The Contralateral Unimpaired Arm as a Control for Upper Extremity Kinematic Analysis in Children With Brachial Plexus Birth Palsy

Jonathan S. Wang, BS, Kyria Petuskey, MS,† Anita M. Bagley, PhD,†‡ Michelle A. James, MD,†‡ and George Rab, MD†‡*

Background: Kinematic studies of abnormal upper extremity (UE) motion provide the unique and valuable perspective of motion analysis during simulated functional tasks. However, they require comparison with healthy control data. Obtaining this control data usually entails testing a healthy population, which can be costly and time consuming, requiring separate subject inclusion criteria, recruitment, and institutional review board approval. The kinematics of the unimpaired UE in people with unilateral impairment have not been analyzed and documented. The purpose of this study was to compare UE motion during activities of daily living in the contralateral unimpaired arm of subjects with brachial plexus birth palsy (BPBP) with an age-matched control population.

Methods: The contralateral arms of 40 subjects with unilateral BPBP were compared with the arms of 15 healthy subjects using an established 3-dimensional upper extremity motion analysis protocol.

Results: There were no significant differences between the 2 arms on 17 of 19 motion parameters. The 2 differences that were statistically significant ($P < 0.05$) were not clinically meaningful.

Conclusions: The contralateral arms of children with unilateral BPBP can be used as controls for future upper extremity motion analysis studies of this population, and further recruitment of age-matched controls is not necessary for comparison with 5- to 8-year-old children with BPBP.

Level of Evidence: This is a retrospective study, investigating whether the contralateral unimpaired arm can be used as a control for upper extremity kinematic analysis in children with BPBP, with a level 2 evidence rating.

Key Words: 3-D kinematics, brachial plexus birth palsy, contralateral arm, motion analysis, upper extremity

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Brachial plexus birth palsy (BPBP) occurs in 0.4 to 4 cases per 1000 live births[1–6] when the brachial plexus is injured during delivery.[1–3] Brachial plexus birth palsy is usually unilateral, with the incidence rate for bilateral BPBP being 0.073 cases per 1000 live births.[7] It is associated most commonly with elbow and shoulder weakness caused by upper trunk (C5, C6, ±C7) injury.[3,4,6,8] These deficits limit upper extremity (UE) motion necessary to perform activities of daily living (ADL), such as grooming and personal hygiene.

Different methods exist to assess and evaluate the condition of patients with BPBP. However, no one technique has been routinely used to document multiplanar functional limitations in this patient population. Observational methods, such as the Mallet classification, Toronto test score, and Hospital for Sick Children Active Movement Scale, are based on subjective visual assessments of the patient,[9] and goniometric measurements provide static single-plane measurements for shoulder analysis but do not assess the position of the arm during ADL or other activities.[10] Three-dimensional upper extremity motion analysis (UEMA) offers an objective assessment of upper extremity motion during simulated functional tasks.[11,12] Previous UEMA studies have shown that this technique measures the differences between the involved arms of children with BPBP and the arms of healthy controls,[13] and between the involved arms of children with axillary burns and the arms of healthy controls.[14]

Recent research on BPBP has focused on better understanding the functional deficits of the patients' involved arms. However, there is limited research on the contralateral arm of children with unilateral BPBP, which is normally the dominant side.[15] For children with unilateral BPBP, if the UEMA parameters of the contralateral limb do not differ from those of healthy controls, this limb could serve as the own age-matched control of the patient with BPBP, allowing for comparisons to be made without testing a healthy population in future UEMA studies.

The purpose of this study was to determine whether upper extremity motion of the contralateral arms of children with unilateral BPBP during simulated ADLs differs from that of age-matched healthy control subjects.

METHODS

Kinematic studies were performed on both arms of 40 patients with unilateral BPBP who were candidates for shoulder external rotation tendon transfer and of 15 healthy control subjects aged 5 to 8 years using a previously described protocol[11] between May 1999 and December 2004. The mean age was 6.0 years (SD, ±1.5 years) in the BPBP group and 6.5 years (SD, ±1.4 years) in the control group. There were

From the *University of California Davis School of Medicine, Davis, †Shriners Hospitals for Children–Northern California; and ‡Department of Orthopaedic Surgery, University of California Davis Medical Center, Sacramento.

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Reprints: Michelle A. James, MD, Shriners Hospitals for Children–Northern California, 2425 Stockton Blvd, Sacramento, CA 95817. E-mail: mjames@shrinenet.org.

TABLE 1. Point of Task Achievement (in Degrees) for Selected ADL

	High Reach			Hand to Head			Hand to Back Pocket		
	Contralateral (n = 37)	Healthy Controls (n = 15)	P	Contralateral (n = 39)	Healthy Controls (n = 15)	P	Contralateral (n = 36)	Healthy Controls (n = 15)	P
Shoulder flexion	134 (14)	141 (16)	0.14	88 (16)	87 (16)	0.97	−49 (9)	−50 (6)	0.65
Shoulder abduction	38 (12)	37 (15)	0.78	40 (16)	42 (13)	0.59	1 (7)*	7 (11)	0.04
Shoulder external rotation	−20 (16)	−21 (19)	0.77	−32 (19)	−33 (15)	0.88	−32 (10)	−33 (12)	0.65
Elbow flexion	23 (11)	17 (8)	0.09	103 (10)	103 (8)	0.99	59 (19)*	72 (15)	0.02
Forearm pronation	49 (30)	49 (33)	0.96	−46 (20)	−49 (12)	0.59	−71 (16)	−68 (18)	0.59
Trunk flexion	−24 (8)	−20 (10)	0.13	−23 (6)	−20 (8)	0.16	−16 (6)	−14 (4)	0.22
Neck flexion				7 (10)	8 (10)	0.82			

*Statistically significantly different ($P < 0.05$).
Values are expressed as mean (SD).

17 boys and 23 girls in the BPBP group, and 9 boys and 6 girls in the control group. In both groups, the hand dominance of each patient was determined by asking which hand was used by the patient to write. Indications for shoulder external rotation tendon transfer included lack of active shoulder external rotation in abduction, passive shoulder external rotation greater than neutral in adduction, active shoulder abduction greater than 60 degrees, and good wrist and hand function.[16] This case-control study was approved by the University of California Davis institutional review board.

An 8-camera ExpertVision motion analysis system (Motion Analysis Corporation, Santa Rosa, Calif) was used to record UE kinematic data. A 10-segment biomechanical model was used to calculate kinematic data derived from 18 reflective markers attached to each subject over bony landmarks of the upper extremities and trunk.[11] Each subject was asked to perform 5 movements intended to simulate specific ADLs. Kinematic data relevant to BPBP upper extremity limitations were reported for 3 of the 5 simulated ADLs. This data set included high reach (raising the hand as high as possible to simulate reaching overhead climbing), hand to head (placing the hand on top of the head to simulate grooming face and hair), and hand to back pocket (touching the back pocket to simulate performance of perineal hygiene). Six joint movements (shoulder flexion/extension, shoulder abduction/adduction, shoulder external/internal rotation, elbow flexion/extension, forearm pronation/supination, and trunk flexion/extension) were analyzed during the performance of 2 tasks (high reach and hand-to–back pocket movements), and 7 movements were analyzed during hand-to-head movement (neck flexion was analyzed for hand-to-head movement only because neck movement was not as relevant for the other ADLs), providing 19 different joint measurement parameters. The starting position for each movement was defined as standing comfortably with arms resting at sides. Each subject was asked to perform each movement, 1 arm at a time, dominant side first, and then to return the arm back to starting position. Kinematic data were recorded throughout the entire movement as degrees of angular displacement. Positive values represented flexion, abduction, external rotation, and pronation, whereas negative values represented extension, adduction, internal rotation, and supination. The data were statistically analyzed at the point of task achievement (PTA), defined as the instant the ADL was accomplished. This point was reliably determined using movement graphs. Two-tailed Student *t* tests were used for analysis. Type I error was set at 0.05.

RESULTS

A comparison between the joint positions at the PTA of the contralateral arms of patients with BPBP and those of the dominant arms of the healthy control population is reported in Table 1. Data for all the upper extremity joint motions (including PTA, range of motion, and composite graphs) collected for all 5 ADLs is available upon request from the corresponding author. For 17 of 19 joint position comparisons, there were no statistically significant differences between these 2 groups. Differences between shoulder abduction and elbow flexion during the hand-to–back pocket movement were statistically significantly different. Children with BPBP used an average of 1-degree shoulder abduction and 59 degrees of elbow flexion to reach their back pocket with their unimpaired arm, compared with 7 degrees of shoulder abduction and 72 degrees of elbow flexion for healthy controls.

There was an outlier in our healthy population for shoulder abduction during the hand-to–back pocket movement. This subject's PTA (37 degrees) was more than 2 SDs from the control group's mean of 7 degrees. However, on examination of the videotape of this subject's test session, there did not seem to be any errors on how this subject performed the movement; thus, the data were kept in our study.

DISCUSSION

The kinematic measurements of contralateral arms of children with unilateral BPBP during 3 simulated ADLs were very similar to those of age-matched controls. The 2 differences found during hand-to–back pocket movement (6-degree difference in shoulder abduction and 13-degree difference in elbow flexion) are clinically insignificant. In addition, the outlier mentioned in the Results section increased the discrepancy between the shoulder abduction for the 2 groups during hand-to–back pocket movement. Thus, the results of this study indicate that the contralateral arm of children with unilateral BPBP can be used as a control.

This study has several weaknesses. A larger sample size of the healthy population would decrease the effect of an outlier on the results and provide greater power, and studying the condition of each child twice would make the data more reliable. All children with BPBP met the inclusion criteria for shoulder external rotation tendon transfer but they did not all have identical deficits; subcategorizing them further on the basis of the severity of their deficit might expose a difference in the contralateral arms of patients with more severe BPBP. Finally, comparing older age groups may reveal different results, based on the changes in shoulder anatomy with age.[17]

The results of this study support the hypothesis that the contralateral arms of patients with unilateral BPBP during ADL can be used as controls for future studies on this population, and further study of age-matched controls is not necessary for comparison with 5- to 8-year-old children with BPBP.

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