Journal of Electromyography and Kinesiology 40 (2018) 16–22

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

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

Arm-trunk coordination in wheelchair initiation displacement: A study of anticipatory and compensatory postural adjustments during different speeds and directions of propulsion

Soufien Chikh[a,*], Cyril Garnier[b,c,d], Arnaud Faupin[e,f], Antonio Pinti[b,g], Samuel Boudet[h,i], Fairouz Azaiez[a], Eric Watelain[b,c,d]

[a] Institut Supérieur du Sport et de l'Education Physique de Sfax, Unité de Recherche GEDES, Faculté des lettres et des Sciences Humaines de Sfax, Tunisia
[b] Univ Lille Nord de France, F-59000 Lille, France
[c] UVHC, LAMIH-Dptm SHV, F-59313 Valenciennes, France
[d] CNRS, UMR 8201, F-59313 Valenciennes, France
[e] LAMHESS, EA 6312, Université de Toulon, F-83957 La Garde, France
[f] LAMHESS, EA 6312, Université Nice Sophia Antipolis, 06205 Nice, France
[g] EA 4708, I3MTO, CHRO - 1 rue Porte Madeleine, 45032 Orléans, France
[h] Univ Nord de France, F-59000 Lille, France
[i] Unité de Traitement de Signaux Biomédicaux, Faculté de Médecine et Maïeutique de l'Université Catholique de Lille, France

ARTICLE INFO

Keywords:
Coordination
Arm-trunk
Human movement
EMG
Wheelchair

ABSTRACT

Arm-trunk coordination during the initiation of displacement in manual wheelchair is a complex task. The objective of this work is to study the arm-trunk coordination by measuring anticipatory and compensatory postural adjustments. Nine healthy subjects participated in the study after being trained in manual wheelchair. They were asked to initiate a displacement in manual wheelchair in three directions (forward *vs.* left *vs.* right), with two speeds (spontaneous *vs.* maximum) and with two initial hand's positions (hands on thighs *vs.* hands on handrails). Muscular activities in the trunk (postural component) and the arms (focal component) were recorded bilaterally. The results show two strategies for trunk control: An anticipatory adjustment strategy and a compensatory adjustment strategy with a dominance of compensation. These two strategies are influenced by the finalities of displacement in terms of speed and direction depending on the hands positions. Arm-trunk coordination is characterized by an adaptability of anticipatory and compensatory postural adjustments. The study of this type of coordination for subjects with different levels of spinal cord injury could be used to predict the forthcoming displacement and thus assist the user in a complex task.

1. Introduction

During upper limbs movement in a sitting position, and from the anatomical point of view, the trunk is interposed between the support basis and the effectors members. It has a key role of support which participates in the movement execution (Fayad et al., 2008). Therefore, a precise coordination between arms movements and trunk movements is necessary. For Lee et al. (2008), in adults, coordination is often associated with the notion of 'functional synergy', which means the spatiotemporal organization of muscles and joints related to the task success. This coordination is ensured by the central nervous system (CNS) by the mean of adaptive motor commands according to the forthcoming movement (Robertson and Roby-Brami, 2011). Therefore, the CNS sends motor commands to the focal component for movement execution as well as to the postural component to ensure anticipatory postural adjustment (APA) and compensatory postural adjustment (CPA) for the gesture adequacy to the desired goal by the motor execution (Chikh et al., 2016). The postural component has an counter-perturbation role caused by the focal movement which will alter the postural balance (Bouisset et al., 2000), a role of protection of standing postural stability (Aruin et al., 1998; Wang et al., 2014) as well as a participation role in the movement execution according to its parameters (Saling et al., 1996; Flanders et al., 1999; Allison et al., 2008).

One of the central problems in experimental studies of motor control is to understand the movement control as well as the ability of the CNS to anticipate and simulate the behavior of the motor apparatus

* Corresponding author at: Institut Supérieur du Sport et de l'Education Physique de Sfax, Unité de Recherche GEDES, Faculté des lettres et des Sciences Humaines de Sfax, Tunisia.
E-mail addresses: soufien_chikh@yahoo.com (S. Chikh), cyril.garnier@univ-valenciennes.fr (C. Garnier), faupin@univ-tln.fr (A. Faupin), antonio.pinti@univ-valenciennes.fr (A. Pinti), samuel.boudet@univ-catholille.fr (S. Boudet), fairouz.kyranis@yahoo.com (F. Azaiez), eric.watelain@univ-valenciennes.fr (E. Watelain).

https://doi.org/10.1016/j.jelekin.2018.03.001
Received 25 September 2017; Received in revised form 31 January 2018; Accepted 12 March 2018
1050-6411/

(Blakemore and Sirigu, 2003). The adaptability of the APA to the movement parameters is generally observed according to different dominant characteristic(s) of the forthcoming movement, such as speed, direction, or weight (Chikh et al., 2016), also according to different sources of constraints imposed to the postural system like biomechanical, temporal and psychological sources (Yiou et al., 2012).

For disabled persons, with an insufficient lower limb functionality to move in bipedal position, locomotion can be ensured using a manual wheelchair. The control of the bi-manual propulsion and the displacement in manual wheelchair is complex and remains considered as an inefficient way of locomotion (De Groot et al., 2013). Few studies have been interested in the arm-trunk coordination during displacement in wheelchair and many works are still necessary in order to better understand, improve or even assist this mode of locomotion. This mode of locomotion must be controlled in three dimensions (Oh et al., 2008) and has two levels of perturbation: propulsion (segmental kinematics) and displacement (inertia of the subject-chair couple). Arm-trunk coordination is thus paramount. The abdominal and dorsal muscles contractions, in particular at the end of the recovery phase and at the beginning of the pushing phase ensure the sufficient trunk stability to meet propulsion requirements (Yang et al., 2006) and this in parallel with the activation of the arms muscles (Louis and Gorce, 2010).

To date, there are ample investigations on manual wheelchair propulsion when the subject is already in displacement. However, to our knowledge, the passage from static to displacement phase of propulsion has not been the object of previous study. This transition phase will be called initiation of displacement in manual wheelchair. The arm-trunk coordination at initiation of displacement in manual wheelchair is paramount considering the important forces to generate to overcome the inertia of the manual wheelchair and the subject. The level of adaptability of this coordination, or more generally of the muscular patterns during the initial phases of propulsion are of particular interest because more abrupt motions likely occur more frequently throughout the day than smooth steady state propulsion (Morrow et al., 2010). This, coupled with the fact that propulsion is inherently repetitive and inefficient, supports the notion that propulsion improvements could be impactful to health and wellbeing.

In order to study this postural control during the initiation of displacement in manual wheelchair, that is to say the anatomical and functional demands, the presence of the whole postural component must first be identified as well as the focal muscle that will allow the temporal division of the APA and CPA windows. The activation time of the focal muscle is defined as the **T0** *'time zero'* (Aruin & Almeida, 1997). Then, we must take into account the fact that the movement of the two arms is complex in view of the degrees of freedom (Bernstein, 1967) in relation to the movements of the trunk and the head. This makes difficult to identify the focal muscle or *prime mover*. Finally, the user population of manual wheelchair is very heterogeneous as a result of the deficiency or deficiencies that led to this locomotion in manual wheelchair. To define the population to be studied to invest this trunk coordination via APAs and CPAs requires then to make choice of functional categorization.

Against this set of difficulties, two methodological solutions have been chosen: (i) the training of a homogeneous group of healthy able bodied subjects in manual wheelchair which will enable the whole focal and postural muscles to be studied; (ii) measuring the muscular contraction of the entire focal component to select the *prime mover* at each trial.

Thus, the aim of this work is to study the arm-trunk coordination by measuring the APAs and CPAs in the initiation of displacement in manual wheelchair. We hypothesized an adaptability of muscular patterns to the different finality of initiation of displacement in manual wheelchair in terms of speeds and directions according to each hands position.

2. Method

2.1. Participants

Nine healthy subjects (eight men and one woman) have voluntarily participated in the experiment. Means and standard deviations of age, weight and height were respectively 23.6 ± 7.1 years, 75.2 ± 8.8 kg and 180 ± 10 cm. The subjects (novice, healthy able bodied) received the basic knowledge of wheelchair travel (how to propel the wheelchair in straight line, how to turn…) and were trained as part of a course in adapted physical activity. All subjects signed an informed consent approved by the university's institutional review board.

The inclusion criteria are: (1) have theoretical knowledge on propulsion in manual wheelchair; (2) have a minimum of 15 h on manual wheelchair handling; (3) be right handed; (4) be motivated to participate voluntarily in this study. The exclusion criteria are: (1) have a neurological, cardiopulmonary, muscular or joint disease that can alter the propulsion in manual wheelchair; (2) be under medication that may affect the equilibrium, propulsion or understanding the instructions.

2.2. Tools, variables and measures

2.2.1. Tools

Electromyography EMG: electrodes (FOAM Ag/AgCL-oval 32 mm * 36 mm) were placed bilaterally (left (L) and right (R)) on the following muscles for the two components: (1) the focal component; deltoid anterior (DA), deltoid posterior (DP), biceps brachii (BB) and pectoralis major (PM) and (2) the postural component; rectus abdominis (RA), obliquus externus (OE), and erector spinae (ES). This step was carried out in accordance with the recommendations of Hermens et al. (2000) by the same experimenter. Muscular activities were recorded using the "Bipolar Zero wire 16-channel AURION amplifier". Data sampling was accomplished at 1000 Hz. Manual wheelchair: the same manual wheelchair, ACTION2000, was used by all subjects. Data recording and processing were performed using HP pavilion dv7 Notebook PC.

2.2.2. Variables and measures

The relative intensity of APAs: corresponds to the relative intensity between −100 and +50 ms with respect to **T0**.

The relative intensity of CPA: corresponds to the relative intensity between +50 and +200 ms with respect to **T0**.

2.3. Tasks and procedures

2.3.1. Before experiment

Each subject is informed of all steps of the experiment and signs an informed consent. After abrading the upper part of the epidermis with an abrasive face sponge and cleaning the skin with alcohol, the electrodes were placed bilaterally. A standardized warm up of 5 min was made by each subject (move forward, turn right and turn left 5 times in each direction, at two speeds: spontaneous then maximum). Before starting the actual experiment, the subject makes three passages without recording to check the proper functioning of the acquisition and the understanding of the experimental conditions.

2.3.2. Wheelchair position and instruction

Subjects positioned the rear wheels according to the direction of displacement requested (forward, right or left). For forward direction, subject facing forward; for left direction, subject facing rightward (90°); for right direction, subject facing leftward (90°) (Fig. 1). Then, they receive information about the type of displacement to be carried out:

– Hands position (hands on the thighs or hands on the hand rims).
– Spontaneous speed or maximum speed, then recording is initiated.