Reliability of the MMAAS in patients with multiple sclerosis

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1. INTRODUCTION

In the management of multiple sclerosis (MS) moderate exercise has been shown to improve the patients' physical fitness [1], walking [2] as well as quality of life [3], particularly through a combination of resistance and endurance training [1]. Alternative forms of exercise training both for upper and lower limbs include the use of robot-mediated therapy, which has gained support, mainly in stroke rehabilitation, as an established method to provide treatment of the same quality as that provided by a trained therapist for the improvement of motor function [4]. However in the management of MS there is still limited evidence on the benefits of this treatment. MS patients who used a robot-controlled manipulandum have been shown to adapt to haptic force fields [5], and additional evidence indicates that upper limb motor coordination also improved mainly in patients with ataxia who performed reaching tasks using, again, a robotic manipulandum [6]. Several research groups have begun to investigate the effect of upper limb training in MS using virtual reality and robot-based exercise programmes for wheelchair-bound patients who presented muscle weakness [7].

In the course of the Interreg IV project we developed a robot-mediated virtual learning environment, named I-TRAVLE (Individualized Technology and Robot-Assisted Virtual Learning Environment) that can provide upper limb therapy to subjects recovering from neurological conditions [8]. However in order to assess the effect of robot therapy on the quality of a patient's arm movements, clinically interpretable outcome measures should become available. In addition to the dynamic measurements recorded by the robot [9], kinematic measurements of compensation, muscle and joint activity provide the most objective methods to monitor and quantify clinical progresses. In order to obtain more objective measurements a portable motion capture system (Motion and Muscle Ambulatory Activity System or MMAAS) was developed to enable wireless monitoring of upper limb function in clinical settings [10]. A system's reliability is one of the pre-requisites in the clinic. In this study we present a reliability analysis on the measurements carried out using the MMAAS on a group of MS patients who received upper limb robot therapy. The aim of this study is to evaluate whether the test-retest reliability of the MMAAS is sufficient to use it as a clinical assessment tool. We discuss the significance of the results and their implication for remote monitoring of MS subjects receiving therapeutic treatment.

2. METHODS

Subjects

Six MS subjects participated in the study, 4 subjects presented muscle weakness on the left arm and 2 subjects on the right arm (age 55 ys ± 3.8 ys; EDSS score 7.3 ± 1.6; MI tested side 55.8 ± 24.5). Ethical approval was obtained for the study (Adres Ethical Committee, Overpelt, Belgium). Subjects were asked to wear a jacket where 4 MMAAS sensors (inertial and magnetic) were embedded. The sensors were located on the thorax, the cranial edge of the scapular spine, the middle of the arm facing the lateral side and on the dorsal side of the distal end of the forearm. A fifth sensor was attached to a grounded support parallel to the thorax. The arm and forearm sensors were secured with additional straps to limit their movement relatively to the skin. The setup is illustrated in Fig. 1. The axes of the different body segments were oriented according to the ISB recommendations [11]. The joint angles were calculated in the MMAAS software from the sensor data according to the procedure described in [12].

Measurement Protocol

The participants were instructed to perform a series of activities from a standardized protocol. Subjects were instructed to perform the task using the affected arm, while measurements with the MMAAS were carried out by the same investigator. In order to evaluate test-retest reliability each subject performed the protocol twice, with the jacket being removed and put back on between the two occasions. The protocol consisted of daily activities. Each activity was performed by starting and ending at the same point, indicated to the subject, while

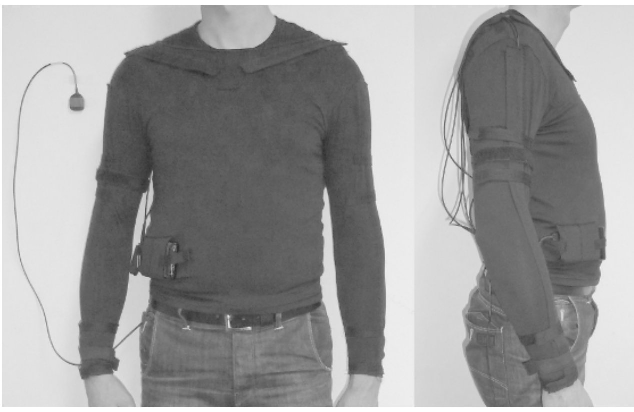

Figure 1. Front and side view of the MMAAS jackets and sensors.

4 repetitions were completed according to a set of instructions explained beforehand. Several activities from the protocol were analyzed for reliability, as described in Table 1.

Data Analysis

The parameters considered in this study were: active range of motion (*AROM*) during the task, maximum angular value, and minimum angular value. The movements considered were chest flexion, shoulder abduction, rotation and flexion, elbow flexion and elbow rotation. The values used in the reliability analysis were the means across the 4 repetitions of these parameters. The intraclass correlation coefficient (*ICC*) was used to quantify test-retest reliability: *ICC* for consistency in the two-way mixed effect model was used. The standard error of the measurement (*SEM*) was also calculated to quantify the reliability within individual subjects. The *SEM* was calculated as the square root of the error mean square term in the repeated measures ANOVA [13].

3. RESULTS

The results of the reliability analysis are reported in Table 1. Although the number of subjects was limited statistically significant results were found on a number of activity/parameter combinations. The values for the *ICC* found in this study were comparable with those found in reliability studies on 3D gait measurements using optoelectronic motion capture systems [14]. The *SEM* values were generally higher than the 2-5º error range reported in the literature for 3D gait studies [14]. *ICCs* ranging between 0.7 and 0.9 are considered acceptable in measurements with human subjects and indicate moderate to good reliability respectively [15]. However the results should be interpreted in the contexts of subject variability as explained below.

A decrease in *AROM* was observed in some subjects during the third and fourth repetition of activities involving reaching. The subjects also remarked on feeling fatigued while performing the tasks where decreasing *AROM* was observed. The movement pattern is illustrated in Fig. 2 left. This movement pattern is expected from participants affected by MS. As part of the protocol, an activity consisting solely of shoulder internal/external rotation was also analyzed for reliability but was not reported in Table 1 as the result was not significant. It was observed that the *AROM* during this activity was very small as the participants found difficult to accomplish shoulder external rotation.

4. DISCUSSION

The aim of this study was to evaluate whether the test-retest reliability of the MMAAS was sufficient to use it as a clinical assessment tool. The relative large values found for the *ICCs* indicate a good reliability (*ICC* 0.8-0.9) for most of the tasks considered. The interpretation of the *ICC* should however be carried out while considering the amount of between-subject variability [13], which in this study can be attributed to the heterogeneous movement abilities of the MS group also indicated by the variability in the MI score. Particular attention should be paid to the *SEM* to discern whether large between-subject variability is not masking poor subject consistency [13]. Based on the results showed in Table 1 it can be observed that elbow and thorax *AROM* were the movements with the highest consistency between trials, while shoulder flexion and elbow rotation *AROM* were the less consistent ones. Thus although reliability of the system is comparable to that found in 3D gait studies, subject consistency can still be reduced. In particular further research should be concentrated on assessing the influence of factors such as sensor placement, skin movement artifacts and muscle fatigue. An additional reliability study of the MMAAS has been carried out exclusively on healthy subjects using the same movement protocol described here [16]. The *ICCs* found ranged between 0.7-0.9 and are comparable with those found in this study, while the *SEM* values ranged between 2-6º and are lower, but not considerably. However, in that study statistical significance was also found for shoulder rotation.

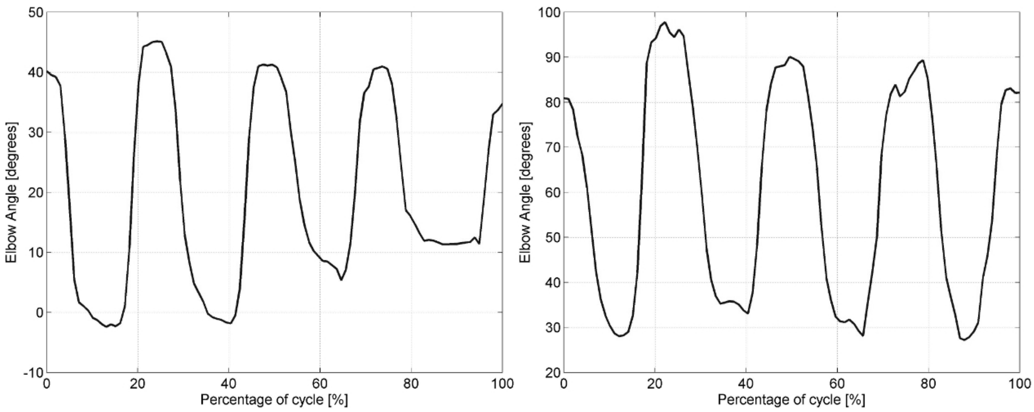

Figure 2. Elbow flexion (+) / extension (-) angle for a subject reporting fatigue during the 3rd and 4th repetition (left) and for a subject who reported no susceptibility to fatigue (right). The task considered was Reaching to the contralateral side and is described in Table 1.

Limits of the present study were the restriction in the number of subjects and the number of measurement occasions. These should be both addressed in further investigations on the clinical value of the system. In this study the test group consisted of MS subjects rather than of individuals with no impairment. This choice was made to understand the statistical consistency of the clinical measurements done using the MMAAS. In conclusion the results are comparable to those found in 3D gait using optoelectronic systems as far as the *ICC* is concerned, but should be kept in perspective by taking into account the *SEM* for specific movements. A system with reliability and validity comparable to that of an optoelectronic motion capture equipment would facilitate the assessment of patients outside laboratory setting and make home monitoring more robust. Future developments will be focused on a validity study and on extending the clinical reliability study to a group of subjects suffering from stroke.

Table 1. Test-retest reliability results during selected activities.

Activity	***Parameter***	***ICC***	***SEM (degrees)***
Sitting with arm and hand in the anatomical position, abduct the arm up to 120º and return to the initial position	Shoulder Abduction/Adduction *AROM* (between thorax and arm)	0.866 *(p<0.01)*	7.7
“	Max Shoulder Abduction	0.918 *(p<0.01)*	7.8
Sitting with arm and hand in the sagittal plane, flex the arm up to 120º and return to the initial position	Shoulder Flexion/Extension *AROM* (between thorax and arm)	0.808 *(p<0.05)*	11.0
“	Max Shoulder Flexion	0.812 *(p<0.05)*	7.9
Sitting with elbow flexed at 90º, execute full supination-pronation	Elbow Pronation/Supination *AROM*	0.764 *(p<0.05)*	10.9
Sitting with elbow flexed at 90º, reach from middle to contralateral side at arm length and return to the initial position. Target was at shoulder height and one shoulder width	Throax Flexion/Extension (relative to grounded support)	0.795 *(p<0.05)*	2.5
“	Shoulder Flexion/Extension *AROM*	0.782 *(p<0.05)*	5.7
“	Elbow Flexion/Extension *AROM*	0.916 *(p<0.01)*	4.1
“	Max Elbow Flexion	0.809 *(p<0.05)*	7.1
Sitting with elbow flexed at 90º, reach from middle to mouth and return to the initial position	Elbow Flexion/Extension *AROM*	0.690 *(p<0.05)*	4.9
“	Max Elbow Flexion	0.737 *(p<0.05)*	6.1

5. ACKNOWLEDGMENT

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