AMSE JOURNALS-AMSE IFRATH Publication –2016- Modelling C; Vol. 77; N° 2; pp 145-154
Submitted Sept. 2016; Accepted Oct. 31, 2016

Hand Use during the Lift Phase of Parallel Sitting Transfers of Two Spinal Cord Injured Subjects

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Abstract

The purpose of this study is to list the shapes and locations used by both hands of spinal cord injured people during parallel transfers. Two spinal cord injured subjects were filmed while realizing 24 transfers each in a reconstructed aircraft cabin. An observation grid was developed to analyze the obtained videos in a systematic manner. The results show that the fist shape is mostly used, and that the hands were most often located on the seat surfaces. The preservation of the upper extremities is an important issue for spinal cord injured persons, because they are depending on them for all displacements. The results of this study give perspectives for further research on the impact of different hand shapes and locations on adjacent joints. Results might also be used to design products and services related to sitting transfers.

Key words

Transfers, spinal cord injury, hand shape, hand location, accessibility, air transport

1. Introduction

Since the United Nations released the Convention on the Rights of Persons with Disabilities [1] in 2006, efforts have been made to enhance the accessibility of public transport. Despite some progress, wheelchair users are still complaining the air travel conditions [2]. One of the least satisfying issues for disabled passengers is the aircraft seat [3]. As disability is a result of the dynamic interaction between an individual and the environment [4], it is possible to decrease the disability experience of an individual through modifications of the aircraft seat (environment).

Spinal cord injured (SCI) people depend on lateral transfers to get out of their wheelchair and attain another sitting surface [5]. These transfers are realized in accordance with the environment surrounding the seat surfaces. Some authors analyzed the Sitting Pivot Transfer (SPT), during which the subject pivots around his feet. The preferred angle between the seat surfaces is approximately 90° for such transfers [6]. In some situations however this type of transfer is not feasible, especially if space is lacking besides the target surface [7]. An alternative for the SPT in this case may be the parallel transfer, that is realized with the two sitting surfaces next to each other. This type of transfer is necessary when a SCI person travels by plane. A boarding chair is placed parallel to the aircraft seat and the person transfers laterally. To realize transfers a SCI person uses his upper extremities to lift up his body. Several studies measured the ground reaction forces beneath both hands and feet during SPT. These studies showed that 20-30% of bodyweight is supported by the lower extremities, even though motor control is absent. However, the major part of bodyweight is supported by the upper extremities, approximately 30-40% of bodyweight for each hand [6]. In these studies the subjects were forced to place their hands flat on a force platform to assure that the trials were repeatable and comparable. Nevertheless, this flat hand position is not recommended as this might enhance the risk to develop a carpal tunnel syndrome [7]. One study realized in 2008 [8], did not impose the shape of the hands during the SPT trials of 11 participants, the researchers reported three different hand shapes. The hands could be placed flat, on the fist, or on the finger tips. In another more ecological study, a transfer from a wheelchair to a personal car was analyzed [10]. These researchers showed that several different locations were used by the hands to transmit forces, these were the driver's seat, the wheelchair seat, the steering wheel, the doorframe and the overhead grab bar.

As to our knowledge no research have been done on the parallel transfer, the aim of this study is to list the shapes and locations of the hands used spontaneously by spinal cord injured subjects during a parallel transfer realized in an ecological environment of an aircraft.

2. Materials and methods

A. Subjects

Two SCI subjects were recruited from a local sports association. A 19 years old female with a complete lesion on T12 level following a congenital tumor and a 48 years old male with a complete lesion on T4 level following a car accident in adulthood. Their height was respectively 165 cm and 185 cm. Both the subjects were independent for all daily life transfers. The index of postural sitting stability (score postural de Bourges), was 4 for the female subject (maintains sitting stability without back support and is able to move arms and head) and 1 for the male subject (maintains sitting stability with back support). Both subjects signed informed consent before the start of the experimental session.

B. Materials

For this study a part of an aircraft cabin was reconstructed. The experimental set-up includes three aircraft cabin seat rows (Z300 model, Zodiac Seats France) placed on a tiltable platform to simulate an airborne aircraft (3° tilted) and an aircraft during boarding (horizontal platform). The seat rows are removable creating a modular platform. This modularity allows to build up 6 different spatial configurations going from low (one seat row) to high (a seat row in front) spatial constraint. Three synchronized digital cameras are placed around the experimental set-up to film the subjects form three different angles (figure 1).

Figure 1. The female subject during a parallel transfer, captured from three different angles

C. Methods

The volunteering subjects realized the parallel transfers from a boarding chair towards the aircraft seat (always situated at the left side of the boarding chair) and then returned towards the boarding chair (figure 2). A boarding chair is a chair on wheels which is designed to bring persons unable to walk into the aircraft, the width of the chair is compatible with the aisle width.

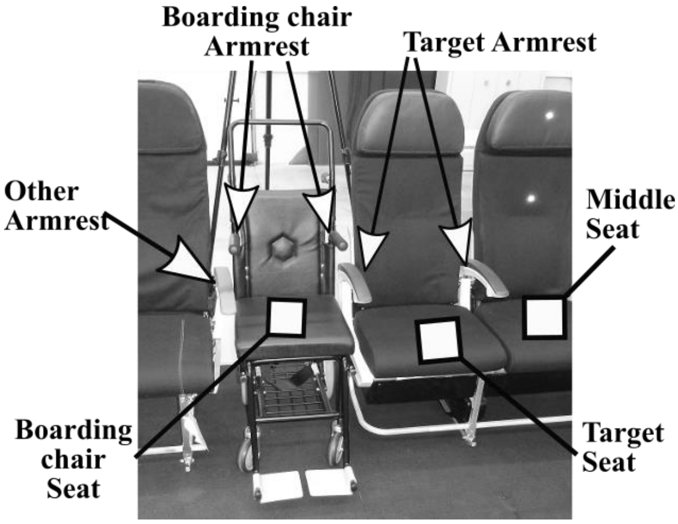

Figure 2. The aircraft environment in which the transfers were realized, the possible hand locations are specified. The boarding chair seat is approximately 3 cm higher than the aircraft seat.

The subjects were invited to realize the parallel transfers as natural as possible. To respect the chronological order in which the transfers are realized in an airplane, the first transfer was always realized from the boarding chair towards the aircraft seat (ingress to the left) and the return transfer in the opposite direction from the aircraft seat towards the boarding chair (egress to the right). Overall both subjects realized 24 transfers (12 ingress and 12 egress) alternating the 6 different spatial configurations and 2 platform conditions (airborne and boarding). These different configurations were presented in a random order.

An evaluation of the difficulty perceived as well as the pain experienced during the transfer was obtained after each spatial configuration through a Visual Analogue Scale (VAS) on a tactile tablet. At the end of the experimental trials a semi-structured interview was conducted to explore more in depth the feelings of the subjects concerning the impact of the spatial constraints.

3. Results

Both subjects realized the 24 parallel transfers without any difficulty. The proposed spatial constraints did not impact the difficulty experienced during the transfers (maximal VAS difficulty score was 0.5). As a consequence the video analysis was realized for all the transfers of each subject without considering the spatial configuration. 48 transfers were analyzed.

A. Development of the observation grid

The videos obtained were analyzed a first time in order to develop an observation grid able to quantify the different elements identified during the first analysis. The parallel transfer of the two volunteering subjects realized in an aeronautical setting is composed of two major actions; the displacement of the pelvis and the displacement of the lower extremities. The observation grid allows to specify the shapes and locations of both hands and feet during these displacements. For the present study it is decided to focus on the shapes and locations of both hands during pelvis displacements.

For the 48 transfers analyzed, 167 pelvis displacements were observed. These pelvis displacements were decomposed in actual seat change displacements (only once per transfer) and preparing and adjusting displacements, respectively before and after the actual seat change displacement. The preparing displacements allow the subject to approach the border of the initial seat and so to prepare for the actual seat change. The adjusting displacements allow the subject to attain a comfortable seated position on the target seat.

B. Shape of the hand while weight bearing

The video analysis shows that only 6 hand shapes served to lift up the pelvis; support on the proximal phalanges of a closed hand (Fist), support on the edge of the seat (Envelop), support on an armrest (Grab), support on the palmar surface of the hand and fingers (Flat), support on the fingertips (Fingertips) and support on the thumb and some phalanges (Phalanx) (figure 3).

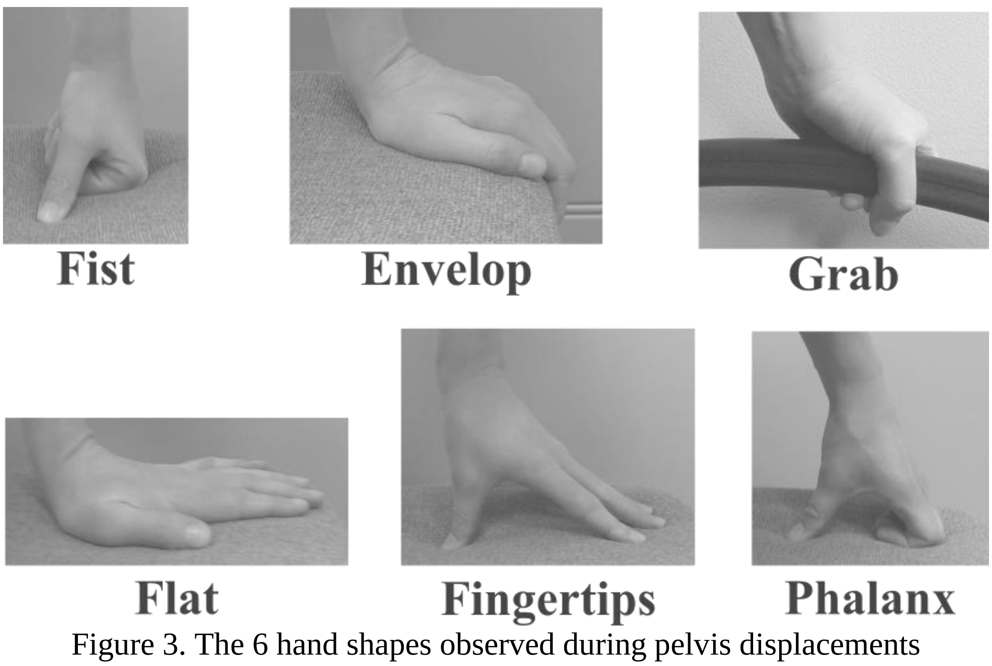

Figure 3. The 6 hand shapes observed during pelvis displacements

For the actual seat change displacements the shape mostly observed for both hands is Fist (respectively 92% and 65% for the left and right hand). The two other shapes observed for the left hand were Flat (6%) and Fingertips (2%). For the right hand four other shapes were observed; Grab (21%), Fingertips (2%), Envelop (6%) and Flat (6%). For the preparing and adjusting displacements the hand shapes observed were more variable. For the left hand (respectively right hand) the distribution was as followed: Fist 39% (33%), Envelop 23% (31%), Grab 10% (17%), Flat 8% (19%), Fingertips 18% (0%) and Phalanx 2% (0%) (figure 4).

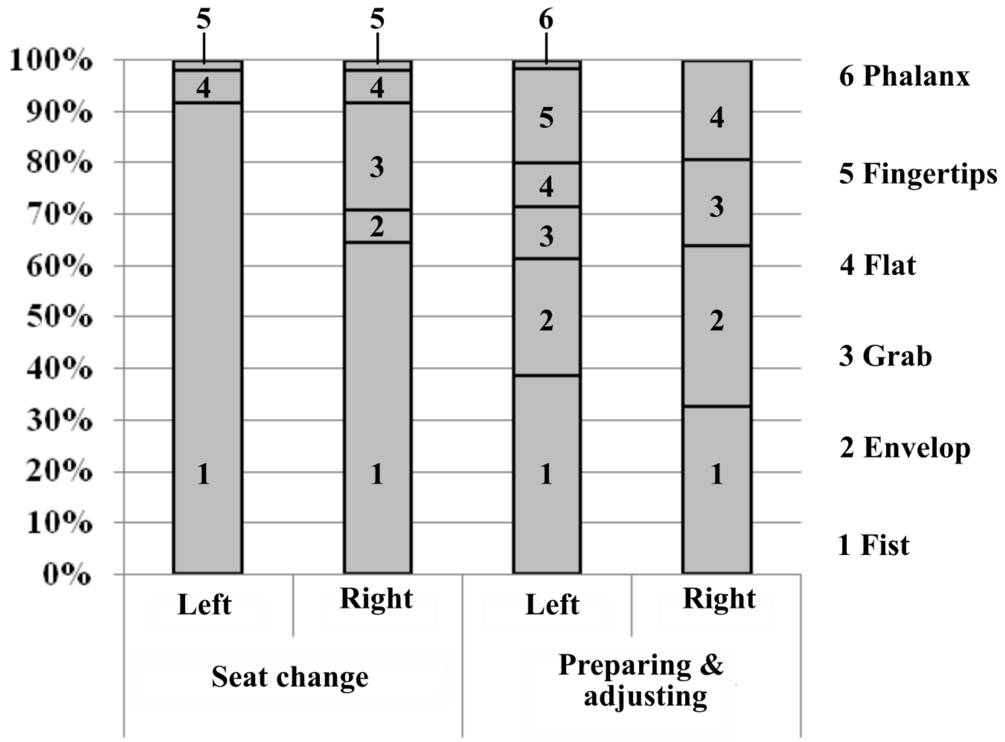

Figure 4. Distribution of the hand shapes (in %) used during actual seat change displacements (n=48) (left half of figure) and during preparing and adjusting displacements (n=119) (right half).

C. Combinations of hand shapes

Both hands were always used simultaneously to lift up the pelvis. During the actual seat change displacements only 8 of the possible 36 hand shape combinations (6*6) were observed. The combination mostly used was two hands Fist, concerning 58% of all actual seat change displacements. The other combinations observed were; left hand Fist / right hand Grab (21%), left hand Fist / right hand Other (Fingertips, Envelop or Flat) (13%), and left hand Other (Fingertips or Flat) / right hand Other (Fist or Envelop) (8%).

For the preparing and adjusting displacements, 22 hand shape combinations were observed among the 36 possible combinations. 73% of all of these displacements were distributed in 8 major combinations, regrouped as followed; two hands Fist (24%), two hands Envelop (17%), left hand Fingertips / right hand Other (Fist, Envelop, Flat or Grab) (18%), and left hand Fist / Right hand Other (Flat or Grab) (14%).

D. Hand location

During the pelvis displacements four combinations of hand locations were observed: (1) left hand on the aircraft seat and right hand on the boarding chair seat, (2) one hand on a seat and the other on an armrest, (3) two hands on the same seat, and (4) two hands on two different armrests. (See figure 2 for the possible placements). During the actual seat change displacements, the combinations 1 (79%) and 2 (21%) were used exclusively. For the preparing and adjusting displacements the distribution was as followed: (1) 52%, (2) 21%, (3) 24%, and (4) 3%.

4. Discussion

The results show that the two SCI subjects displaced their pelvis several times to get in an aircraft seat which was positioned parallel to the initial seat. To displace the pelvis both subjects used different hand shapes to get support from the surrounding surfaces. For the actual seat change displacements the shape mostly used was Fist. During the preparing and adjusting displacements still the Fist shape was most observed, but the distribution among 5 other hand shapes was more variable. The two subjects mostly took support on the seat surfaces, while the armrests were relatively slightly used.

In a study on SPT realized by [9], three different hand shapes were observed for the left hand: Flat (7 out of 11 subjects), Fist (3 out of 11), and Fingertips (1 out of 11). The supporting surface in this study was a force platform of which the density was not specified, but the figures in their research article show that the surface of the force platform was not covered by foam, which might explain why the Fist shape is proportionally less observed then in our study.

Following a clinical practice guideline for the preservation of upper limb function following SCI [8], the Flat hand shape should be avoided as it might increase the risk to develop a carpal tunnel syndrome (CTS). This guideline advises to place the hand on the edge of the seat (as the Envelop shape observed in our study) or to use an armrest when available. The Fist shape is proposed as an alternative as it assures a neutral position of the wrist limiting the risk to develop a

CTS. Considering the results of our study the Fist shape seems to be a convenient support as it is the one that was mostly used. Neither pain nor difficulties were experienced by the two volunteering subjects in our study.

In the actual study the left hand is almost exclusively used in a Fist shape, while the right hand shows more variability. The boarding chair seat is approximately 3 cm higher than the aircraft seat and the boarding chair was always situated at the right side of the aircraft seat in this study. The left hand was therefore always situated on the lower surface height. The Fist shape might allow the subjects to lengthen the upper extremity a several centimeters to be able to compensate for this height difference between the seats.

One research group [10] studied the locations of the hands used by SCI subjects during car transfers. For the right hand three locations were identified: (1) the driver's seat, (2) the steering wheel, and (3) the overhead grab. For the left hand four locations were used: (1) the wheelchair (seat or wheel), (2) the doorframe, (3) the steering wheel, and (4) the overhead grab. The locations most used in this study were the driver's seat and the wheelchair (19 out of 29 subjects), this is in accordance with the results shown in the present study. The steering wheel was less used, which is comparable to our results on the use of the armrests.

The two subjects who volunteered in our study mostly used the seat surfaces to place their hands for support, and this even though armrests were available, which are recommended for use to limit extensive wrist extension [8]. Probably the position (height, spreading) of the armrests did not satisfy the subjects in our study to serve as a support. As in our study the height and spreading of the armrests stayed the same throughout all configurations, it is possible that other values of these parameters (for example a lower armrest or a modular spreading) do increase the use of armrests.

The results of our study allow for future work concerning the choice of hand supports during lateral transfers of SCI subjects. Our two subjects spontaneously used 6 different hand shapes. To our point of view these hand shapes are not chosen randomly, and therefore it will be interesting to study the reason why these shapes are used as well as why some shapes are used more than others. It is possible that the characteristics of the surfaces predispose a particular hand shape.

Our results should not be generalized to all lateral transfers. Firstly because the actual study is done with only two SCI subjects. Besides, this study was realized in an aeronautical setting. The seat surfaces were soft foam and the armrests removable, but fixed in height and spreading. This set-up is ecological, but does not reflect all daily life situations. SCI people realize transfers on hard surfaces (for example in bathrooms), soft surfaces (bedroom and wheelchair cushions), or with grab bars (armrests) at different heights and spreading then those used in our study. Therefore, the results presented in this paper have to be considered in this particular aeronautical environment.

To confirm our results, it is necessary to analyze additional parallel transfers of other SCI subjects. It is important to find out which impact the shape of the hand during weight bearing has on adjacent joints (especially the wrist), allowing as to estimate the risk to develop upper limb pain as a consequence of a particular hand shape. It is also of interest to search for other support surfaces for the hands that might suit people to realize lateral transfers. Because the use of armrests is recommended whenever these are available, it will be interesting to understand what is their ideal position (height, spreading). The opinions of SCI subjects have to be considered in these studies.

The results of this study as well as those of future work could serve product engineers to modify some elements in the environment where transfers might be expected. The knowledge on the preferences of SCI people as well as the impact of hand shapes and locations on the prevention of upper extremity pain can be integrated in the development of environmental adaptations. The disability experience of wheelchair dependant people as well as the accessibility can be enhanced through environmental modifications.

Conclusion

This study has analyzed the spontaneous use of hands during parallel lateral transfers of two spinal cord injured subjects. 6 hand shapes and 4 combinations of hand locations were identified. The subjects mostly applied support with their fists on the seat surfaces. These observations encourage future in-depth research aiming to understand which factors impact the choice of the shape and location of the hands, as well as to know which impact the hand shape has on the adjacent joints. The results of this study and future work could serve product designers to modify some elements of the environment in which transfers are expected, to enhance the accessibility for wheelchair dependant people.

Acknowledgements

This research was supported financially by Zodiac Seats France and Direction Générale de l'Aviation Civile (project n°2014 930181).

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