Coordination and Balance in Children with Birth-Related Brachial Plexus Injury: A Preliminary Study

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ABSTRACT

Purpose: Most children with severe birth-related brachial plexus injury (BRBPI) have some functional impairment, but information on the impact of BRBPI on coordination and balance is limited. The study's purpose was to determine whether children with BRBPI exhibit deficits in body coordination and balance.

Method: A prospective cohort study involving 39 children with BRBPI aged 5–15 years was conducted. Range of motion, strength, active movement, and balance and coordination motor skills were assessed using the Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), and the Movement Assessment Battery for Children—Second Edition (MABC-2). A self-report measure of physical disability, the Activities Scale for Kids—Performance Version (ASKp), was also administered. **Results:** Participants scored a mean of 44.72 on the BOT-2 Body Coordination composite subtest; scores can range from 20 to 80. Eleven participants (28.2%) scored below average on this test. Participants scored a mean of 7.3 on the Balance subtest of the MABC-2; scores can range from 1 to 19. Twenty-six participants (66.7%) scored below average on this test. Of 38 participants, 25 (65.8%) had an ASKp score indicating some level of disability (<95/100); we found a statistically significant difference in balance ($p = 0.007$) between these 25 participants and those without disability (ASKp score 95–100). **Conclusions:** The majority of our study population scored in the categories of at risk or significant difficulty for balance on the MABC-2. Balance rehabilitation may be a valuable treatment adjunct for children with BRBPI.

Key Words: birth injuries; brachial plexus; ataxia; paralysis; obstetric; postural balance.

RÉSUMÉ

Objet : La plupart des enfants qui ont une grave lésion du plexus brachial reliée à la naissance (LPBRN) ont une déficience fonctionnelle, mais l'information au sujet de l'effet de la LPBRN sur la coordination et l'équilibre est toutefois limitée. L'étude visait à déterminer si les enfants qui ont une LPBRN montrent des déficiences de la coordination et de l'équilibre. **Méthode :** On a procédé à une étude de cohorte prospective portant sur 39 enfants ayant subi une LPBRN âgés de 5 à 15 ans. On a évalué l'amplitude du mouvement, la force, le mouvement actif, l'équilibre et la coordination de la motricité au moyen du test de Bruininks–Oseretsky de la maîtrise de la motricité (BOT-2) et du test d'évaluation du mouvement chez les enfants (MABC-2). On a aussi administré une mesure autodéclarée de l'incapacité physique, la version de l'échelle des activités pour la performance des enfants (ASKp). **Résultats :** Les participants ont obtenu une moyenne de 44,72 comme score composite de la coordination du corps BOT-2, qui peut varier de 20 à 80. Onze participants (28,2%) ont obtenu un résultat inférieur à la moyenne. Les participants ont obtenu un résultat moyen de 7,3 au sous-test de l'équilibre du test MABC-2, résultat qui peut varier de 1 à 19; 26 participants (66,7%) ont obtenu un résultat inférieur à la moyenne. Sur 39 participants, 25 (65,8%) ont obtenu un résultat ASKp indiquant une certaine incapacité (<95/100); il y avait une différence statistiquement significative au niveau de l'équilibre ($p = 0,007$) entre ces 25 participants et ceux qui n'avaient pas d'incapacité (résultat ASKp de 95 à 100). **Conclusions :** La majorité des membres de la population à l'étude ont obtenu un résultat dans les catégories « à risque » ou « à difficultés importantes » au niveau de l'équilibre indiqué par le test MABC-2. Le rétablissement de l'équilibre peut constituer un traitement d'appoint valable pour les enfants qui ont une LPBRN.

Birth-related brachial plexus injury (BRBPI) is a complication associated with a difficult childbirth and traction to the infant's brachial plexus, a group of nerves that originate in the spinal cord of the neck and branch out toward the hands; motor nerves of the brachial plexus transmit

signals from the brain to the upper limb to control movement. Excessive traction to the child's head or arm in delivery can sometimes overstretch or tear the brachial plexus,^{1,2} resulting in partial or complete paralysis of the muscles of the upper limb. Diagnosis is mainly based on

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Contributors: All authors designed the study; collected, analyzed, and interpreted the data; drafted or critically revised the article; and approved the final draft.

Competing Interests: None declared.

This study received Telethon Grant funding from the British Columbia Children's Hospital Foundation.

Acknowledgments: The authors acknowledge Angie Kennedy and Ross Petersen for their assistance with grant proposal writing and for study set up and recruitment; Doug Courtemanche, Boris Kuzeljovic, Ruth Milner, and Jeffrey Yu for their assistance with methodology and statistics; and Anne Rankin for her critical review.

Physiotherapy Canada 2015; 67(2);105–112; doi:10.3138/ptc.2013-77

physical characteristics, ranging from mild weakness of the shoulder and elbow to a completely flail arm. Most commonly, only the upper nerves are involved, producing less weakness in the hand and wrist and more involvement of the shoulder and elbow (Erb's palsy). The reported incidence of brachial plexus palsy varies from 0.9 to 4.6 infants per 1,000 live births and is 1.2 per 1,000 in British Columbia, as reported by the Canadian Institute for Health Information.²⁻⁵

Although treatment strategies have become more sophisticated, infants with severe brachial plexus damage will have some degree of functional impairment throughout their lives, including asymmetry and residual deficits.⁶ For example, Haerle and Gilbert⁷ reported that 75% of their patients had poor or below-average results in tests of shoulder, wrist, and hand function after nerve repair surgery. This finding highlights that children with BRBPI will potentially have asymmetry and residual deficits in the affected arm throughout their life.

Current research on children with BRBPI by Strömbeck and Fernell,⁸ focusing on participation in daily life, found that teenagers with BRBPI had the same interests, activities, and social life as their unaffected peers but that their self-esteem was lower for participating in sports and motor activities, which was more evident in the group of children with more severe BRBPI. They also reported that adolescents with BRBPI were more concerned than their peers about the risk of injury. Strömbeck and Fernell concluded that psychological support might be helpful for these children in long-term follow-up.⁸

Spaargaren and colleagues⁹ looked at 7- and 8-year-old children with BRBPI; they found less restriction in participation among children at this younger age but a difference in the fine motor activity of writing using standardized normative scales. Bailey and colleagues¹⁰ found a loss of participation in daily activities, and especially leisure activities, among adult patients after nerve injuries. A long-term follow-up study by Kirjavainen and colleagues,¹¹ which followed 112 children with BRBPI who underwent surgery, revealed that 35% of the study population needed help with activities of daily living.

Bellew and colleagues¹² found a positive correlation between severity of initial brachial plexus injury and level of developmental attainment in children aged 12 to 51 months. The developmental delay applied to all scales used in the study, including those measuring locomotion, eye and hand coordination, and performance. Their findings suggested that further research addressing developmental issues is necessary to improve long-term outcomes for this population.

In a study of postural control in children with BRBPI, Ridgway and colleagues¹³ found that 97% had postural control deficits. Their study led them to hypothesize that the combination of the initial injury and further postural control deficits may contribute to a decrease in function with increasing age. Similarly, Partridge and

Edwards¹⁴ surveyed adults with BRBPI and found increasing disability and exacerbation of symptoms with age; 7 of 36 respondents in their study (19.4%) self-reported poor balance.

The existing literature does not tell us whether lower self-esteem among children with BRBPI is purely psychological or whether it is based on repeated poor performance. We do not know whether the reported decrease in activity participation as people with BRBPI age is due to their actual deficits or to less practice in gross motor skills. People with BRBPI appear physically able to participate in all sports and leisure activities, although functional limitations increase with age. To date, no research has been published evaluating long-term balance and body coordination deficits among children with BRBPI and examining correlations with their physical disabilities.

Parents of children with BRBPI attending the BC Children's Hospital (BCCH) Brachial Plexus Clinic have expressed concerns about what they see as their children's excessive stumbling, falling, and developmental delay in coordination tasks relative to their peers or siblings. Although no literature has characterized the frequency of falls in this population, parents' concerns have motivated us to study the long-term impact of BRBPI on balance and coordination.

We hypothesized that body coordination and balance may be affected in children with BRBPI, either as a result of possible asymmetry of upper extremity strength and range of motion (ROM) between the affected and unaffected arms or as a result of less practice in gross motor skills. Regardless, this preliminary study examined the existence of balance and body coordination deficits in children with BRBPI.

The primary purpose of our study was to determine whether children with BRBPI exhibit gross motor function deficits in balance and coordination, as measured by standardized norm-referenced tests. Our secondary objectives were to evaluate functional outcomes using a self-report measure of physical disability and to examine how any measured balance and coordination deficits relate to age, severity of injury, and level of disability.

METHODS

Our prospective cohort study was approved by the University of British Columbia Children's and Women's Research Ethics Board (REB) and was conducted at the BCCH from 2010 to 2011. We obtained informed consent from the parents or legal guardians of all participants and assent from all participating minors aged 7 to 18 years. The procedures followed were in accordance with the ethical standards of the REB and the Helsinki Declaration, as revised in 2008.

Participants

The lack of research evidence on balance and coordination issues in BRBPI populations limited the relevant

information available for calculating the sample size. Therefore, on the basis of our experience with long-term follow-up studies, we adopted a conservative estimate of 50 participants to allow us to develop estimates for a future intervention study.

We identified potential participants through a review of the BCCH physiotherapy database of brachial plexus injuries from 1997 to 2009. This database reflects patient history, demographics, and cumulative examination scores for each patient visit and is managed by the clinic physiotherapist.

Patients of the BCCH Brachial Plexus Clinic who had previously been evaluated for a BRBPI and were at least 5 years old at the time of recruitment were eligible to participate in the study, regardless of their previous treatment (primary repair via sural nerve grafts, secondary repair via Hoffer transfers¹⁵ or other muscle or nerve transfers, botulinum A toxin injection, and conservative treatment using rehabilitation therapy).

Children whose charts contained incomplete contact information and those whose charts recorded no deficits on the Toronto Active Movement Scale (AMS;¹⁶ i.e., all scores 7/7) at their first clinic visit were excluded from the study. We also excluded children with any comorbidity that could potentially influence balance or coordination (e.g., neuromuscular disorders) or cognitive delay, which could prevent participants from performing the functional assessments. Last, patients with isolated birth-related radial nerve injuries were excluded.

Our initial screening identified 218 children seen in the clinic at BCCH for BRBPI. Of these, 71 were outside the study age bracket, leaving 147 children aged 5 years or older at the time of recruitment. Further screening excluded another 54 potential participants on the basis of geographical barriers ($n = 33$), lack of movement deficits as measured by the Toronto AMS at the initial clinic visit ($n = 11$), other comorbidities ($n = 8$), or missing contact information ($n = 2$). A total of 93 children were identified as eligible and were invited to participate in the study.

Eligible patients' families were sent a letter of invitation and a consent form describing the study by postal mail. A research assistant contacted all eligible families by phone 2 weeks after the initial mailing to answer any questions and inquire about participation. Study visits were scheduled for the 39 children whose parents verbally consented to participate; we obtained written consent (as described earlier) before evaluation.

Data collection

Participant demographics, information on the mechanism of the brachial plexus injury, and the participant's course post-injury were collected by reviewing hospital charts and interviewing participants. A pediatric physiotherapist and a plastic surgeon from the BCCH Brachial Plexus Clinic performed the study examinations and recorded the results on a data collection form. Both were

investigators in the study and were not masked to the study outcomes.

Outcome measures

Outcome measures for the upper limb included passive range of motion (PROM), active range of motion (AROM), and strength. Balance and body coordination were also examined using standardized tests.

PROM of the affected arm was measured with the participant in a sitting position with hips and knees bent and lumbar spine flat. For the purposes of the study, PROM was recorded as full in all ranges or as limited in at least one range.

AROM of both affected and non-affected upper limbs was measured and reported using the Toronto AMS, which is specifically designed for children with BRBPI¹⁶ and scores each active movement of the arm on an 8-point scale (0 = *no contraction with gravity eliminated*, 7 = *full motion against gravity*). This scale, which is now used globally for children with BRBPI, has been shown to have excellent interrater reliability.¹⁶

Strength of the upper limbs was assessed bilaterally using the Medical Research Council (MRC) Scale,¹⁷ which assesses muscle strength on a 6-point scale (0 = *no observed movement*, 5 = *normal muscle contraction against full resistance*).

Body coordination and balance were measured using the Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2),¹⁸ a norm-referenced validated measure used with children and youths aged 4–21 years that uses goal-directed activities to measure motor skills.¹⁹ The BOT-2 can be used to assess the motor proficiency of normally developing children and children with moderate motor skill deficits. The BOT-2 consists of subtests that are summed to produce a composite score. The composite Body Coordination score is obtained by summing two subtests: Bilateral Coordination, which measures the motor skills involved in sports and recreational activities, and Balance, which consists of nine activities to evaluate motor skills integral to posture with walking, standing, and reaching. Each subtest score is mapped in the BOT-2 score tables, which take sex and age differences into account, to generate a score ranging from 1 to 35. The two subtest scores are then summed to produce the composite Body Coordination standard score and percentile rank. The composite standard score in BOT-2 can range from 20 to 80, with a mean of 50 (SD 10). BOT-2 composite standard scores are classified into five categories: well below average (≤ 30), below average (31–40), average (41–59), above average (60–69), and well above average (≥ 70).

Balance was also measured using the Balance subset of the Movement Assessment Battery for Children—Second Edition (MABC-2),²⁰ a norm-referenced standardized test that provides objective, quantitative data on movement competence, used to assess children with

motor difficulties. The MABC-2 produces individual item scores and subset scores obtained by summing the individual item scores. The Balance subset consists of the following individual items, depending on the child's age: one-leg balance, walking heels raised, and jumping on mats (ages 3–6 years); one-board balance, walking heel-to-toe forward and one-leg hopping on mats (ages 7–10 years) and two-board balance, walking toe-to-heel backward, and zig-zag hopping on one leg (ages 11–16 years). The Balance subset score, adjusted for age, is converted to a standard score ranging from 1 to 19, with a mean of 10 (SD 3), and a percentile rank. The Balance standard score is used to determine whether a child has no balance difficulty (>7), is at risk of a balance difficulty (5–7), or has a significant balance difficulty (≤ 4).

Self-reported functional outcomes were assessed using the Activities Scale for Kids—Performance Version (ASKp),²¹ a valid and reliable self-report measure of physical disability for children aged 5–15 years who are experiencing physical activity limitations as a result of musculoskeletal disorders. Although the ASKp has not been validated for children with BRBPI specifically, we chose this measure because it is designed to assess children with limitations that may cause activity restrictions and because it fully matched the age of our study cohort. The ASKp contains 30 activity items in nine sub-domains: personal care, dressing, eating and drinking, miscellaneous, locomotion, stairs, play, transfers, and standing skills. Questions are answered by the participant on a 5-point ordinal scale; the answers are then aggregated into an overall summary score out of 100. Results are categorized as either *without disability* (95–100) or *indicative of disability* (<95).

Data analysis

Results are reported using descriptive statistics. We converted results from the norm-referenced BOT-2 and MABC-2 to percentiles and basic frequencies, then graphed the percentiles. For the ASKp scores, we graphed basic frequencies.

On the basis of the functional outcomes from the ASKp, we divided the study cohort into two subgroups: without disability (95–100) and indicative of disability (<95). We then compared BOT-2 and MABC-2 results for the two ASKp subgroups using Mann–Whitney *U* tests and calculated CIs.

We also divided the study cohort into three subgroups on the basis of severity of injury. The first subgroup consisted of children who showed no deficits on the Toronto AMS at the time of study assessment. Children in the second group were those with at least one range less than 7 in the shoulder, elbow, or forearm but no deficits on the AMS for the wrist or hand. The third subgroup consisted of children with shoulder and elbow deficits who also showed wrist involvement, hand involvement (total plexus injury), or both. We compared BOT-2 Body

Coordination composite scores, BOT-2 Bilateral Coordination scale scores, BOT-2 Balance scale scores, and MABC-2 Balance scores for the three subgroups using the Kruskal–Wallis rank sum test.

The relationship between age and functional outcomes (BOT-2 Body Coordination composite score, MABC-2 Balance, ASKp) was tested using Pearson correlation coefficients.

All analyses were performed with IBM SPSS Version 18.0 (IBM Corp., Armonk, NY) and R Version 3.0.1 (Revolution Analytics, Palo Alto, CA).

RESULTS

All 39 participants successfully completed all study examinations, except 1 participant who did not complete the ASKp because of a language barrier.

Participant demographics

Participants ranged in age from 5 to 15 years; their mean age was 9.0 years. There were 15 participants aged 5–8 years, 14 aged 8–11 years, and 10 aged 11–15 years; 22 participants were male, and 17 were female. BRBPI affected the left side for 18 participants; 21 were affected on the right side. All participants had received conservative treatment before the study; 14 had also received surgical treatment. Demographic information is reported in Table 1.

Passive range of motion

PROM was limited in at least one range for 22 participants (56.4%).

Active movement

AROM was measured and reported using the Toronto AMS; Table 2 shows mean results for the affected limb. The lowest mean score was shoulder external rotation, at 5.4/7 (SD 1.9); the second most affected score was forearm supination, with a mean of 6.3/7 (SD 1.2).

A total of 15 participants (38.5%) scored all 7s on the Toronto AMS for the affected limb, and 3 (7.7%) scored <7 on the affected wrist or hand. The remaining 21 participants (53.8%) scored <7 on at least one range of shoulder, elbow, or forearm active movement.

Strength

Table 2 shows the mean strength of the affected limb as assessed using the MRC Scale. The most affected movement was shoulder external rotation, with a mean strength of 4.1/5 (SD 0.9); shoulder internal rotation was the second weakest, with a mean of 4.2/5 (SD 0.9).

Body coordination and balance

Body coordination and balance were measured using the BOT-2 standardized test. The BOT-2 Body Coordination score is a composite of two subtest scores: Bilateral Coordination and Balance. Our cohort's mean scale scores were 12.8 (SD 4.4) for balance and 13.3 (SD 3.6) for bilateral coordination, meaning that both fell into

Table 1 Patient Characteristics ($n = 39$)

Characteristic	No. (%) [*]
Age, y, mean (range)	9.00 (5.36–15.13)
Sex	
M	22 (56.4)
F	17 (43.6)
Side of injury	
L	18 (46.2)
R	21 (53.8)
Hand preference	
L	14 (35.9)
R	24 (61.5)
Undefined	1 (2.6)
Preferred hand injured	6 (15.4)
BMI category	
Underweight	3 (7.7)
Healthy weight	22 (56.4)
Overweight	7 (17.9)
Obese	7 (17.9)
Conservative treatment	
Physical therapy	35 (89.7)
Home exercise program	39 (100)
Splinting	18 (46.2)
Follow-up clinic visits	39 (100)
Surgery	
Primary only	5 (12.8)
Secondary only	3 (7.69)
Primary + secondary	6 (15.4)

*Unless otherwise indicated.

M = male; F = female; L = left; R = right; BMI = body mass index.

the lower segment of the average range (10–20). Further analysis of the Balance subtest revealed that 11 participants scored below the average range, 27 within the average range (10–20), and 1 above it. The mean Body Coordination composite score was 44.7 (SD 7.4); the mean percentile rank was 32.8 (SD 22.6). Percentile rank frequencies for body coordination are graphed in Figure 1.

Although the mean Body Coordination composite score fell within the average range, the distribution curve is positively skewed: Eleven participants (28.2%) obtained standard scores of 40 or lower and thus fell into the below-average category for body coordination.

Balance was also measured using the MABC-2 Balance score, which consists of three individual item scores: balance, walking, and hopping or jumping. We converted the Balance component score to a standard score and percentile, then graphed the percentiles (see Figure 2). The mean MABC-2 Balance standard score was 7.33; 26 participants (66.7%) scored below average, 4 (10.3%) fell into the significant difficulty category, and the remaining 22 (56.4%) were in the at-risk category. The mean percentile rank (25.47) was also quite low.

Self-reported functional outcomes (ASKp)

One participant did not complete the ASKp questionnaire. Of the remaining 38, 25 (65.8%) scored <95 on the ASKp, which indicates some level of disability. No one

Table 2 Physical Examination of the Affected Limb ($n = 39$)

Measure	Mean (SD), range [*]
UE PROM, no. (%)	
Full in all ranges	17 (43.6)
Less than full	22 (56.4)
Toronto AMS score	
Shoulder abduction	6.56 (1.17), 2–7
Shoulder adduction	7.00 (0.00), 7–7
Shoulder flexion	6.49 (1.19), 2–7
Shoulder external rotation	5.36 (1.93), 0–7
Shoulder internal rotation	6.92 (0.35), 5–7
Elbow flexion	6.87 (0.66), 3–7
Elbow extension	6.85 (0.96), 1–7
Forearm pronation	6.59 (1.16), 2–7
Forearm supination	6.26 (1.16), 2–7
Wrist flexion	7.00 (0.00), 7–7
Wrist extension	6.59 (1.48), 0–7
Finger flexion	6.90 (0.64), 3–7
Finger extension	6.69 (1.36), 0–7
Thumb flexion	6.87 (0.80), 2–7
Thumb extension	6.72 (1.28), 0–7
MRC Scale score (strength)	
Shoulder flexion	4.74 (0.50), 3–5
Shoulder extension	4.33 (1.03), 1–5
Shoulder abduction	4.79 (0.47), 3–5
Shoulder adduction	4.74 (0.64), 2–5
Shoulder external rotation	4.10 (0.94), 1–5
Shoulder internal rotation	4.21 (0.89), 2–5
Elbow flexion	4.51 (0.36), 3–5
Elbow extension	4.54 (0.79), 1–5
Pronation	4.64 (0.71), 2–5
Supination	4.49 (0.64), 3–5

*Unless otherwise indicated.

UE = upper extremity; PROM = passive range of motion; AMS = Active Movement Scale; MRC = Medical Research Council.

activity item consistently received a lower score among participants who scored <95. The mean score was 90.92 (range 57.50–100.00). Frequencies for the ASKp are graphed in Figure 3.

Comparison of BOT-2 and MABC-2 across ASKp subgroups

Table 3 shows the results from our comparison of the ASKp with the BOT-2 and MABC-2. We compared BOT-2 Bilateral Coordination, BOT-2 Balance, BOT-2 Body Coordination, and MABC-2 Balance scores for the two ASKp subgroups. We found no statistically significant difference between participants without disability (≥ 95) and those with ASKp scores indicative of disability (< 95) for Bilateral Coordination ($p = 0.44$) or Body Coordination ($p = 0.24$) scores. However, we found statistically significant differences in balance between the two subgroups, as measured with the MABC-2 ($p = 0.007$) and the BOT-2 Balance subtest ($p = 0.011$).

Comparison of outcome measures across severity-of-injury subgroups

We used Kruskal–Wallis rank sum tests to identify the potential differences in outcome measures across the

Figure 1 Percentile ranks for body coordination measured by the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition.

Figure 2 Percentile ranks for balance measured by the Movement Assessment Battery for Children - Second Edition.

three subgroups divided by severity of injury: no deficits on the Toronto AMS (15 participants), only shoulder or elbow deficit on the Toronto AMS (21 participants), and wrist and hand involvement (3 participants). The BOT-2 Body Coordination composite score ($p = 0.13$), the BOT-2 Bilateral Coordination scale score ($p = 0.19$), the BOT-2 Balance scale score ($p = 0.27$), the MABC-2 Balance

Figure 3 Activities Scale for Kids—Performance Version score.

standard score ($p = 0.47$), and the ASKp ($p = 0.76$) did not show statistically significant differences between the three subgroups.

Correlation of outcome measures with age

When we tested for correlations between age and outcome measures using Pearson correlation coefficients and generated scatter plots of the results, at the 95% confidence level we found the critical value of the correlation coefficient for this 39-participant cohort to be 0.325. The ASKp showed positive correlation with age ($r = 0.522$); in contrast, we found no significant correlation between BOT-2 Body Coordination composite score ($r = -0.127$), BOT-2 Bilateral Coordination subset ($r = -0.302$), BOT-2 Balance subtest ($r = 0.062$), or MABC-2 Balance ($r = -0.040$) and participants' age.

DISCUSSION

The evidence as to how BRBPI can affect coordination and balance is limited; however, asymmetrical muscle strength, ROM, and arm swing in the affected arm, as well as potential delays in gross motor development, have been studied in this population.¹² In our study of children with BRBPI, 26 of 39 participants (66.67%) scored below average on the MABC-2 Balance test; although participants performed better on the BOT-2 Balance subtest, 11 (28%) still scored below the average range. Because the current literature provides no information on balance in children with BRBPI, we cannot compare our results with the findings of other centres. However, both test results might be interpreted as indicating potential difficulties with balance. Because this is a preliminary study, we cannot draw final conclusions,

Table 3 Comparison of Body Coordination and Balance between the ASKp Subgroups

Test comparison	No.	Median	95% CI	Mann–Whitney <i>U</i> test (<i>p</i>)
Bilateral Coordination (measured by BOT-2)				0.44
ASKp $\geq$ 95 (Result indicating individual without disability)	13	13.0	9.5–16.0	
ASKp $<$ 95 (Result indicative of individual with disability)	25	14.0	12.0–16.0	
Balance (measured by BOT-2)				0.011
ASKp $\geq$ 95 (Result indicating individual without disability)	13	16.0	12.0–18.0	
ASKp $<$ 95 (Result indicative of individual with disability)	25	10.0	9.0–14.0	
Body Coordination (measured by BOT-2)				0.24
ASKp $\geq$ 95 (Result indicating individual without disability)	13	46.0	42.09–52.37	
ASKp $<$ 95 (Result indicative of individual with disability)	25	42.0	40.66–46.22	
Balance (measured by MABC-2)				0.007
ASKp $\geq$ 95 (Result indicating individual without disability)	13	9.5	7.38–10.85	
ASKp $<$ 95 (Result indicative of individual with disability)	25	6.0	5.46–7.62	

BOT-2 = Bruininks–Oseretsky Test of Motor Proficiency, Second Edition; ASKp = Activities Scale for Kids—Performance Version; MABC-2 = Movement Assessment Battery for Children—Second Edition.

but our findings do suggest future research is warranted in this area.

With respect to body coordination, 11 participants (28%) scored below the average range on the BOT-2, which may be interpreted as indicating impairment. There is evidence that lower self-esteem among adolescents with BRBPI reduces their participation in sports and motor activities;⁸ we do not know, however, whether this lack of participation might contribute to less practice in balance and coordination activities and more effort when competing against nondisabled peers.

The concept of neuroplasticity is gaining in popularity and helping to explain improvements in long-term functional outcomes. The possibility of rewiring neuronal circuits in response to injury may reduce balance and coordination issues in our study participants and other children with BRBPI. Yet a study of adults with BRBPI found that 7 of 36 participants (19.4%) self-reported issues with balance,¹⁴ which may indicate perceived issues with balance but may also be due to actual balance deficits. In our study, the self-reported functional outcome measure (ASKp) indicated some level of disability in 66% of participants, whose balance scores on both MABC-2 and BOT-2 were also significantly lower than those of participants with no indications of disability on the ASKp. The similarities between our findings and those of the adult study warrant further research on this issue.¹⁴

Comparisons of outcome measures showed no statistically significant difference depending on severity of injury, although we should note that the small number of participants with more severe injury (i.e., wrist and hand involvement) limits the potential for exhibiting significance. The positive correlation of age with ASKp scores may be attributed to progressively increased independence in activities of daily living as children age.

Further studies are warranted to address the need for earlier therapy intervention for balance and coordination for children with BRBPI.

LIMITATIONS

One limitation of our study is the small sample size. On the basis of a conservative estimate for this preliminary study, our target sample size was 50 participants; however, exclusion criteria and geographical considerations reduced our pool of eligible participants to 39, limiting the potential of our results to show statistical significance, especially given the variability within our cohort. Children with BRBPI have been well documented to show limitless variability in their presentation and medical treatment (e.g., limb length, surgical protocols, use of splints, physiotherapy treatments); therefore, it is very difficult to achieve a homogeneous sample. A larger sample size could have allowed stratification—for example, of surgical (primary, secondary, or both) versus non-surgical participants. Because it is those more severely affected by BRBPI who require surgery, this characterization would likely reveal more definitive results. Similarly, the age range of 5–15 years might be considered too wide for a small cohort with high variability in clinical presentation.

The fact that the assessor was not blinded to study outcomes also represents a potential limitation. It is also possible that families of children with BRBPI who have balance concerns may have been more prone to volunteer for participation in the study, although our selection of participants was not influenced by this factor.

Finally, the BOT-2 Balance subtest score used in this study is also part of the BOT-2 Body Coordination composite score. We are not aware of an independent standardized coordination and balance measurement tool, but development of one standardized test that examines balance and body coordination in this pediatric population would be a future consideration.

CONCLUSION

Two-thirds (66%) of our participants scored below average on the MABC-2 test for balance, and 25 participants (64%) had a functional outcome indicative of

disability on the ASKp. The difference in balance, as assessed by the BOT-2 and the MABC-2, between those participants whose ASKp score indicated disability and those whose score indicated no disability was statistically significant, which suggests that those with ASKp scores indicative of disability may have balance issues.

Conservative physical therapy treatment of school-age children with BRBPI includes strengthening, ROM, gross motor activities, developmental stimulation, and a variety of other treatments and recommendations; balance is not necessarily specifically targeted. Our findings suggest that balance rehabilitation may be a treatment adjunct for children with BRBPI. All of these considerations assist in providing long-term rehabilitation for these individuals, which should not focus on the affected arm alone.

KEY MESSAGES

What is already known on this topic

Most children with severe BRBPI have some functional impairment throughout their lives. Older children and adolescents with BRBPI are reported to have lower self-esteem for sport and motor activities than their unaffected peers. For children with BRBPI, postural control deficits may contribute to decreased function as they age. Adults with BRBPI have been found to experience increasing disability and exacerbation of symptoms with age.

What this study adds

Our preliminary study is the first to report that balance may be affected in children and adolescents with BRBPI. Body coordination in this population warrants further investigation. Balance rehabilitation may be a treatment adjunct in this population.

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