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Motion capture of the upper extremity during activities of daily living in patients with spastic hemiplegic cerebral palsy

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ABSTRACT

Investigations using motion capture to analyze limitations in range of motion (ROM) of the upper extremity in adults with cerebral palsy (CP) are scarce. To evaluate the influence of those limitations on activities of daily living (ADL) and to determine potential mechanisms of compensation, we investigated 15 adults with hemiplegic CP using motion capture while they performed 10 defined ADLs. Data from the nonaffected body side and those from an age-matched able-bodied group were also collected and compared with our subjects. We measured motion of the elbow, shoulder, and trunk and found significant differences in ROM at these sites. The most pronounced reduction in ROM was observed distally in supination and pronation of the elbow. Here, the affected body side of the adults showed a reduction in supination of 45° compared to the able-bodied group. Furthermore we found a correlation between the Manual Ability Classification System (MACS) and the limitations in ROM. In summary, adults with spastic, hemiplegic CP show limitations in ROM accentuated distally during ADLs. The MACS gives conclusive information about those limitations.

1. Introduction

Cerebral palsy (CP) is induced by a nonprogressive neurological disorder of the infantile brain that adversely affects muscle tone, causing spasticity, poor balance and muscle control and a dependence on primitive reflex patterns for ambulation [1]. The clinical features of CP can be subdivided into tetraplegic, diplegic, and hemiplegic types. Hemiplegic CP, in particular, is caused predominantly by unilateral damage of the developing brain [2], which leads to unilateral, asymmetric muscle tone abnormalities, and deformities. As a consequence patients with hemiplegic CP show unilateral, irregular movements and limitations in range of motion [2]. The severity of this impairment is affected by the extent of the primary, central lesion. Most of these patients are able to walk and handle their daily life, but have difficulties with fine motor skills [1,3].

Meanwhile, marker-based, three-dimensional gait analysis to record and investigate movement of the lower extremity is used routinely. In contrast no standardized method is available to detect and specify disorders in movement of the upper extremity. Only a few publications have analyzed movement and activities of daily living (ADL) of the upper extremity in patients with CP via motion capture [4–6]. Most of these studies used simple activities of daily living such as movement of hand to mouth or movement of hand to the contralateral shoulder to reflect the range of motion of the upper extremity [7]. To evaluate the influence of limitations in range of motion of the upper extremity on the activities of daily living and to determine potential mechanisms of compensation objectively, multifunctional movements need to be analyzed in a standardized manner. In a previous study we defined 10 movements in daily living, which were tested and analyzed in a non-CP control group [8]. Publications comparing motion of the upper extremity in patients with CP to those of a non-CP control-group do exist, but most of them are limited to children [3,5,6,9,10]. Here, several authors reported that longer movement durations as well as multiple restrictions in range of motion of the elbow with compensatory increases in trunk movement in performing tasks such as “reach to touch” or “reach to grasp” are found in children with hemiplegic CP as compared to a healthy control group. Furthermore, the limitations in range of motion were accentuated distally [5,7,10,11]. In contrast, investigations analyzing limitations in range of motion of the upper extremity in adults with CP are scarce [7]. As a part of daily life, the workplace and the respective manual tasks that are required these are important, especially in adults with CP. Investigations analyzing single manual tasks are available [5,10], but objective data analyzing a correlation between the functional impairment in a representative group of ADLs and the detected limitation of range of motion in the movement analysis as well as publications analyzing a connection

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between spasticity and abnormal kinematics of the upper extremity are still lacking.

The purpose of the present study, therefore, was to describe and analyze the range of motion of the upper extremity in patients with hemiplegic CP by using three-dimensional motion analysis and to compare the results to those of a group of able-bodied subjects. We aimed to determine whether those patients with a restricted passive range of motion of the upper extremity show limitations in 10 selected activities of daily living. Another objective was to analyze a potential correlation of the functional handicap in the Manual Ability Classification System (MACS) and the Disability of Arm, Shoulder, and Hand Index (DASH) and determine whether compensatory mechanisms resulting from potential limitations in range of motion are present.

2. Methods

Between May and November 2010, 15 adults with a spastic hemiplegic CP [nine male, six female; mean age 28 years (minimum 18 years, maximum 52 years)] were examined bilaterally and compared to an able-bodied group of 15 normally developed subjects (eight male, seven female; mean age 30 years (minimum 20 years, maximum 59 years). Six of the CP patients were handicapped on the right side while in nine of them the left side was affected. Inclusion and exclusion criteria as well as activities of daily living that were tested are listed in Table 1.

The passive range of motion of shoulder and elbow joints was tested. Furthermore, the patients were classified according to MACS [12]. The DASH questionnaire was applied for each patient and a correlation between the MACS and DASH index was calculated [13,14].

3D motion capture was performed, applying the Heidelberg Upper Extremity model (HUX; [15]). Reference markers were mounted on anatomical landmarks of the shoulder and elbow. The patients were instructed to perform bilateral shoulder flexion/extension, shoulder abduction, and elbow flexion/extension for dynamic calibration and location of the elbow and shoulder joint. Following the calibration, the subjects were asked to perform 10 ADLs as listed in Table 1. Those included uni- and bimanual tasks such as "move a box on a desk" as illustrated in Fig. 1. The control group used their nondominant upper extremity to perform the unimanual tasks. For a more detailed description of the motion capture, see [8].

End positions of the shoulder and elbow were determined for each subject and ADL. Data from three repeated movement measurements were averaged. The maximum–minimum values were also calculated. In addition, the global maximum and minimum values across all 10 ADLs were calculated for each subject.

2.1. AROM

An "Activity of daily living related range of motion" (AROM) was introduced to facilitate the analysis of the range of motion and limitations during the ADLs. For each subject and joint direction, the global maximum and minimum in joint position reached during the 10 ADLs were documented.

The AROM was checked for significant differences between the different MACS groups and between the hemiplegic and the able-bodied group. A correlation analysis was performed.

2.2. Study design

Two groups (group 1 is subdivided into Group A and Group N):
Group 1: adult patients with spastic, hemiplegic CP

Table 1
Inclusion and exclusion criteria. Further the tested activities of daily living (ADL) are shown.

Inclusion criteria	Exclusion criteria	Tested ADL
Age > 18 years	Cognitive impairment	Eat with a spoon Drink water from a glass
Spastic hemiplegic CP	Visual impairment	Pour water Turn the page of a book
MACS 1–3	Prior surgery in the last 6 months	Type on a keyboard
		Use a phone
	Botulinium injection during the last 3 month	Move a box on a desk (Fig. 1)
		Comb hair Intimate care/use toilet Wash hands

Fig. 1. Person of group C performs the task "move a box on a desk".

- Group A: analysis of the affected side
  - MACS level 1: five patients
  - MACS level 2: six patients
  - MACS level 3: four patients
- Group N: analysis of the nonaffected side

Group 2: healthy, adult, able-bodied subjects (analysis of the nondominant side)
- Group C (control)

2.3. Statistical analyses

Standard statistical analyses and multiple regressions were conducted ($p < 0.05$). *T*-test was used to compare groups A, N, and C. For correlating MACS level, DASH index, and limitations in range of motion Spearman's–Rho test was applied. The Kolmogorov–Smirnow test was performed to test normal distribution.

3. Results

3.1. AROM

The range of motion of elbow, shoulder, and trunk in the different directions of each group are shown in Fig. 2.

In group N the values of external rotation and extension of the shoulder were reduced compared to group C significantly. All other measured parameters for shoulder, elbow and trunk showed no significant differences in range of motion of elbow, shoulder, and trunk between the nonaffected upper extremity of the analyzed patients (group N) and the control group (group C) during any ADL. Both groups reached maximum deflection of each direction during the same ADLs. For example, a maximum range of motion of elbow flexion was detected while combing the hair.

3.1.1. Elbow

3.1.1.1. Pronation/supination. The patients of group A showed a pronounced handicap in elbow supination with a reduction of the AROM pronation/supination in total (Fig. 2). While group N and group C had maximum supination during the washing hands activity, group A showed maximum supination during different ADLs.

3.1.1.2. Flexion/extension. Group A showed a reduction of 5° (compared to group N) and 6° (compared to group C) in elbow flexion. Compared to the control group, the extension of the elbow in group A was reduced by 15°. In total the AROM of group A was 14° lower than in group N and 21° lower than in group C (Fig. 2). Nevertheless there was no significant difference between group N and group C.