International Journal of Industrial Ergonomics 41 (2011) 153–166

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

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

A method for calculating the joint coordinates of paraplegic subjects during the transfer movement despite the loss of reflective markers

Jean-François Debril [a,b,c], Philippe Pudlo [a,b,c,*], Emilie Simoneau [a,b,c], Philippe Gorce [d], François Xavier Lepoutre [a,b,c]

[a] Univ Lille Nord de France, F-59000 Lille, France
[b] UVHC, LAMIH, F-59313 Valenciennes, France
[c] CNRS, FRE 3304, F-59313 Valenciennes, France
[d] HANDIBIO EA 43-22, Université du Sud Toulon-Var, F-83957 La Garde, France

ARTICLE INFO

Article history:
Received 17 February 2010
Received in revised form
6 September 2010
Accepted 15 December 2010
Available online 21 January 2011

Keywords:
Motion capture
Marker loss
Humanoid mannequin
Transfer movement
Spinal cord injury
Manual wheelchair

ABSTRACT

During transfers into and out of manual wheelchairs, the upper limbs of paraplegic subjects support nearly the total body weight, which can cause musculoskeletal disorders. Nevertheless, despite the existence of experimental laboratory platforms, the specificities of this population, which cause the reflective markers to fall off the subject, makes it difficult to study these movements. To solve this problem, a two-stage method based on the use of a humanoid mannequin is introduced in this paper. The first stage aims to automatically construct a humanoid mannequin with the same anthropometry as the subject, without resorting to manual reshaping. The second stage uses this mannequin and a trajectory tracking procedure based on a global optimization of the whole body under joint constraints. The hand-supported transfer movement of a healthy subject was reconstructed firstly based on all the markers and secondly based on a reduced number of markers. These two reconstructions were then compared. The results of this comparison were good. The joint coordinates resulting from these two reconstructions were correlated at 0.98 ± 0.03, their average difference was lower than $\pm 7^{\circ}$, and the average Root Mean Square was $2.17 \pm 2.29^{\circ}$. This method thus constitutes a good alternative for calculating the joint coordinates in order to study the sitting pivot transfer movement.

Relevance to industry: The proposed method can be applied to other movements, other populations and other hardware configurations without *a priori* knowledge. It can also be applied to any type of humanoid model. As this method is simple to implement, it allows to decrease the number of markers needed for the reconstruction while guaranteeing the measurement quality.

1. Introduction

1.1. Context

Improving the quality of life of wheelchair users requires finding the right match between the wheelchair user and the wheelchair design. The ergonomics of the wheelchair is thus a key factor in the user's wheelchair choice. Research has been performed to improve the ergonomics of wheelchairs. Studies have been conducted about, for instance, the anthropometry of the wheelchair users (Paquet and Feathers, 2004), the reach capabilities of wheelchair users (Jarosz, 1996; Kozey and Das, 2004), Manual wheelchair (MW) propulsion (Boninger et al., 2005; Brubaker, 1992; Tomlinson, 2000), the comfort of the seat (Eckrich and Patterson, 1991), and the effects of MW use on musculoskeletal disorders (Curtis et al., 1999).

Indeed, in their everyday life, manual wheelchair users overuse their upper limbs (Van Der Woude et al., 2001; Van Drongelen et al., 2005). This overuse can lead to musculoskeletal disorders affecting the joints of the upper limbs (Boninger et al., 2005; Curtis et al., 1999; Sawatzky et al., 2005; Van Drongelen et al., 2005). These musculoskeletal disorders include, for instance, tendinitis of the rotator cuff in the shoulder and carpal tunnel syndrome in the wrist. Moreover, one out of four MW users with spinal cord injuries develops elbow pain (Consortium for Spinal Cord Medicine, Clinical Practice Guidelines, 2008).

Better understanding of MW propulsion can improve the MW design, though the MW user's other needs, such as prevention of

Abbreviations: MW, Manual wheelchair; ISB, International Society of Biomechanics; MPIS, Middle of the posterior iliac spines; S0, World coordinate system.

* Corresponding author. Tel.: +33 03 2751 1429; fax: +33 03 2751 1316.
E-mail addresses: jean-francois.debril@univ-valenciennes.fr (J.-F. Debril), philippe.pudlo@univ-valenciennes.fr (P. Pudlo), emilie.simoneau@univ-valenciennes.fr (E. Simoneau), philippe.gorce@univ-tln.fr (P. Gorce), francois-xavier.lepoutre@univ-valenciennes.fr (F.X. Lepoutre).

0169-8141/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.ergon.2010.12.003