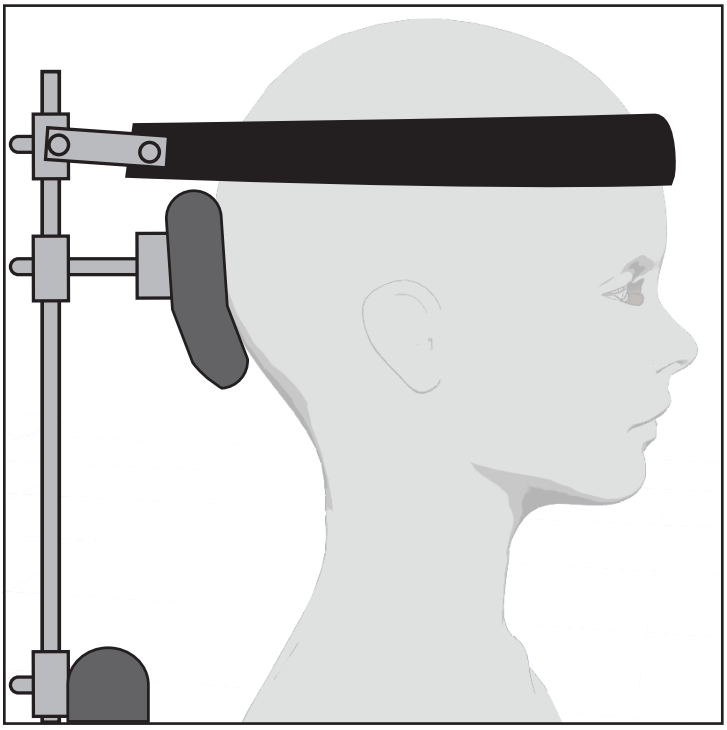
A concern regarding the use of a wheelchair headrest is that it can break free in a crash and injure other vehicle occupants. Precautions can be made to firmly attach or tether the headrest to the wheelchair so that it will not break free in a crash.

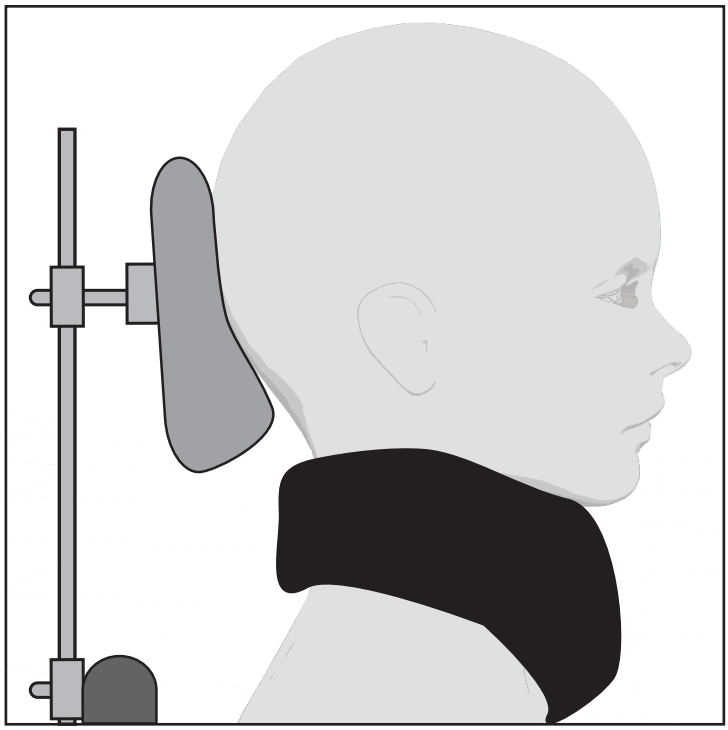
Recommendations for Headrests:

- A properly positioned wheelchair headrest can help protect the head and neck during travel in a motor vehicle.
- Headrests should be placed as close to the back of the head as possible and no more than 2 in. (50 mm) from the rear of the head, and at a height such that the middle of the headrest aligns with the top of the ears.
- Firmly attach or tether the headrest so that it will not break free in a crash.
- Headrest selection should consider the wheelchair-seated rider's additional support and postural needs during typical driving conditions. It is important that the rider's head be positioned and supported to prevent the head from going under or around the headrest pad while the vehicle is in motion.

2.4 Anterior head supports and neck supports

Description: Wheelchair users with very limited head control may require anterior head support or neck support to maintain their head in an upright position. Some users risk asphyxiation if their head falls forward causing their airway to be blocked. Other users require support to enable their faces to be observed for indication of a seizure or other serious medical event. These individuals are often provided either a neck support (i.e., neck collar) that surrounds the neck and supports the head under the chin or a forehead strap attached to the wheelchair that limits forward head rotation.





Issues related to use during motor vehicle travel:
While it is possible that anterior head supports and neck supports could contribute to neck injury in a frontal crash, their postural benefit for the user may outweigh the potential injury risk in an unlikely crash event. However, precautions can be taken to reduce the likelihood of serious injury.

When anterior head support is necessary, soft collars that are not attached to the wheelchair are preferred over stiff collars or forehead strap systems that are anchored to the wheelchair. Some preliminary data on neck collars tested with child restraint systems show an increase in anthropomorphic test device (ATD or crash-test dummy) neck tension with stiff collars. The increased neck tension resulted from the bottom of the chin pivoting on the top of a stiff neck collar and stretching the neck during a frontal crash. Since stiffer collars produced higher neck tensions, it is recommended to use the softest and lightest collar that can perform the needed medical function.

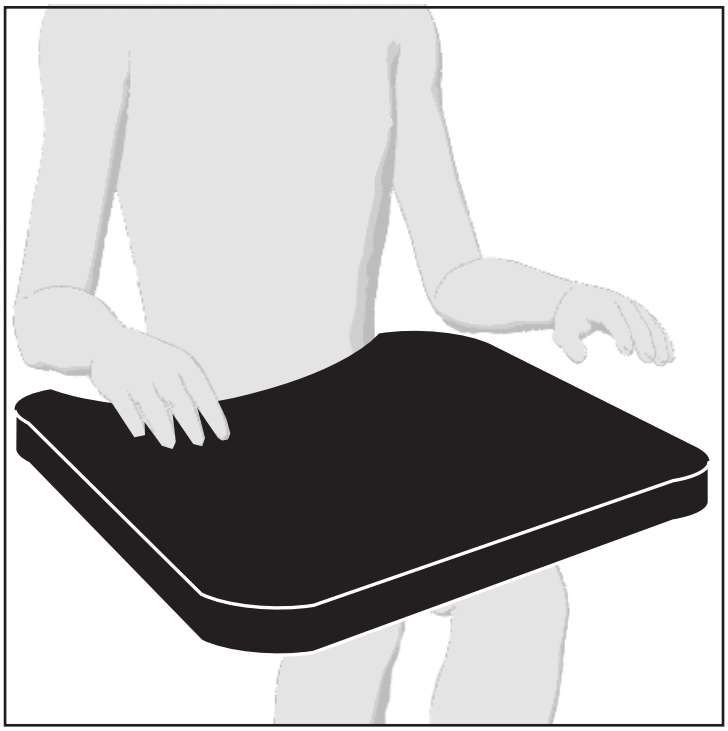
Forehead straps could cause neck hyperextension in a frontal crash. Preventing the head from forward movement while at the same time allowing forward movement of the torso due to belt stretching or loose torso belts or supports may result in neck extension injuries. If these devices are necessary during vehicle travel, they should release at the lowest force possible while still providing effective postural support. Another potential concern with forehead straps is that they will become misplaced and slide down and across the occupant's neck, causing severe injury.

Recommendations for Anterior head supports and neck supports:

- For those individuals that must use a neck collar for head support to maintain open airways and/or safe positioning, use the softest collar possible.
- It is preferable not to use a forehead strap attached to the wheelchair during travel in a motor vehicle. If these devices are necessary during vehicle travel, they should release at the lowest load that is consistent with effective postural support performance.

2.5 Lap Trays

Description: Lap trays are an upper extremity support surface and are used to help in torso, head and neck positioning.[7]



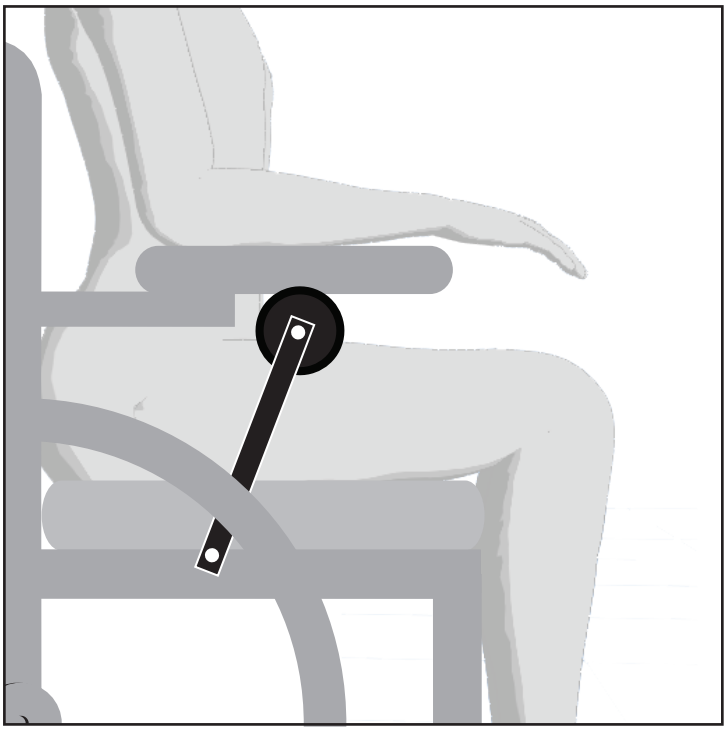
Issues related to use during motor vehicle travel:
Hard trays may cause injury to the abdomen if the wheelchair user contacts the tray in a frontal crash. When possible, hard trays should be removed and secured separately in the vehicle. A dense foam tray or arm troughs can be used in place of a rigid tray during vehicle travel. When it is not possible to remove the hard tray, dense padding should be placed between the wheelchair user and the tray. A second concern with lap trays is that they may cause injury to other passengers if they break free from the wheelchair. Trays should be securely attached to the wheelchair to prevent them from breaking loose in a crash.

Recommendations for Lap trays:

- Use of hard trays during travel in a motor vehicle is strongly discouraged.
- Hard trays should be removed and secured separately.
- If upper extremity support is necessary, options include arm troughs or lightweight, nonflammable dense foam trays.

2.6 SubASIS bars

Description: A subASIS bar is a rigid pelvic stabilization device used to maintain a neutral position of the pelvis and prevent pelvic rotation. [7, 13]



Issues related to use during motor vehicle travel:
SubASIS bars are rigid devices that cross or contact the pelvis and, therefore, may interfere with proper placement of the crash-tested pelvic belt. In addition, the device design and attachment to the wheelchair frequently do not permit easy evacuation from the wheelchair in a vehicle emergency. When feasible, a subASIS bar should be replaced with alternative pelvic stabilization devices during vehicle travel, such as a pelvic positioning belt that anchors in four locations to the wheelchair (two rearward and two downward).

Recommendations for SubASIS bars:

- It is preferable not to use subASIS bars during travel in a motor vehicle.
- Consider the following alternatives to a subASIS bar during motor vehicle travel:
  - determine whether a wheelchair-anchored, crash-tested pelvic belt is available for the wheelchair (previously described in section 1.3) and if it will provide the necessary pelvic stabilization during motor vehicle travel, or
  - use either two pelvic positioning belts anchored in two locations (rearward and down), or a four-point pelvic positioning belt. [14-16]

2.7 Medial upper leg supports (pommel)

Description: A medial upper leg support, commonly referred to as a hip abductor or pommel, is used to maintain the legs in an abducted position.

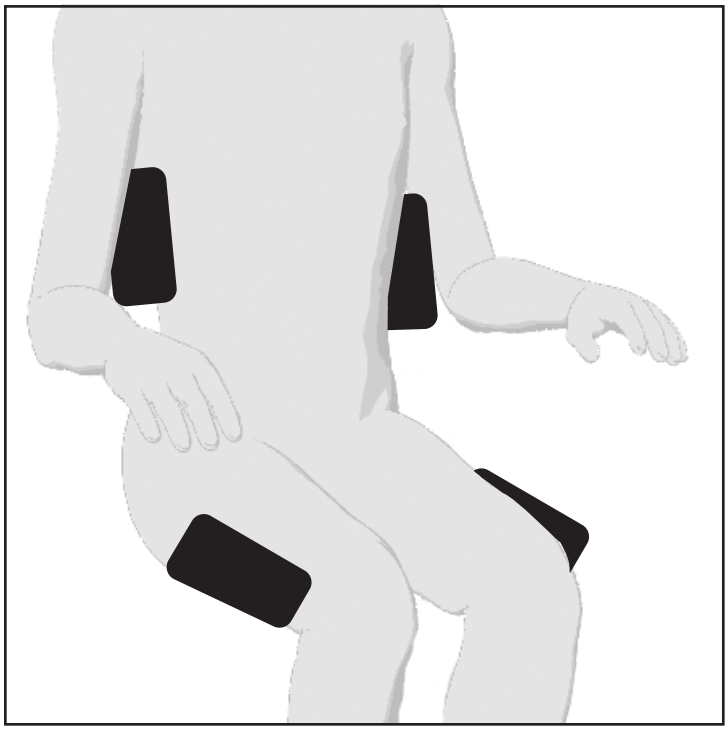
Issues related to use during motor vehicle travel:
This device could potentially contact and press on the groin during a frontal crash and result in injury. To reduce the risk and severity of injury, it is important that a properly fitted occupant restraint be used to minimize forward movement of the pelvis and potential injury to the groin by the support.

Recommendations for Medial upper leg supports:

- To avoid potential damage to the groin by medial upper leg support during a frontal crash, it is important to use a properly positioned pelvic occupant restraint to minimize forward movement of the pelvis.

2.8 Lateral thoracic supports and lateral upper leg supports

Description: Lateral supports are used to aid the individual in maintaining a midline position.[7]



Issues related to use during motor vehicle travel:
A potential benefit of lateral supports is that they can help wheelchair users maintain an upright and midline posture, which improves occupant restraint performance. If the posture of the wheelchair user becomes slouched or asymmetrical during transit, the shoulder belt will not remain properly positioned on the chest and shoulder. Optimal shoulder belt performance depends on the belt being in contact with the shoulder for the duration of the crash event.

A concern related to use of these devices during vehicle travel is that the lateral support pads can interfere with optimal pelvic or shoulder belt placement. It is very important that the occupant restraint belts be properly positioned and worn directly against the body. Placement of the lateral supports should allow for the clearance necessary to route and correctly place the 3-point occupant restraint (see section 1.6 above). Improper routing or usage of occupant restraints can compromise their effectiveness and result in a higher risk for injury in an accident.

Recommendations for Lateral thoracic supports and lateral upper leg supports:

- Wheelchair users who need lateral supports will also benefit from using them while traveling in a motor vehicle; they may help improve or maintain rider position so that crash-tested occupant restraints can be effective.
- Lateral supports should be positioned to allow for effective routing and placement of pelvic and shoulder restraints (see section 1.6 above).

2.9 Ankle/Foot straps

Description: Ankle and foot straps are used to prevent the foot from sliding off the footplate and to improve seating stability. [7] Foot and ankle straps are usually constructed of fabric that crosses the top of the foot or encircles the ankle and are secured with hook and loop closure (e.g., Velcro®) or quick release buckles.

Issues related to use during motor vehicle travel:
It is not anticipated that there will be an additional risk of severe injury to the wheelchair user who uses ankle or foot straps. The use of ankle/foot straps may reduce lower extremity injuries in a crash by preventing the lower legs from hitting another object in the vehicle during a crash. In addition, by helping to maintain pelvic position, they can aid in maintaining good pelvic belt fit.

Recommendations for Ankle/Foot straps:

- For those individuals for whom movement of the lower extremities compromises pelvic position and pelvic restraint fit (low across the front of the pelvis, not high over the abdomen), ankle/foot straps can be used to maintain a body position necessary for effective occupant restraint performance.

References

1. Fuhrman, S.I., M.E. Buning, and P. Karg. Prescription patterns of secondary postural support devices and concerns related to their use during vehicle transportation. In RESNA 2005. 2005. Atlanta, Georgia: RESNA.

2. ANSI/RESNA, ANSI/RESNA WC-19: Wheelchairs Used as Seats in Motor Vehicles. 2000, American National Standards Institute (ANSI)/ Rehabilitation Engineering Society of North America (RESNA).

3. Society of Automotive Engineers, SAE J2249: Wheelchair Tiedowns and Occupant Restraint Systems - Surface Vehicle Recommended Practice. 1999, SAE: Warrendale, PA.

4. ISO, ISO 10542-3: Technical systems and aids for disabled or handicapped persons - Wheelchair tiedown and occupant-restraint systems - Part:3 Docking type tiedown systems. 2005, International Organization for Standardization: Geneva, Switzerland.

5. Department of Transportation, FMVSS 201 Occupant protection in interior impact. 2002.

6. ISO, Draft Standard ISO/FDIS 7176-26: Wheelchairs - Part 26: vocabulary. 2005.

7. Cook, A.M. and S.M. Hussey, Assistive technologies: principles and practice. 2nd ed. 2002, St. Louis: Mosby. xix, 523 p.

8. Forziati, K.T., Development of a Methodology to Dynamically Evaluate the Efficacy and Safety of Wheelchair Occupant Support Devices, in Mechanical and Aerospace Engineering. 1994, University of Virginia. p. 129.

9. Karg, P., Development of methodology to evaluate the transportation safety of adaptive seating devices, in Biomedical Engineering. 1993, University of Virginia.

10. Karg, P. and S. Sprigle. Determining the transportation safety of chest and pelvic restraints. In RESNA '93 Annual Conference. 1993. Washington D.C.: RESNA Press.

11. Karg, P. and S. Sprigle, Development of test methodologies for determining the safety of wheelchair headrest systems during vehicle transport. Journal of Rehabilitation Research & Development, 1996. 33(3): p. 290-304.

12. Paskoff, G., Transportation of wheelchair users: an assessment of neck injury risk during rear collisions, in Biomedical Engineering. 1995, University of Virginia: Charlottesville. p. 87.

13. Bergen, A.F., J. Presperin, and T. Tallman, Positioning for function: wheelchairs and other technologies. 1990, Valhalla: Valhalla Rehabilitation Publications, Ltd. 367.

14. Varilite: Positioning devices.

15. Bodypoint: pelvic positioning: Seattle.

16. Simple Abilities: four point belt: Richmond, BC, Canada.

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