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Review

Review of quantitative measurements of upper limb movements in hemiplegic cerebral palsy

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ABSTRACT

This review provides an overview of results found in literature on objective measurements of upper limb movements in children with hemiplegic cerebral palsy (HCP). Seventeen articles were selected following a systematic search. Analysed tasks varied from simple reaching and gross motor functions to complex, fine motor tasks. Spatiotemporal characteristics have been extensively studied and longer movement durations, slower movement speed and reduced trajectory straightness at the affected upper limb, compared to the non-affected side or healthy children, were most frequently reported. Joint kinematics has been far less studied. The limited data confirm the clinical impression of children with HCP using less elbow extension and supination to reach for an object, which is compensated by increased trunk flexion. Increased trunk involvement was also reported during gross motor functions. Although three-dimensional (3D) movement analysis seems promising to provide additional insights in the pathological upper limb movements observed in HCP, future standardisation of the entire protocol is crucial. No consensus exists on the procedures for data collection, processing, analysing and reporting of results, or what upper limb tasks should be assessed. The International Society of Biomechanics recently proposed recommendations on the definition of upper limb joint coordinate systems and rotation sequences. These guidelines were not yet applied in these studies. Although the diverse methodological approaches used in the studies complicate the comparison of published results, some general conclusions could be drawn. A further standardisation of the protocol for 3D upper limb movement analysis will provide the foundation for comparable and repeatable results and eventually facilitate the selection and planning of treatment interventions.

1. Introduction

Hemiplegia is the most common form of cerebral palsy (CP) among children born at term and second to diplegia among preterm infants [1]. Children with hemiplegic CP (HCP) are faced with various motor and sensory impairments, e.g. muscle weakness, spasticity, lack of selective motor control and sensory disturbances, with the upper limb more involved in about half of the children [2]. These upper limb impairments contribute to the difficulties experienced when reaching, grasping and manipulating objects [2–4]. Deficiencies in one or more of these basic functions hinder proper performance of activities of daily living (ADL) and as such may impact on independency and quality of life of the hemiplegic child.

Adequate treatment planning is imperative, though requires an extensive knowledge of all upper limb dysfunctions. A clinical assessment, combined with objective and quantitative measurements of the upper limb could provide the necessary insights. Current methods of clinical assessment evaluate both motor (range of motion, spasticity, muscle strength) and sensory impairments (exteroception, proprioception, two-point discrimination, stereognosis). Available clinical scales primarily assess the quality of upper limb movement during several functional tasks (e.g. Melbourne Assessment of Unilateral Upper Limb Function [5], Quality of Upper Extremity Skills Test [6], Shriners Hospital for Children Upper Extremity Evaluation—SHUEE [7]). These scales are widely used to evaluate upper limb function in HCP as they are easy to administer with a straightforward scoring system. However, the main disadvantage of these qualitative outcome

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measures is that they provide a subjective description of the upper limb task performance based on the assessor who visually scores the range and quality of movement during task execution. Moreover, some of these outcome assessments have been criticised for not being sensitive enough to detect clinically meaningful change in upper limb function after intervention [8]. To provide a more detailed and objective description of upper limb movement patterns, quantitative measurements are needed. Quantitative outcome measures are measurement methods that provide an objective description of the upper limb task performance based on technical measures and calculations, e.g. joint angles, movement duration, and speed. Three-dimensional (3D) movement analysis is a powerful tool for such quantitative assessment of a movement in all degrees of freedom. The 3D analysis of the lower limbs, e.g. gait analysis, has already widespread use in biomechanical research and many clinical applications. 3D analysis thus seems valuable to provide additional information on the upper limb movement patterns observed in HCP and to better understand the resulting compensations.

Nonetheless, the transfer of knowledge and experience gained from gait analysis to the upper limb turns out to be difficult. The lack of cyclic movements, the variety of functions and abundant degrees of freedom make the upper limb analysis considerably more complex [9]. To promote the standardisation of 3D upper limb movement analysis, the International Society of Biomechanics (ISB) recently published some recommendations on the definition of joint coordinate systems and rotation sequences for the trunk, shoulder, elbow, wrist and hand [10]. These recommendations are based on the ISB standard for reporting kinematic data published by Wu and Cavanagh [11]. A definition for the local axis system in each articulating segment or bone is provided for each joint, while respecting the upper limb anatomy and clinical interpretation of joint movements [10]. Upper limb joint coordinate systems and rotation orders are chosen to minimise the possible occurrence of singularity problems. For the description of shoulder rotations, this rotation order implies gimbal lock at 0° and 180° of elevation. If a movement around these positions is of interest, other rotation sequences are recommended, e.g. the sequence flexion–abduction–rotation is recommended for movements in the sagittal plane, and abduction–flexion–rotation for movements in the frontal plane [12]. However, a consensus on the entire protocol for 3D upper limb movement analysis is still required in order to facilitate the comparison of results and encourage communication among researchers and clinicians.

In the past decade, several studies have been published on the quantification of upper limb movements in HCP. The aim of this review was to give a comprehensive summary of results found in literature on objective measurements of upper limb movements in HCP. Clinically relevant results on spatiotemporal and/or joint angle movement characteristics will be discussed. To promote further standardisation of the protocol for 3D upper limb movement analysis in HCP, some methodological reflections will also be put forward.

2. Literature search

Papers were selected from following electronic databases: PubMed, CINAHL, Cochrane Library and Web of Science (until December 2007), using keywords for cerebral palsy ('cerebral palsy', 'CP') and the upper limb ('upper limb', 'upper extremity'). To limit results, these terms were combined with a search for movement patterns, including 'biomechanics or kinematics', 'movement patterns' and 'reach or grasp'. To ascertain no study was missed, an online search of journals likely to contain target articles and a manual screening of the reference lists of all included studies was conducted.

Inclusion criteria were: (1) hemiplegic cerebral palsy; (2) objective description of upper limb movement characteristics (spatiotemporal and/or joint angles); (3) full papers. Studies only describing a biomechanical upper limb model or measurement procedure without results on movement characteristics or studies primarily assessing anticipatory movement planning and motor control (feed forward and feedback control) were not considered. Studies were also excluded if they were not published in English. Two independent reviewers screened title and abstract of the selected papers for inclusion. In case of disagreement, the full article was read and discussed until consensus was reached.

The database search identified 96 articles; another eight articles were retrieved from the online journal search and reference screening. Based on the predefined inclusion and exclusion criteria, 17 articles were selected for inclusion in the current review. Study details are summarised in Tables 1–4.

Table 1
Study population.

Study	Subjects	Age range	Upper limb impairment	Brain lesion	Clinical assessment
Coluccini et al. [13]	HCP spastic (*n* = 5)	–	Mild–moderate	PVL	Melbourne Assessment
Rönnqvist and Rösblad [17]	HCP (*n* = 11)	5–12	Mild–moderate	–	–
Kreulen et al. [18]	HCP (*n* = 10)	11–27	–	–	AROM
Mackey et al. [19]	HCP spastic (*n* = 10)	10–17	–	–	–
Wright et al. [14]	HCP spastic/dystonic (*n* = 8)	4–9	–	–	–
Wright et al. [15]	HCP spastic/dystonic (*n* = 8)	4–9	–	–	–
Steenbergen and Meulenbroek [20]	HCP (*n* = 5)	14–18	–	–	Purdue Pegboard-Box&Block test-ASS
van der Heide et al. [16]	HCP preterm (*n* = 34)	2–11	Mild–moderate–severe	PVL (mild–severe)	ASS-PEDI
Ricken et al. [23]	HCP spastic (*n* = 10)	5–11	–	–	–
Volman et al. [24]	HCP spastic (*n* = 12)	8–14	Mild–moderate	–	–
van Thiel and Steenbergen [22]	HCP (*n* = 8)	15–20	Mild–moderate	–	–
Steenbergen et al. [21]	HCP spastic (*n* = 6)	14–19	–	–	–
Fitoussi et al. [26]	HCP (*n* = 15)	7–15	–	–	A/PROM-ASS-sensibility-Zancolli-Corry classif
Mackey et al. [25]	HCP spastic (*n* = 10)	5–15	–	–	–
Kreulen et al. [28]	HCP (*n* = 10)	11–27	–	–	AROM
Kreulen et al. [27]	HCP (*n* = 10)	5–29	–	–	AROM
Hurvitz et al. [29]	HCP spastic (*n* = 9)	7–16	–	–	A/PROM-MAS-PEDI-FIM-Purdue Pegboard-BOMPT

HCP: hemiplegic cerebral palsy; PVL: periventricular lesion; AROM: active range of motion; PROM: passive range of motion; ASS: Ashworth Scale for Spasticity; MAS: modified ASS; PEDI: Pediatric Evaluation of Disability Inventory; TPD: two-point discrimination; FIM: Functional Independence Measure; BOMPT: Bruininks-Oseretsky Motor Proficiency Test.
–, not reported.