International Journal of Industrial Ergonomics 48 (2015) 167–173

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

Time and force required for attendants boarding wheelchair users onto aircraft

Catherine Holloway, Roselle Thoreau*, Esther Petit, Nick Tyler

Department of Civil, Environmental and Geomatic Engineering, University College London, United Kingdom

ARTICLE INFO

Article history:
Received 14 August 2014
Received in revised form
25 March 2015
Accepted 9 April 2015
Available online 26 May 2015

Keywords:
Wheelchair
Accessibility
Disability
Aircraft boarding
Attendant propelled wheelchairs

ABSTRACT

Ensuring equal opportunity to all transport modes, including air travel, allows disabled people the same freedom of travel available to the rest of the population. However, boarding of wheelchair users onto airplanes is physically demanding for attendant airline or airport personal whom assist and time consuming and costly for airlines. This paper presents a comparison between two methods of boarding wheelchair users, measuring the forces required and the duration taken. Participants were asked to act as attendants and to board weighted wheelchairs onto simulated aircraft vestibules using two different manoeuvre methods ("going forwards" and "going backwards"), with two different loadings ("light" and "heavy") in two different access scenarios ("level access" and "sloped access") between the jet-way/scissor-lift and the aircraft. The results reveal that the "going backwards" technique is a slightly faster manoeuvre method but no difference in the forces required exist between the two methods. The weight of the wheelchair affected the forces required to complete the boarding and exceeded health and safety guidelines for attendants. Reducing the height of the step between the aircraft and the jet-way or scissor-lift is recommended.

Relevance to industry: The research highlights the juxtaposition between the need to board wheelchair users and the excessive force required by the attendants propelling the wheelchair.

1. Introduction

In Europe more than 45 million adults have a long standing health problem or disability (European Commission, 2007). Many of these use wheelchairs to move about the environment. In the United Kingdom (UK) alone current figures for wheelchair users are estimated at 1.2 million, with 825,000 of those being regular, long term users (Huonker et al., 1998) and their use is increasing (Manty et al., 2007). This group of people faces more difficulty than most in moving with ease around their environment and accessing transport options (Meyers et al., 2002; Mathews and Vujakovic, 1995; Bromley et al., 2007; Shaw and Coles, 2004; Petzäll, 1995).

Ensuring equal opportunity to travel is a key commitment in the UK, in Europe and globally. Disabled people need access to the same modes of transport available to the rest of the population. This includes air transport where wheelchair users face numerous obstacles (Chang and Chen, 2011).

Globally, disabled persons' rights are protected by United Nations' Convention on the Rights of Persons with Disabilities (UN, 2006). The rights of a person to access places and modes of transport are detailed in Article 9, which states "States Parties shall take appropriate measures to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation… and to other facilities and services open or provided to the public, both in urban and in rural areas." and "… *These measures, which shall include the identification and elimination of obstacles and barriers to accessibility*".

Mobility impaired people within Europe are protected by European Regulations (European Commission, 2007). The European Regulation (EC) 1107/2006 [page 1] states that "*disabled persons and persons with reduced mobility, whether caused by disability, age or any other factor, should have opportunities for air travel comparable to those of other citizens*". In addition, regulations demand assistance to be provided to transport passengers free of charge (EC 1107/2006).

* Corresponding author. Department of Civil, Environmental and Geomatic Engineering, University College London, Gower Street, London, WC1E6BT, United Kingdom.
E-mail address: r.thoreau@ucl.ac.uk (R. Thoreau).

http://dx.doi.org/10.1016/j.ergon.2015.04.003
0169-8141/

In the UK the Department for Transport (DfT) have set out a code of practice. In it they remind that the UK laws in this area are governed by the EU regulations and that these must be met anywhere in the UK. Furthermore they state that, by law: *Companies should review their policies, procedures and practices to ensure that they meet the needs of disabled persons and persons with reduced mobility* (DfT, 2008) and they recommend that the: *Responsibility for meeting the needs of disabled persons and persons with mobility should be accepted at the highest levels and delegated to people with the skills and authority to influence the design and operation of aircraft and airport terminals or to alter procedures* (DfT, 2008).

The law is very clear that disabled people must be allowed access to be able to board aircraft and that airports and airline have a legal duty to adhere to this. However, within the airport and airline industry, providing this service can be problematic. This is because the physical effort involved in boarding a wheelchair is high.

The act of pushing wheeled devices, including carts and wheelchairs requires significant force (Ciriello et al., 2001; Haslam et al., 2002; Jung et al., 2005; Petzäll, 1995). The push force is affected by a number of factors. For example the forces required when manoeuvring carts is less when pushing forwards than when pulling backwards (Lawson et al., 1993; De Looze et al., 2000; Jung et al., 2005). Push handle height, weight load and orientation can also affect push forces. A review of the evidence by Jung et al. (2005) showed weight load is the parameter which has the most effect in pushing wheeled device. Although handle height is also of great importance. Al-Eisawi et al. (1999) found that elbow height handles make pushing or pulling the most force efficient. In general for wheelchairs handles a higher handle height is preferred for pulling than pushing. Higher than the commonly used 92 cm height handles would make wheelchair manoeuvres easier (Van der Woude et al., 1995).

Manoeuvring wheelchairs has been linked with injuries for both the person in the wheelchair (when self-propelled) and the person pushing (if attendant propelled). For attendants both pushing and pulling have been found to cause lower back pain and shoulder injuries (Chaffin et al., 1984; Hoozemans et al., 2004; Lee et al., 2013; Pope, 1989; Van der Woude et al., 1995). Where possible lifts are used to reduce the likelihood of injury. Some injury, particularly musculoskeletal disease, are associated with the handle height of chairs in relation to the height of the attendant. Handles which are too low put greater pressure on forces needed to manoeuvre a wheelchair (Lee et al., 2013; Van der Woude et al., 1995).

Within the Health and Safety Executive (HSE) guidance the force required for pulling or pushing should not exceed 150N for women and 200N for men. In addition, HSE guidance on wheelchairs boarding airplanes state "*chairs should be designed such that the force required to push and turn (on a level surface) a wheelchair or boarding chair occupied by a 99th percentile weight male should not exceed the maximum force which can be exceeded by a 5th percentile female*" (HSE, 2007). There is an issue here to balance the needs of disabled people (as represented in law) and the protection of their employees health and the economic requirements of the industry. The UK recommends they "*managing bodies should ensure that they "ensure that the appointed service provider has suitable equipment to facilitate boarding which minisimises risks to staff and passengers. Equipment must be well maintained to ensure adequate availability*" (DfT, 2008).

Airlines must ensure the health and safety of the staff involved in boarding wheelchair bound passengers and therefore it is important for airlines to understand the forces necessary to move a passenger with their wheelchair onto a plane. Manoeuvring wheelchairs requires strength and boarding users onto airplanes can be especially difficult as it can require going up a step. A step of approximately 20 cm is common at the entrance of an aircraft even when a jet-way is used. The force required to mount a step of this height is impossible for many to achieve (Petzäll, 1996). A ramp is often used to remove this step. However, even with the use of a ramp, the effort required for the person manoeuvring the wheelchair is significant. Where possibly, airlines prefer to board wheelchair users via a lift as this reduces the effort required by staff and lowers the risk of injury. However, in many cases, even when a lift is present there is still a step between aircraft and lift.

Providing this service for disabled people is also costly for an airline. Keeping aircraft on the ground is expensive for the airlines. As a result they keep their planes in a terminal for the minimal amount of time needed for safety of the vehicle and the supply of goods (Nyquist and McFadden, 2008). However the boarding of mobility impaired passengers in wheelchairs can take a long time.

The potential mismatch between the requirement to allow disabled users access to a transport service and potential violation of Health and Safety guidelines is vital to empirically understand. Data needs be gathered on the force levels required by different boarding methods.

In order to produce this information a small sample comparison study was carried out. The study aimed to understand the time and force required by an attendant to push a wheelchair onto an aircraft, how this changed as a result of passenger weight, wheelchair manoeuver method (Going Forward and Going Backward), and whether the force required fell within Health and Safety guidelines. The focus for this research was limited to the manoeuver of the wheelchair and its passenger onto to the plane and did not include the requirements of transferring the passenger into and out of the transfer chair.

2. Methods

2.1. Experimental design

Experiments were carried out in a real-world model of an aircraft vestibule and on a flat version of one (see Figs. 1–3). Ten participants were asked to perform each of the two manoeuvres, with two different wheelchair loads, three times each in the two settings. Before the recordings were made, participants tried each manoeuvre at least once in each setting. They were allowed to practice as many times as they wanted. Once the participants had finished the manoeuvres in one location they were asked to rate how demanding the manoeuvres were wing the Borgs scale of

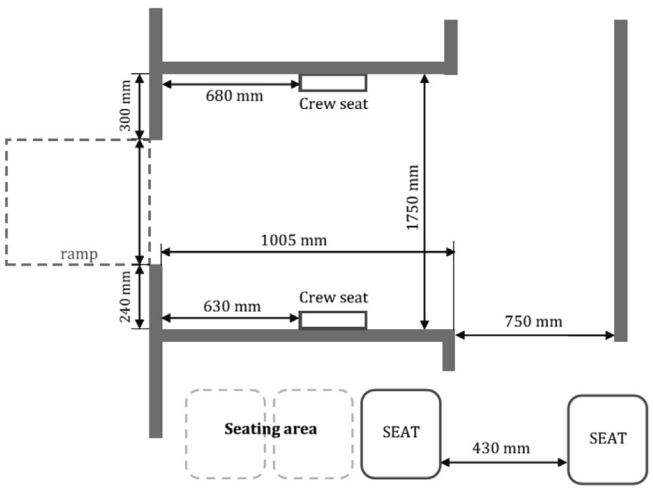

Fig. 1. Aircraft model dimensions (drawing not to scale).