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THE ARM PROFILE SCORE: A NEW INDEX TO QUANTIFY UPPER LIMB MOVEMENT PATHOLOGY

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SUMMARY

Although three-dimensional movement analysis is being increasingly used to evaluate upper limb movements, information on how to interpret the complex data is still missing.

This paper introduces a new summary index, the "Arm Profile Score" (APS), to evaluate upper limb movement quality based on kinematic data. Intra-session reliability and the correlation between the APS and clinical measures of motor impairment were assessed in a group of 20 children with hemiplegic cerebral palsy. Intra-session variability was low. The APS showed good correlations with the measures of distal muscle tone, distal manual muscle strength and grip strength.

This study provided a sound base to use the APS to evaluate movement quality in hemiplegic children. Further study will need to confirm its value as an outcome measurement.

INTRODUCTION

In children with hemiplegic cerebral palsy (HCP), basic upper limb functions such as reach, grasp and release objects are often compromised. To improve their functionality and independency in daily life, a well-targeted treatment planning based upon the child's individual needs, is crucial. This in turn requires an accurate and complete evaluation of the upper limb. Although three-dimensional movement analysis is being increasingly used to evaluate upper limb movements, information on how to interpret the complex data is still missing. We proposed a measurement procedure for UL-3DMA, including the recommendations from the International Society of Biomechanics (ISB) [1]. Given the variety of upper limb functions, a comprehensive set of tasks was selected to represent clinically relevant activities for children with HCP. The procedure was proven reliable in typically developing children (TDC) [2] and children with HCP [3]. To establish its true value as a clinical tool, a next step is to further expand our understanding of the information obtained from this 3DMA. As a first step in the interpretation and determination of the clinical relevance of the kinematic data obtained from the UL-3DMA in children with HCP, this paper proposes the "Arm Profile Score" (APS). Face and construct validity are presented through the construction of the index and by relating it with other clinical upper limb measurements.

METHODS

Twenty children with congenital HCP (11 boys, 9 girls; age 10.9 years ± 2.9 years) and 20 individually age-matched TDC with no history of musculoskeletal or neurological problems (11 boys, 9 girls; age 10.9 years ± 3.0 years) were selected. Data from 20 TDC formed the reference database for this study. Ethical approval was granted by the University Hospital Ethics Committee (Leuven, Belgium). Written informed consent was signed by all children's parents.

Marker tracking was done with Vicon-camera's (Oxford Metrics Group, UK). Kinematics for the trunk, scapula, shoulder, elbow and wrist were calculated with BodyMech (www.bodymech.nl) and additional custom-written routines (Matlab®) [2-4]. The movement protocol consisted of three reach tasks; two reach-to-grasp tasks; and three gross motor tasks. Children were seated in a custom-made chair with individually adjustable reaching distance/height and sitting position. Tasks were executed with the non-preferred arm at self-selected speed, i.e. the hemiplegic arm in children with HCP and the non-dominant arm in TDC.

Passive range of motion (PROM) at the level of the shoulder, elbow and wrist was assessed with a universal goniometer. All joint movements were graded dichotomously (>10° decreased PROM). Muscle tone was evaluated with the Modified Ashworth Scale for spasticity [5] at the shoulder, elbow, wrist and fingers. Muscle strength at the shoulder, elbow, and wrist was scored according to the Manual Muscle Testing [6]. For each modality, the total score and subscores were calculated. Grip strength was evaluated with a Jamar-dynamometer. The ratio of the mean of three maximum voluntary contractions of the hemiplegic versus the non-hemiplegic hand was reported. Interrater and test-retest reliability of these assessments have been established in children with HCP [7].

The Arm Variable Score (AVS), Arm Profile Score (APS) and Arm Movement Analysis Profile (A-MAP) were calculated following the mathematical construction of the Gait Profile Score (GPS), as described by Baker et al. [8].

The AVS gives an index of deviation for a single joint angle and is calculated as the root mean square error (RMSE) between the point-by-point comparison of the joint angle of the hemiplegic child and that of the reference database (20 individually age-matched TDC).

The RMSE average of all 13 joint angles equals the APS, an index summarizing the overall severity of upper limb movement pathology. The APS and 13 AVS-scores are presented together in a bar chart, creating the "Arm Movement Analysis Profile" (A-MAP, Fig. 1). The A-MAP thus provides insight into the contribution of each variable to an elevated APS.

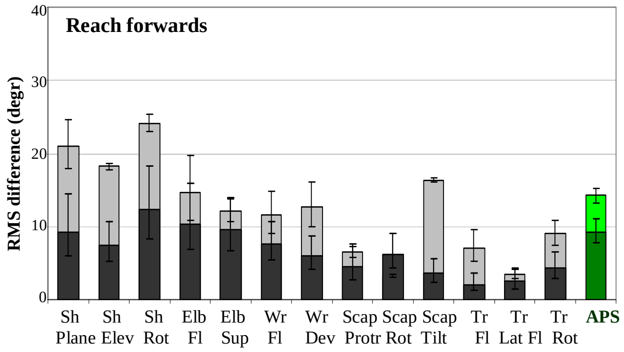

Figure 1: The Arm Movement Analysis Profile (A-MAP) for an 11 year old boy with right HCP. Each grey column corresponds to the Arm Variable Score of a single joint angle. The height represents the RMS difference across time between an individual movement cycle and the average movement cycle from TPD (black columns). The APS is displayed on the rightmost column (green), and is the average RMS difference across time for all kinematic variables.

Tr: trunk; Sc: scapula; Sh: shoulder; Elb: elbow; Wr: wrist

The APS is a Euclidian distance measure, likely to have a Chi-square distribution. Results are therefore reported in terms of median values and inter-quartile ranges (IQR) [8]. Intra-session variability was calculated as the median IQR of the APS for each child. Spearman-rank correlation coefficients were calculated between the APS and the total scores and sub-scores of PROM, muscle tone, manual muscle strength and grip strength.

Correlation coefficients > 0.70 were considered to indicate high, 0.60-0.70 good, 0.50-0.60 moderate, 0.40-0.50 fair and < 0.40 weak or no association [9]. The level of significance was set at 0.05. Statistical analyses were carried out using SAS E-Guide 4.1 (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

For the intra-session variability, the median IQR of the APS for every task ranged from 0.62°-1.35°, whereby 87.5% of all children had an IQR< 2°. These low IQR indicate that the APS can be used as a reliable measure within a single session for the different tasks

Spearman-rank correlations between the motor impairments and the APS are given in Table 1. No significant correlations were found for PROM. Moderate to high correlations were found between the APS and muscle tone at the wrist for all but one task (ρ 0.56-0.81) and between the APS and muscle strength of the forearm and grip strength for the reach and reach-to-grasp tasks (ρ 0.54-0.76). Total strength and wrist strength correlated highly with the APS for forward reaching and spherical grasping (ρ 0.64-0.71).

Current results pointed towards the role of distal muscle tone and strength in upper limb movement quality, suggesting that treatments aimed at distal tone reduction or strength training, might influence the AVS.

Table 1: Spearman rank correlations per task between motor impairments and the APS

PROM	**RF**	**RS**	**RU**	**RGS**	**RGV**	**HTM**	**HTH**	**HTS**
Total	0.22	0.24	0.15	0.25	0.17	-0.16	0.01	0.12
Shoulder	0.05	0.01	-0.00	0.12	0.02	-0.19	0.01	0.15
Elbow	0.15	0.26	-0.02	0.11	0.18	-0.16	0.16	0.04
Wrist	-0.01	-0.03	-0.03	0.08	-0.09	-0.15	-0.34	-0.23
MAS	**RF**	**RS**	**RU**	**RGS**	**RGV**	**HTM**	**HTH**	**HTS**
Total	0.52°	0.33	0.40	0.54°	0.45°	0.14	0.22	0.26
Shoulder	0.28	0.13	0.05	0.30	0.27	-0.01	0.16	0.14
Elbow	0.05	-0.15	0.09	0.03	-0.03	-0.24	-0.12	-0.16
Wrist	0.69$^{¥}$	0.66*	0.69$^{¥}$	0.81§	0.64*	0.56°	0.37	0.62*
MMT	**RF**	**RS**	**RU**	**RGS**	**RGV**	**HTM**	**HTH**	**HTS**
Total	-0.71$^{¥}$	-0.48°	-0.57*	-0.70$^{¥}$	-0.65*	-0.43	-0.48°	-0.57*
Shoulder	-0.31	-0.27	-0.22	-0.27	-0.44	-0.21	-0.20	-0.24
Elbow	-0.57*	-0.32	-0.49°	-0.61*	-0.44	-0.22	-0.27	-0.40
Forearm	-0.72$^{¥}$	-0.54°	-0.63*	-0.76§	-0.71$^{¥}$	-0.58*	-0.58*	-0.62*
Wrist	-0.64*	-0.40	-0.39	-0.70$^{¥}$	-0.57*	-0.30	-0.43	-0.45°
GRIP	**RF**	**RS**	**RU**	**RGS**	**RGV**	**HTM**	**HTH**	**HTS**
Ratio	-0.67*	-0.55°	-0.56°	-0.73$^{¥}$	-0.70$^{¥}$	-0.60*	-0.48°	-0.66*

§ <0.0001; $^{¥}$ <0.001; * <0.01; °<0.05

RF: reach forwards; RS: reach sideways; RU: reach upwards; RGS: reach to grasp a spherical object; RGV: reach to grasp a vertically oriented object; HTM: hand to mouth; HTH: hand to head; HTS: hand to shoulder

PROM: passive range of motion; MAS: modified Ashworth Scale for Spasticity; MMT: manual muscle testing

CONCLUSIONS

This study introduced and validated the APS, a summary index to grade the severity of movement pathology based on kinematic data. The APS can be decomposed into deviating scores per joint angle (AVS). Results showed good correlations between the APS and other clinical upper limb measures, providing a sound base for its use as a tool to evaluate movement quality in hemiplegic children. Further study will need to confirm its value as an outcome measurement, as well as its applicability for other pathologies, e.g. quadriplegic CP.

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