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# Outcome Measures in OBPP

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## Abstract

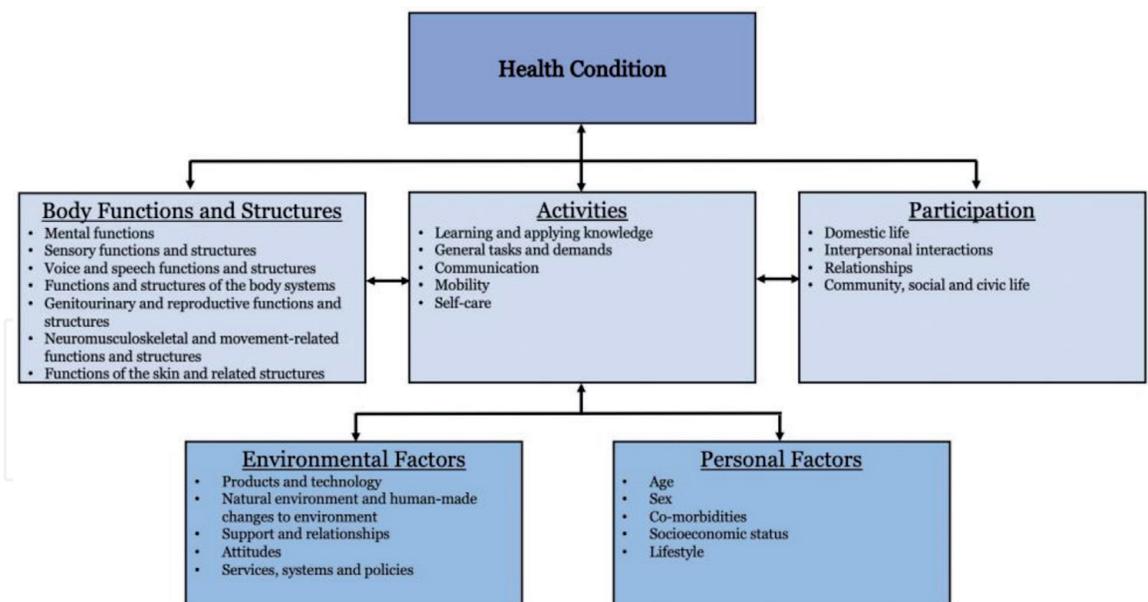
Traditional outcome measurement scales, such as the Medical Research Council (MRC) score, the Active Movement Scale (AMS), and Mallet score, are used by surgeons to assess outcomes in patients with obstetric brachial plexus palsy (OBPP). The measurement scales used to evaluate patients fall under the International Classification of Functioning (ICF) domains of Body Function, Body Structure, Activity, Participation, and Environment and are used to assess function and disability of patients. Currently used outcome measures scales for OBPP are also contrasted with those used for another perinatal condition affecting the upper limb, cerebral palsy (CP).

**Keywords:** brachial plexus injury, brachial plexus palsy, evaluation measurement, international classification, outcome assessment

## 1. Introduction

Patients with OBPP are treated with a multidisciplinary approach. As soon as the diagnosis is suspected, patients are referred to neurology, as well as physical and occupational therapy. Rehabilitation focuses on contracture prevention, including passive range of motion exercises at relevant joints, supportive splints for elbows and hand, and muscle strengthening exercises to promote normal function [1, 2]. Primary or secondary surgical intervention is indicated in cases of severe nerve injury and absent or suboptimal functional recovery. Interventions include nerve microsurgery, joint and bony procedures, tendon lengthening and transfers [3]. Post-operative management after nerve surgery can also include electrical muscle stimulation to facilitate muscle function [4]. Botulinum toxin injections can be used to treat muscle imbalance and contractures. A systematic review identified 4 groups of indicators for botulinum injection: contracture of shoulder adduction, limited active elbow flexion and extension, and pronation contracture of the lower arm [5]. However, specific indications for nerve repair or secondary surgery are largely institution-specific due to a lack of randomized trials and multicenter prospective studies.

Outcomes are often difficult to compare due to the variability of anatomical lesions, variety in surgical technique, and difference in outcome reporting [6]. While the majority of OBPP outcome measurements focus on the functional limitation of the upper extremity, affected children often have associated psychosocial problems, most commonly in the area of activity and participation, such as sports [7]. In comparison to healthy children, children with OBPP have been found to be at high risk for anxiety, depression, and aggression. Mothers with children with OBPP



**Figure 1.**  
Integrated ICF Model [9].

have been found to have increased maternal distress compared to mothers with healthy children [8].

The International Classification of Functioning, Disability and Health (ICF) is a validated and valuable tool developed by the World Health Organization for identifying and comparing areas of function and disability of persons in several domains. The ICF framework consists of five domains: body structure, body function, activity, participation, and environmental factors [9]. These domains are detailed in the integrated biopsychosocial model in **Figure 1**. The activity domain evaluates task execution in the context of disablement or physical ability. The participation domain addresses patient involvement in activities of daily living (ADL) or patient self-perception of engagement and psychometric well-being [10]. Children, adolescents, and young adults with OBPP are important stakeholders, and the application of holistic OBPP evaluation that measures various ICF domains can help improve understanding of their situation. In this chapter, we describe all currently used outcome measures for OBPP, map them against domains in International Classification of Functioning, Disability and Health, and contrast OBPP with another perinatal condition affecting the upper limb, cerebral palsy (CP).

## 2. Outcomes in OBPP

### 2.1 Traditional OBPP outcome measures

With the onset of World War I and II alongside the spread of poliomyelitis, surgeons and neurologists saw a rapid increase in peripheral nerve injuries in the hospitals. A majority of these cases affected the upper limb, including brachial plexus lesions. In response, the British Medical Research Council (MRC) created the MRC score to examine the limbs for peripheral nerve lesions as seen in **Table 1**. It tested limb segment positioning without and against gravity, and manual resistance was tested to grade muscle strength on a six point scale measuring no activity, flicker, movement with gravity eliminated, movement against gravity, and normal power. Grade 4 is subdivided into 3 categories: slight, moderate, and strong resistance. However, these subdivisions are subjective and thus, levels of resistance are highly

MRC score	
Grade	Clinical Finding
0	No contraction
1	Flicker, trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and resistance
5	Normal power

**Table 1.**  
 MRC score [11].

dependent on the evaluator [11]. The MRC scale has become the most recognized scale for evaluating strength in patients with peripheral nerve injuries, and it is commonly used for assessing elbow flexion in infants with OBPP [12–16]. Individual surgeons often develop and use their own modifications for documenting results, especially for how grade 4 can be defined for different movements or muscles.

Over time, the Gilbert Muscle Grading System emerged in 1987 to address MRC's limitations with manual resistance as seen in **Table 2**. It evaluates shoulder function on a 0–5 point scale, representing: flaccid, no active external rotation (ER) at abduction to 45°, no active ER at abduction to <90°, weak active ER at abduction to 90°, weak active ER at abduction to <120°, and complete active ER at abduction to >120° [17]. The Gilbert shoulder abduction sub score can be converted into the Mallet shoulder abduction sub score by utilizing the corresponding range of motion [18]. In both cases, the MRC scale is not suitable for infants due to the cognitive requirement for the exam [19].

The Miami scale was developed to address the limitation in choosing a grade within the Gilbert system. It totals the score for shoulder abduction and external rotation to calculate a grade of 0–5, where 0 represents no function and 5 is excellent. This score has been found to have a weak correlation with Gilbert and Mallet, but it has not been validated for OBPP [20].

A decade earlier, the Mallet score was created in 1972 to evaluate OBPP injuries on a scale of 1–5 by testing functionality of the affected limb as seen in **Table 3** [21]. Commonly used to assess shoulder abduction before and after surgery, the Mallet score translates grade of shoulder external rotation into degrees of deficiency. A score of 1 corresponds to a flail shoulder and a score of 5 indicating a normal shoulder [22]. The Mallet classification system includes 5 sub scores for shoulder movements: abduction, external rotation, hand to neck, hand on spine, and hand to mouth, to give a maximum score of 25. Active range of motion measurements can be translated into the Mallet scale [21].

Modified versions of the Mallet scale have also been created. In addition to the classical shoulder assessments of the Mallet system, Birch's modified Mallet system evaluates resting position and fixed forearm supination on a scale of 1–5, with 1 being most affected and 5 being normal [23]. Nath et al's modified Mallet system integrates Birch's modification to further define deformity [24]. Terzis and Papakonstantinou created a modified Mallet scale that measures the same shoulder movements as the original Mallet scale, but it uses a scale of 1–4 [25]. Abzug et al's modification measures a 6th sub score to the original Mallet system: hand to belly; this additional internal rotation position improves assessment of postoperative midline function [26, 27].

Gilbert Shoulder Classification	
Grade (Function)	Clinical Finding
0 (none)	Flaccid shoulder
1 (poor)	No active external rotation at abduction to 45°
2 (fair)	No external rotation at abduction to 90°
3 (satisfactory)	Weak active external rotation at abduction to 90°
4 (good)	Weak active external rotation at abduction to <120°
5 (excellent)	Complete active external rotation at abduction to >120°

**Table 2.**  
Gilbert Shoulder Classification [17].

Mallet Score	
Grade	Clinical Finding
I	Flail shoulder
II	0° of external rotation Active abduction <30° Hand to mouth with marked trumpet sign Hand to back of neck impossible Hand to back impossible
III	External rotation < 20° Active abduction 30°– 90° Hand to mouth possible with partial trumpet sign (> 40° shoulder abduction) Hand to back of neck with difficulty Hand to back with difficulty
IV	External rotation > 20° Active abduction > 90° Hand to mouth easy with <40° shoulder abduction Hand to back of neck easy Hand to back easy
V	Normal shoulder

**Table 3.**  
Mallet score [21].

After noting the deficiencies in the Mallet and MRC scoring systems, the active movement scale (AMS) was created in 1995 as a novel evaluative tool to be used on infants and children at any time point (**Table 4**). While a child is playing, upper limb movement is observed in the gravity-eliminated and anti-gravity planes. At the shoulder, abduction, and adduction, flexion, external rotation, internal rotation are tested; at the elbow, flexion and extension; at the forearm, pronation and supination; at the wrist, finger, and thumb, flexion and extension. AMS is quantified on an 8 point scale (0 for no visible contraction to 7 for full motion) based on the percent of active motion noted within individual joint passive range of motion [28]. It is recommended that the estimated passive range of motion (PROM) be verified with goniometry for accurate scoring [29]. It has showed moderate to excellent reliability in children with OBPP between 1 month and 15 years of age [30]. Active range of motion measurements can be reliably converted to the AMS scale. The extended numerical scale improves distinguishing ability and allows for extended statistical analysis.

However, upper-extremity movements of forearm pronation and supination are less reliably evaluated with AMS [19]. AMS has been shown to be more popular in North America while Europe has shown preference towards MRC. Although it has been shown to work on an extended age range, AMS is typically used in younger children [31]. Though this is the case, AMS is often time consuming in younger children as it requires patience and creativity from the provider and cooperation from the child to elicit all the desired motions [32].

The Toronto Test Score was created in 1994 to predict a child's prognosis prior to microsurgical intervention (**Table 5**). Shoulder flexion, extension, abduction, and external rotation is measured; elbow flexion, radioulnar supination, and wrist extension is also recorded. On a scale of 0 (no motion or contraction) to 7 (full motion), if a 3 month child scores < 3.5, this result recommends nerve surgery [33]. It has been validated for use in children with OBPP. Composite Toronto and AMS scores have demonstrated a strong correlation [34].

In 1993, the Raimondi hand and wrist score was developed specifically for OBPP with a scale ranging from 1, for total palsy, to 5, for nearly normal hand function (**Table 6**). By incorporating sensation and motor function in its evaluation, the Raimondi scale is able to determine extent of hand function [35]. The Gilbert-Raimondi score classifies elbow function in OBPP by analyzing flexion, extension,

AMS Score	
Grade	Clinical Finding
0	Gravity eliminated: no contraction
1	Gravity eliminated: contraction, no motion
2	Gravity eliminated: motion < ½ range
3	Gravity eliminated: Motion > ½ range
4	Gravity eliminated: full motion
5	Against gravity: motion < ½ range
6	Against gravity: motion > ½ range
7	Against gravity: full motion

**Table 4.**  
 AMS Score [28].

Toronto Score		
Grade	Clinical Finding	Score
0	Gravity eliminated: no contraction	0
1	Gravity eliminated: contraction, no motion	.3
2	Gravity eliminated: motion < ½ range	.3
3	Gravity eliminated: Motion > ½ range	.6
4	Gravity eliminated: full motion	.6
5	Against gravity: motion < ½ range	.6
6	Against gravity: motion > ½ range	1.3
7	Against gravity: full motion	2

**Table 5.**  
 Toronto Test Score [33].

<b>Raimondi Hand Score</b>	
<b>Grade</b>	<b>Clinical Finding</b>
0	Complete paralysis or functionally useless finger flexion Non-usable thumbs without grasping function Little or no sensation
1	Limited finger flexion No finger or wrist extension Key grip possible
2	Active wrist extension Passive flexion of fingers (tenodesis) Passive key grip in pronation
3	Complete active finger and wrist flexion Active thumb movement, including abduction and opposition Intrinsic equilibrium No active supination
4	Complete active finger and wrist flexion Active wrist extension but weak finger extension Good opposition of thumb with active ulnar intrinsic muscles Partial pronation and supination
5	Grade 4, but with active finger extension Complete pronation and supination

**Table 6.**  
*Raimondi Hand Score [35].*

and lack of extension to assign a value of I (poor recovery), II (satisfactory recovery) or III (good recovery) [36]. Gilbert-Raimondi can also be used to classify hand function on a scale of 0 to 5 [37].

Active range of motion (AROM) has shown to have the largest support from the international brachial plexus surgeon community according to the iPLUTO study [31]. It has a continuous scale and normative values are readily available. However, the methodology in assessment varies. Some use goniometers for a precise measurement; however, it is cumbersome to use, especially with a fussy child. Passive range of motion (PROM) is also commonly assessed and reported as these children commonly develop internal rotation shoulder and elbow flexion contractures [31].

Traditional surgeon- or therapist-reported physical exam outcome measures, like Mallet, Toronto, and AMS, have been validated for OBPP and can discriminate the deficit in active range of motion in the upper extremity [30]. However, these scales focus primarily on individual muscle power. Systematic review has shown that measures of shoulder or elbow range of motion are most frequently used for outcome assessment for OBPP [38]. Notably, a study surveyed attendees of the International Symposium of Brachial Plexus Surgery over the course of nine months. Fifty-nine participants responded and all but two were surgeons. Most responders were based in Europe or North America and identified as a member of a brachial plexus team. There was a consensus (76%) to include passive range of motion for shoulder adduction and abduction and elbow extension. 95% of respondents believed active range motion should also be measured by evaluating shoulder abduction and adduction, elbow flexion and extension, wrist extension, and finger flexion and extension. 83% expressed that the Mallet score was a suitable outcome measure, and 76% said it should be expressed using its sub scores for each movement, rather than using an aggregate score. There was also insufficient evidence for the use of Azbug et al's modified Mallet scale, which includes hand-to-belly to assess active internal rotation [31].

## 2.2 Importance of ICF framework

At each age group, there is a different motivation for assessment. During infancy, the degree of impairment is identified and recovery is monitored to determine qualification for surgery; thus, range of motion, strength, and limb integration must be evaluated. As the child develops, the assessment must evolve with them. For a school-aged patient, participation in age-related school and leisure activities as well as quality of life is important to their development. Adolescents with OBPP may face functional limitations stemming from factors that these surgeon-centered outcome measures do not assess, such as psychosocial factors, poor self-perception, or social environmental influences [39]. While functional impairment must also be measured, psychometric assessment must now be included to holistically measure OBPP outcomes [10].

Several tools have been developed for global clinical assessment that evaluate domains aside from “body function and structure”, which has been well documented by the MRC, Mallet, and AMS scales. The Brachial Plexus Outcome Measure (BPOM) activity scale, specific for school-aged children with OBPP, measures function relative to activity limitations stemming from brachial plexus nerve injury. It consists of eleven tasks, which contain components of the fifteen movements used in the AMS scale, and performance is graded using the Functional Movement Scale ranging from 1 to 5. Patients fill out the self-evaluation scale with 3 visual analog scales to score perceived hand and arm function as well as aesthetic appearance of the affected limb [40]. BPOM measures a component of the ICF definition of participation by considering the child’s upper limb performance within the context of their life [38]. Its authors recommend clinicians to supplement the BPOM activity scale with a global standardized participation questionnaire when needed to measure the ICF “activity and participation” domain [40].

Sensory discriminatory function in patients with OBPP can be evaluated using Semmes-Weinstein monofilaments and two-point discrimination. The Semmes-Weinstein monofilament test uses five monofilaments of different diameters, where thicker filaments exert higher pressure when applied to skin [41]. Behavior cues, such as retractive movements with active motion and facial grimacing, in response to pin-prick across dermatomes can be classified using the Sensory Grading Scale by Narakas when testing infants [10]. It is classified under the “body function” ICF domain [38].

Noting the lack of sensitivity of the Gilbert-Raimondi hand classification, the nine hole peg test has been validated to evaluate fine upper motor function in patients with OBPP [42]. It requires participants to repeatedly place and subsequently remove nine pegs into nine holes one at a time, as fast as they can. This test has shown to have high interrater and test–retest reliability for both the adult and pediatric population [43]. It is classified under the “activity” ICF domain [44]. However, the iPLUTO survey showed a consensus to not use this tool [31]. Recognizing the dynamics of a dominant and assisting hand in bimanual hand activity, the Assisting Hand Assessment (AHA) was developed in 2003 as a hand function evaluation tool for children with unilateral upper limb dysfunction, including those with OBPP and cerebral palsy (CP). It has been shown to be reliable in children between ages of 18 months and 12 years. Classified under the “activity” ICF domain, the AHA reflects the person’s usual performance in daily activities [45].

The Children’s Hand-use Experience Questionnaire (CHEQ), a tool for evaluating hand function in unilateral upper limb injury, covers the level of activity in the ICF framework. It is administered in two steps. First, a play session requiring bimanual handling of 22 specific toys is observed; then, the session is reviewed by trained assessors to rate each object-related action on a 4-point scale. It is unique as the questionnaire includes the child’s emotional experience of impaired hand function in

bimanual activities. Validity has been demonstrated in adolescents aged 6–18 years with OBPP and CP. It should be noted that ratings for children under 13 years of age are completed by parents, who tend to overestimate their child's problems [46].

Disability is commonly assessed by the Disabilities of the Arm, Shoulder, and Hand (DASH) outcome measure in brachial plexus injuries. It is a 30 item, self-reported questionnaire measuring physical function where every question is answered on a scale from 1 to 5, and the total minimum score ranges between 30 and 150 [47]. It has shown responsiveness and validity across the whole upper extremity in adults and covers the “activity and participation” ICF domain [48, 49]. A shorter version, QuickDASH, is comprised of 11 items assessed on a 5-point scale; it has shown higher discriminatory power in detecting disability and has been proven as a valid instrument for children ages 8–18 [50].

To determine arm and hand spontaneous function in the home environment, the parent-reported Hand Use at Home (HUH) questionnaire was developed, which is categorized under the activity and participation of ICF. It includes a host of bimanual activities and has been validated in children aged 3–10 years with unilateral cerebral palsy and OBPP [51].

The Pediatric Outcomes Data Collection Instrument (PODCI) was developed to provide a standardized outcome measurement for pediatric musculoskeletal conditions, and it has been validated for OBPP [52]. The tool has seven dimensions: upper extremity function, transfers and mobility, physical function and sports, comfort or lack of pain, happiness, satisfaction, and expectations [53]. It falls under the “activity, participation, and environmental” domains of the ICF framework [38].

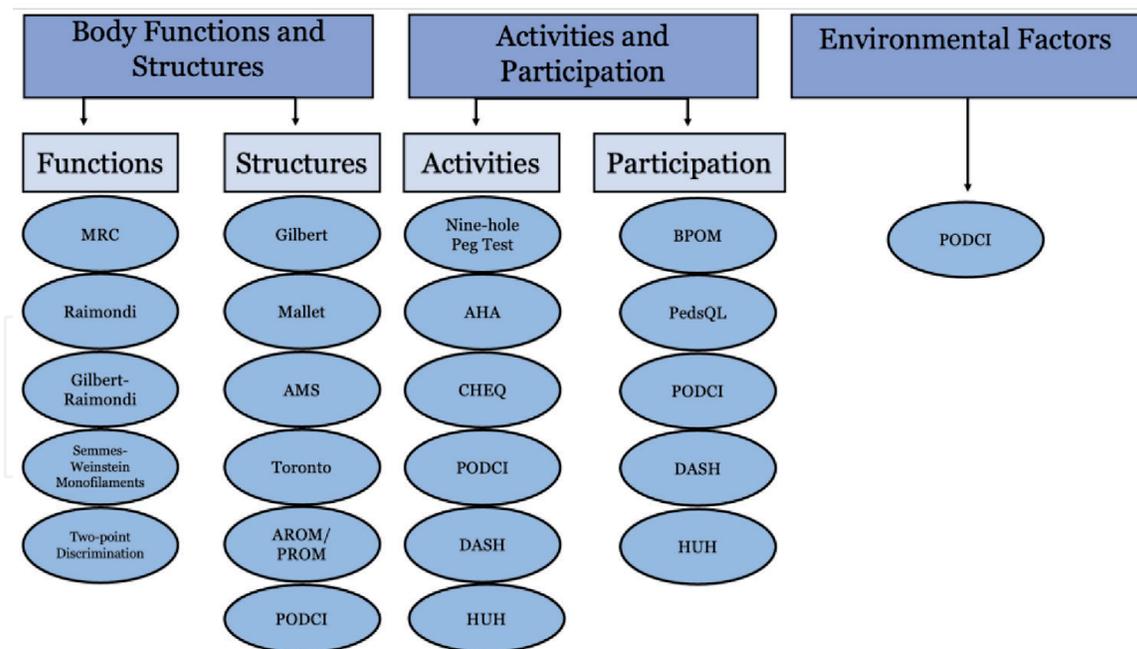
The 36 item Pediatric Quality of Life Inventory, PedsQL, assesses the impact of a child's chronic condition on the family, where a higher score represents low impact [54]. It is developed for pediatric patients with chronic health conditions. It is a promising health-related quality of life instrument designed for a broad age range, including categories for both parents and patients. It measures the core health dimensions outlined by the WHO, including functionality at school [55]. This measurement is a validated outcome measure that is categorized under the “activity and participation” ICF domain [44].

Patient-Reported Outcomes Measurement Information System (PROMIS) developed by the NIH includes several measures to holistically evaluate physical, mental, and social health [56]. The health quality of children with obstetric brachial plexus palsy as measured by PROMIS is not well understood. For other brachial plexus related injuries, such as brachial plexus birth injury, PROMIS domains have shown promise as useful tools for evaluation [56].

A summary of OBPP outcome measure classification by ICF domain can be found in **Figure 2**. In a systematic review of classifying OBPP outcome measures by ICF domain, only 8% (18/217) of papers represented the ICF component of “activity and participation” and only 4% (9/217) of studies incorporated the concept of environmental factors during OBPP measurement; the remaining 88% (190/217) studied the ICF domain of “body structure and function”. In total, only 2% (4/217) of papers evaluated all three ICF domains [38]. It should be noted that the ICF framework does not include the impact of the child's disability on the family. Family members have been found to experience “third-party functioning and disability” as a result of their loved one's health condition [57].

### **2.3 OBPP evaluation contrasted with CP evaluation**

Similar to OBPP, children with the most common type of hemiplegic cerebral palsy (HCP) have a weak upper limb from their pre- or perinatal period. In CP, damage or abnormalities of the cerebral motor cortex affects muscle coordination



**Figure 2.**  
 Classification of OBPP outcome measures by ICF domain.

and movement. Other central nervous system deficits in HCP include sensory impairments, failure of sensorimotor integration, and potential learning disabilities [58]. There has been extensive study of upper extremity dysfunction in children with CP, including the age at which children plateau in function and the use of multimodal therapeutics such as synergistic Botox, occupational therapy, and augmented feedback therapeutics such as virtual reality [58].

Children with HCP often take longer to complete bimanual activities. They may ask for assistance if they are comfortable or they may avoid certain activities due to negative effects on their self-esteem and self-concept. This interplay between body structure and function with environmental and personal factors again proves the importance of the ICF framework.

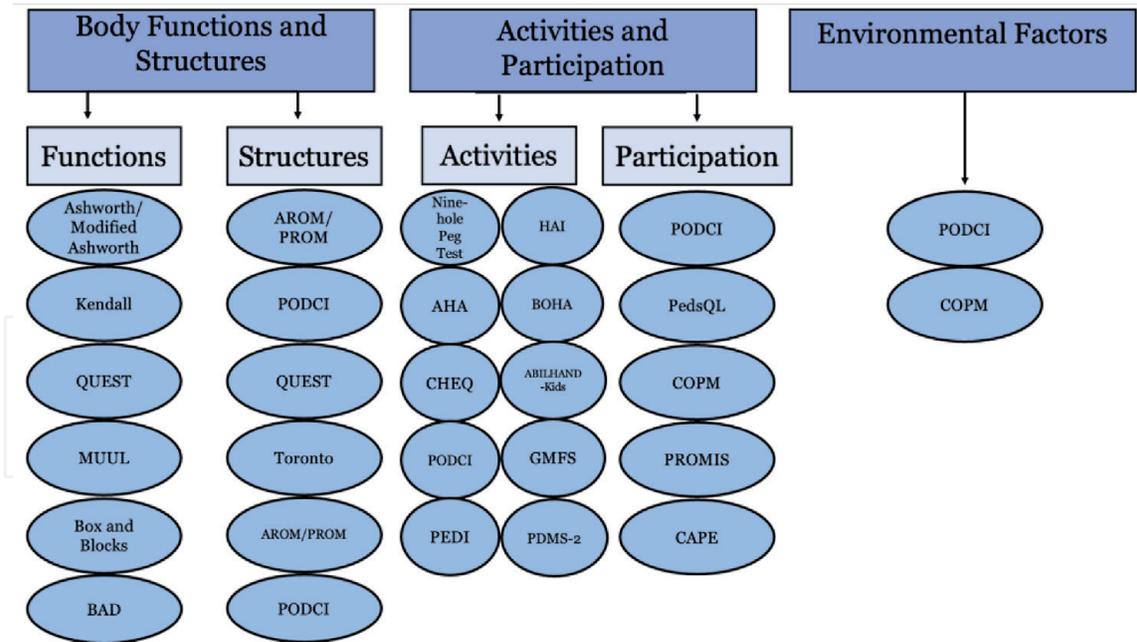
Since cerebral palsy and obstetric brachial plexus palsy both exhibit unilateral upper limb palsy, they share several outcome measurements. AROM and PROM are also often measured by goniometry for CP patients, similar to OBPP patients. For both diagnoses, it is important to note that this outcome can be affected by age, gender, baseline level of physical activity, and any co-existing illness. MRC has been utilized for measuring muscle power in CP patients although this was developed initially for brachial plexus lesions [59]. Mean time to complete nine-hole pegboard, which measures finger dexterity, has been used in CP patients as well [60, 61].

Other scales more specific to CP that fall under the “body function and structure” domain of the ICF framework include the Ashworth and Modified Ashworth scales for spasticity and Kendall scale for muscle strength [62]. The Quality of Upper Extremity Skills Test (QUEST) is used to assess the body structure and function domain by taking into consideration disassociated movement, grasp, protective extension, and weight bearing. The test–retest reliability ranges from 0.75 to 0.95 depending on the factor considered [63]. The Melbourne Assessment of Unilateral Upper Limb Function (MUUL) is a video-based measurement with 16 items, each containing subskills that cover various characteristics of movement including target accuracy, fluency, and movement. A score out of 122 is calculated and then converted into a percentage that describes the quality of upper limb movement in CP patients [64]. The Box and Blocks timed test measures unilateral dexterity by having children move blocks from one side a box to another using the dominant

hand and the non-dominant hand [65]. The Barry-Albright Dystonia (BAD) scale rates the severity of dystonia in eight different body regions—eyes, mouth, neck, trunk, both arms, and both legs [66].

There are also a variety of scales utilized to assess OBPP that are also used for CP that address the activity and participation domain of the ICF framework. One such outcome measure, as previously mentioned, is the Assisting Hand Assessment (AHA). Children with unilateral CP are videorecorded as they play with toys and/or boardgames that provoke use of both hands and are then assigned a raw score between 22 and 88 which are then converted to logit based AHA units [45]. AHA is often used in research and has good reliability and validity in children but requires extensive training to administer the assessment. The Pediatric Outcomes Data Collection Instrument (PODCI) helps families communicate information about their environment and share how it affects the gait and quality of life of children with musculoskeletal health issues. In comparison to its use for OBPP, PODCI only demonstrates moderate sensitivity to detect changes of walking function due to its expansive scoring system [67]. This outcome measure also has high ceiling effects [68]. Children's Hand-use Experience Questionnaire (CHEQ) was developed to be a useful tool to assess patients who have limitations in one hand making it difficult to perform bimanual activities.

There are other outcome measures that fall under the activity and participation domain used for CP but not OBPP. Pediatric Quality of Life Inventory (PedsQL), a part of the participation ICF domain, is used by families to score their children with CP taking into consideration a variety of other factors that affect life [69–71]. One that falls under the ICF framework is Pediatric Evaluation of Disability Inventory (PEDI). PEDI is administered to children less than seven years of age and is formatted as a semi-structured interview administered by proxy [72]. It assesses for ability to provide self-care and maintain social function. The Canadian Occupational Performance Measure (COPM) is a 5-step process used by occupational therapists to evaluate the effect of therapy on various individualized outcomes of importance such as self-care, productivity, and leisure and rate performance and satisfaction on a scale of 1–10 [73]. Jebsen Taylor Hand Function Test (JTHFT) is a timed test of hand dexterity in everyday activities used in children greater than 5 years of age [74]. Although COPM and JTHFT are not diagnosis specific to CP, they have been utilized to evaluate CP patients over time [74, 75]. PROMIS has also been utilized for CP patient evaluation [76]. The Hand Assessment for Infants (HAI) is used to describe unilateral hand function in CP patients by quantifying the contribution of each hand separately and together during a 10–15-minute play session with specific toys eliciting a wide range of motor actions [77]. Both Hands Assessment (BoHA) is a video-taped tool that was developed for children under 12 years of age with bilateral CP and measures the effectiveness of each individual hand during multiple bimanual tasks. Although the scale is highly precise and captures the mobility subdomain of the activity domain of the ICF framework, it requires administrators to undergo formal training and scoring can be time-intensive [78]. ABILHAND-Kids, from the self-care subdomain of the activity domain, is a questionnaire administered to the parents of CP children, thus leading to possible over- or under-estimation of their child's bimanual everyday activities [78]. The Gross Motor Function Scale (GMFS) evaluates a child's ability to complete basic motor functions such as crawling, jumping, or climbing up stairs on a four point scale for each task [79]. Peabody Developmental Motor Scales second edition (PDMS-2) assesses fine motor skills in children with results expressed as raw scores, standard scores and total motor quotient [80]. Children's Assessment of Participation and Assessment (CAPE) is a 55-item questionnaire administered to the child and parent



**Figure 3.**  
 Classification of CP outcome measures by ICF domain.

and is designed to examine how children with physical disabilities like CP participate in everyday activities outside of the school setting and document the diversity, intensity, and enjoyment of activities [81].

A summary of CP outcome measure classification by ICF domain can be found in **Figure 3**. There is a discordance between outcome measures that focus on ICF levels of activity and participation and functional measures that attempt to quantify motion. Both OBPP and CP have effects on patients beyond movement and strength. Quality of life, stress to caregivers, involvement in school and family activities, self-image and self-esteem can all be affected, indicating the need for more biopsychosocial approaches. Although capturing outcomes incorporating multiple domains of the ICF framework is beneficial, the amount of time and training required for measures of activity and participation often leads to these outcomes not being utilized to its full extent in the clinical setting. The existing body of literature shows that compared to OBPP surgeons, CP surgeons report on more domains of the ICF framework. Mallet, MRC, AMS, AROM, PROM, and Gilbert are mostly used in reporting outcomes on OBPP patients, putting emphasis on quantifying motion. In CP, more emphasis may be placed on activity and participation due to the added complexity of the diagnosis with neurological involvement.

### 3. Conclusions

Currently, most tools used to assess OBPP progression measure range of motion and strength, which are classified under the body function and structure domain of the ICF model. Numerous instruments have been developed, such as the DASH and PODCI score, to include other factors of disability, like self-perception and functional impairment. However, these scales are not typically included during standard OBPP assessments, in contrast to CP outcome reporting, which generally focuses more on the activity and participation domain of the ICF model. Further standardization and incorporation of outcomes that fall under the activity and participation domain would be beneficial to assess OBPP more holistically.

## **Conflict of interest**

The authors declare no conflict of interest.

## **Notes/thanks/other declarations**

None.

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## References

- [1] Volpe JJ. Injuries of Extracranial, Cranial, Intracranial, Spinal Cord, and Peripheral Nervous System Structures. *Neurology of the Newborn*. 2008;: 959-85.
- [2] Yang LJ-S. Neonatal brachial plexus palsy—Management and prognostic factors. *Seminars in Perinatology*. 2014;38(4):222-34.
- [3] Spinner RJ, Kline DG. Surgery for peripheral nerve and brachial plexus injuries or other nerve lesions. *Muscle & Nerve*. 2000;23(5):680-95.
- [4] Chuang DC-C, Ma H-S. Current Concepts in the Management of Obstetrical Brachial Plexus Injuries: The Taipei Experience. *Seminars in Plastic Surgery*. 2004;18(04):309-17.
- [5] Gobets D, Beckerman H, de Groot V, Van Doorn-Loogman MH, Becher JG. Indications and effects of botulinum toxin A for obstetric brachial plexus injury: a systematic literature review. *Developmental Medicine & Child Neurology*. 2010;52(6):517-28.
- [6] T Neonatal brachial plexus palsy. Washington, DC: The American College of Obstetricians and Gynecologists, Women's Health Care Physicians; 2014.
- [7] Sarac C, Bastiaansen E, Van der Holst M, Malessy MJ, Nelissen RG, Vliet Vlieland TP. Concepts of functioning and health important to children with an obstetric brachial plexus injury: a qualitative study using focus groups. *Developmental Medicine & Child Neurology*. 2013;55(12):1136-42.
- [8] Alyanak B, Kılınçaslan A, Kutlu L, Bozkurt H, Aydın A. Psychological Adjustment, Maternal Distress, and Family Functioning in Children With Obstetrical Brachial Plexus Palsy. *The Journal of Hand Surgery*. 2013;38(1): 137-42.
- [9] International Classification of Functioning, Disability and Health (ICF) [Internet]. World Health Organization. World Health Organization; [cited 2021Jun1]. Available from: <https://www.who.int/standards/classifications/international-classification-of-functioning-disability-and-health>
- [10] Duff SV, DeMatteo C. Clinical assessment of the infant and child following perinatal brachial plexus injury. *Journal of Hand Therapy*. 2015;28(2):126-34.
- [11] Medical Research Council: Nerve Injuries Committee. Aids to the investigation of peripheral nerve injuries. His Majesty's Stationary Office, London.1942;48
- [12] Ghanghurde BA, Mehta R, Ladkat KM, Raut BB, Thatte MR. Distal transfers as a primary treatment in obstetric brachial plexus palsy: a series of 20 cases. *Journal of Hand Surgery (European Volume)*. 2016;41(8):875-81.
- [13] Chuang DC-C, Mardini S, Ma H-S. Surgical Strategy for Infant Obstetrical Brachial Plexus Palsy: Experiences at Chang Gung Memorial Hospital. *Plastic and Reconstructive Surgery*. 2005;116(1):132-42.
- [14] Noaman HH, Shiha AE, Bahm J. Oberlin's ulnar nerve transfer to the biceps motor nerve in obstetric brachial plexus palsy: Indications, and good and bad results. *Microsurgery*. 2004;24(3): 182-7.
- [15] Xu J, Cheng X, Gu Y. Different Methods and Results in the Treatment of Obstetrical Brachial Plexus Palsy. *Journal of Reconstructive Microsurgery*. 2000;16(06):417-22.
- [16] Malessy MJA, Pondaag W. Neonatal Brachial Plexus Palsy with Neurotmesis

- of C5 and Avulsion of C6. *Journal of Bone and Joint Surgery*. 2014;96(20).
- [17] Terzis JK, Gilbert A, Tassin J-L. In: *Microreconstruction of nerve injuries*. Philadelphia: Saunders; 1987. p. 529.
- [18] Bauer AS, Kalish LA, Adamczyk MJ, Bae DS, Cornwall R, James MA, et al. *Microsurgery for Brachial Plexus Injury Before Versus After 6 Months of Age*. *Journal of Bone and Joint Surgery*. 2019;102(3):194-204.
- [19] Curtis C, Stephens D, Clarke HM, Andrews D. *The active movement scale: An evaluative tool for infants with obstetrical brachial plexus palsy*. *The Journal of Hand Surgery*. 2002;27(3):470-1.
- [20] Grossman JA, DiTaranto P, Price AE, Ramos LE, Tidwell M, Papazian O, et al. *Multidisciplinary Management of Brachial Plexus Birth Injuries: The Miami Experience*. *Seminars in Plastic Surgery*. 2004;18(04):319-26.
- [21] Mallet J. *Obstetrical paralysis of the brachial plexus. II. Therapeutics. Treatment of sequelae. Priority for the treatment of the shoulder. Method for the expression of results*. *Rev Chir Orthop Reparatrice Appar Mot*. 1972;58:166-8.
- [22] Al-Qattan MM, El-Sayed AA. *Obstetric Brachial Plexus Palsy: The Mallet Grading System for Shoulder Function—Revisited*. *BioMed Research International*. 2014;2014:1-3.
- [23] Birch R. *Late sequelae at the shoulder in obstetrical palsy in children*. In: Randelli M, Karlsson J, editor. *Surgical Techniques in Orthopaedics and Traumatology: Shoulder*. Vol. 3. Paris: Elsevier; 2001
- [24] Nath RK, Karicherla P, Mahmooduddin F. *Shoulder function and anatomy in complete obstetric brachial plexus palsy: long-term improvement after triangle tilt surgery*. *Child's Nervous System*. 2010;26(8):1009-19.
- [25] Terzis JK, Papakonstantinou K. *Surgical Treatment of Obstetrical Brachial Plexus Paralysis: The Norfolk Experience*. *Seminars in Plastic Surgery*. 2004;18(04):359-75.
- [26] Abzug JM, Chafetz RS, Gaughan JP, Ashworth S, Kozin SH. *Shoulder function after medial approach and derotational humeral osteotomy in patients with brachial plexus birth palsy*. *Journal of Pediatric Orthopaedics*. 2010;30(5):469-74.
- [27] Greenhill DA, Trionfo A, Ramsey FV, Kozin SH, Zlotolow DA. *Postoperative Loss of Midline Function in Brachial Plexus Birth Palsy*. *The Journal of Hand Surgery*. 2018;43(6).
- [28] Clarke HM, Cunis CG. *An approach to obstetrical brachial plexus injuries*. *Hand Clinics*. 1995;11(4):563-80.
- [29] Bialocerkowski AE, Galea M. *Comparison of visual and objective quantification of elbow and shoulder movement in children with obstetric brachial plexus palsy*. *J Brachial Plex Peripher Nerve Inj*. 2006;1(5). DOI: 10.1186/1749-7221-1-5
- [30] Bae DS, Waters PM, Zurakowski D. *Reliability of three classification systems measuring active motion in brachial plexus birth palsy*. *J Bone Joint Surg*. 2003;85(9):1733-8.
- [31] Pondaag W, Malessy MJA. *Outcome assessment for Brachial Plexus birth injury. Results from the iPluto world-wide consensus survey*. *Journal of Orthopaedic Research*. 2018;36(9):2533-41.
- [32] *A Clinicians Guide to the Active Movement Scale (AMS)* [Internet]. [cited 2021 May 20]. Available from: <https://www.regionvasterbotten>.

se/VLL/Filer/AMS%20A%20Clinicians%20guide%20to%20the%20Active%20Movement%20Scale.pdf

[33] Michelow BJ, Clarke HM, Curtis CG, et al. The natural history of obstetrical brachial plexus palsy. *Plast Reconstr Surg.* 1994;93(4):675-680

[34] Greenhill DA, Lukavsky R, Tomlinson-Hansen S, Kozin SH, Zlotolow DA. Relationships Between 3 Classification Systems in Brachial Plexus Birth Palsy. *Journal of Pediatric Orthopaedics.* 2017;37(6):374-80.

[35] Raimondi P. Evaluation of results in obstetric brachial plexus palsy. The hand. In: *International Meeting on Obstetric Brachial Plexus Palsy; 1993; Heerlen, The Netherlands.*

[36] Haerle M, Gilbert A. Management of Complete Obstetric Brachial Plexus Lesions. *Journal of Pediatric Orthopaedics.* 2004;24(2):194-200.

[37] Ruchelsman DE, Pettrone S, Price AE, Grossman JAI. Brachial plexus birth palsy: an overview of early treatment considerations. *Bull NYU Hosp Jt Dis.* 2009;67(1):83-9.

[38] Sarac C, Duijnisveld BJ, Weide Avan, Schoones JW, Malessy MJA, Nelissen RGHH, et al. Outcome measures used in clinical studies on neonatal brachial plexus palsy: A systematic literature review using the International Classification of Functioning, Disability and Health. *Journal of Pediatric Rehabilitation Medicine.* 2015;8(3):167-86.

[39] Strömbeck C, Fernell E. Aspects of activities and participation in daily life related to body structure and function in adolescents with obstetrical brachial plexus palsy: a descriptive follow-up study. *Acta Paediatrica.* 2007;92(6):740-6.

[40] Ho ES, Curtis CG, Clarke HM. The brachial plexus outcome measure:

development, internal consistency, and construct validity. *Journal of Hand Therapy.* 2012;25(4):406-17.

[41] Anguelova GV, Malessy MJA, van Dijk JG. A cross-sectional study of hand sensation in adults with conservatively treated obstetric brachial plexus lesion. *Dev Med Child Neurol.* 2013;55(3): 257-63.

[42] Johansson GM, Häger CK. A modified standardized nine hole peg test for valid and reliable kinematic assessment of dexterity post-stroke. *Journal of NeuroEngineering and Rehabilitation.* 2019;16(1).

[43] Immerman I, Alfonso DT, Ramos LE, Grossman LA, Alfonso I, Ditaranto P, Grossman JAI. Hand function in children with an upper brachial plexus birth injury: results of the nine-hole peg test. *Developmental Medicine & Child Neurology.* 2012; 54(2):166-9.

[44] Chang KW, Justice D, Chung KC, Yang LJ. A systematic review of evaluation methods for neonatal brachial plexus palsy. *Journal of Neurosurgery: Pediatrics.* 2013;12(4):395-405.

[45] Krumlinde-Sundholm L, Holmfur M, Kottorp A, Eliasson A-C. The Assisting Hand Assessment: current evidence of validity, reliability, and responsiveness to change. *Developmental Medicine & Child Neurology.* 2007;49(4):259-64.

[46] Hermansson L, Sköld A, Eliasson AC. Bimanual Hand-use in Children with Unilateral Hand Dysfunction– Differences Related to Diagnosis Investigated by the Children's Hand-use Experience Questionnaire. *Pediatrics & Therapeutics.* 2013;03(04).

[47] Solway S. The DASH outcome measure: user's manual. Toronto: Institute for Work & Health; 2002.

- [48] Hudak PL, Amadio PC, Bombardier C, Beaton D, Cole D, Davis A, et al. Development of an upper extremity outcome measure: The DASH (disabilities of the arm, shoulder, and hand). *American Journal of Industrial Medicine*. 1996;29(6):602-8.
- [49] Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability, and responsiveness of the Disabilities of the Arm, Shoulder and Hand outcome measure in different regions of the upper extremity. *Journal of Hand Therapy*. 2001;14(2):128-46.
- [50] Quatman-Yates CC, Gupta R, Paterno MV, Schmitt LC, Quatman CE, Ittenbach RF. Internal Consistency and Validity of the QuickDASH Instrument for Upper Extremity Injuries in Older Children. *Journal of Pediatric Orthopaedics*. 2013;33(8):838-42.
- [51] van der Holst M, Geerdink Y, Aarts P, Steenbeek D, Pondaag W, Nelissen RGHH, et al. Hand-Use-at-Home Questionnaire: validity and reliability in children with neonatal brachial plexus palsy or unilateral cerebral palsy. *Clinical Rehabilitation*. 2018;32(10):1363-73.
- [52] Bae DS, Waters PM, Zurakowski D. Correlation of Pediatric Outcomes Data Collection Instrument With Measures of Active Movement in Children With Brachial Plexus Birth Palsy. *Journal of Pediatric Orthopaedics*. 2008;28(5):584-92.
- [53] Daltroy LH, Liang MH, Fossel AH, Goldberg MJ. The POSNA Pediatric Musculoskeletal Functional Health Questionnaire: Report on Reliability, Validity, and Sensitivity to Change. *Journal of Pediatric Orthopaedics*. 1998;18(5):561-71.
- [54] van der Holst M, Steenbeek D, Pondaag W, Nelissen RGHH, Vliet Vlieland TPM. Neonatal Brachial Plexus Palsy in Children Aged 0 to 2.5 Years; Parent-Perceived Family Impact, Quality of Life, and Upper Extremity Functioning. *Pediatric Neurology*. 2016;62:34-42.
- [55] Reinfjell T, Diseth TH, Veenstra M, Vikan A. Measuring health-related quality of life in young adolescents: Reliability and validity in the Norwegian version of the Pediatric Quality of Life Inventory™ 4.0 (PedsQL) generic core scales. *Health and Quality of Life Outcomes*. 2006;4(1).
- [56] Manske MC, Abarca NE, Letzelter JP, James MA. Patient-reported Outcomes Measurement Information System (PROMIS) Scores for Children With Brachial Plexus Birth Injury. *Journal of Pediatric Orthopaedics*. 2021;41(3):171-6.
- [57] Grawburg M, Howe T, Worrall L, Scarinci N. Describing the impact of aphasia on close family members using the ICF framework. *Disability and Rehabilitation*. 2013;36(14):1184-95.
- [58] Basu AP, Pearse J, Kelly S, Wisher V, Kisler J. Early Intervention to Improve Hand Function in Hemiplegic Cerebral Palsy. *Frontiers in Neurology*. 2015;5.
- [59] Steinbok P, Gan PYC, Connolly MB, Carmant L, Barry Sinclair D, Rutka J, et al. Epilepsy surgery in the first 3 years of life: A Canadian survey. *Epilepsia*. 2009;50(6):1442-9.
- [60] Choudhary A, Gulati S, Kabra M, Singh UP, Sankhyan N, Pandey RM, et al. Efficacy of modified constraint induced movement therapy in improving upper limb function in children with hemiplegic cerebral palsy: A randomized controlled trial. *Brain and Development*. 2013;35(9):870-6.
- [61] Keklicek H, Uygur F, Yakut Y. Effects of taping the hand in children with cerebral palsy. *Journal of Hand Therapy*. 2015;28(1):27-33.

- [62] Aroojis A, Sarathy K, Doshi C. Clinical examination of children with cerebral palsy. *Indian Journal of Orthopaedics*. 2019;53(1):35.
- [63] DeMatteo C, Law M, Russell D, Pollock N, Rosenbaum P, Walter S. The Reliability and Validity of the Quality of Upper Extremity Skills Test. *Physical & Occupational Therapy In Pediatrics*. 1993;13(2):1-18.
- [64] Bourke-Taylor H. Melbourne Assessment of Unilateral Upper Limb Function: construct validity and correlation with the Pediatric Evaluation of Disability Inventory. *Developmental Medicine & Child Neurology*. 2003;45(02).
- [65] Mathiowetz V, Federman S, Wiemer D. Box and Block Test of Manual Dexterity: Norms for 6-19 Year Olds. *Canadian Journal of Occupational Therapy*. 1985;52(5):241-5.
- [66] Werning M, Müllner EW, Mlynek G, Dobretzberger V, DjinoVIC-Carugo K, Baron DM, et al. PKAN neurodegeneration and residual PANK2 activities in patient erythrocytes. *Annals of Clinical and Translational Neurology*. 2020;7(8):1340-51.
- [67] Narayanan UG. Management of Children With Ambulatory Cerebral Palsy. *Journal of Pediatric Orthopaedics*. 2012;32(Supplement 2).
- [68] Debusse D, Brace H. Outcome Measures of Activity for Children With Cerebral Palsy. *Pediatric Physical Therapy*. 2011;23(3):221-31.
- [69] Russo RN, Goodwin EJ, Miller MD, Haan EA, Connell TM, Crotty M. Self-Esteem, Self-Concept, and Quality of Life in Children with Hemiplegic Cerebral Palsy. *The Journal of Pediatrics*. 2008;153(4).
- [70] Christmas PM, Sackley C, Feltham MG, Cummins C. A randomized controlled trial to compare two methods of constraint-induced movement therapy to improve functional ability in the affected upper limb in pre-school children with hemiplegic cerebral palsy: CATCH TRIAL. *Clinical Rehabilitation*. 2018;32(7):909-18.
- [71] Postans N, Wright P, Bromwich W, Wilkinson I, Farmer SE, Swain I. The Combined Effect of Dynamic Splinting and Neuromuscular Electrical Stimulation in Reducing Wrist and Elbow Contractures in Six Children with Cerebral Palsy. *Prosthetics & Orthotics International*. 2010;34(1):10-9.
- [72] James S, Ziviani J, Boyd R. A systematic review of activities of daily living measures for children and adolescents with cerebral palsy. *Developmental Medicine & Child Neurology*. 2013;56(3):233-44.
- [73] Law M, Baptiste S, McColl MA, Opzoomer A, Polatajko H, Pollock N. The Canadian Occupational Performance Measure: An Outcome Measure for Occupational Therapy. *Canadian Journal of Occupational Therapy*. 1990;57(2):82-7.
- [74] Tofani M, Castelli E, Sabbadini M, Berardi A, Murgia M, Servadio A, et al. Examining Reliability and Validity of the Jebsen-Taylor Hand Function Test Among Children With Cerebral Palsy. *Perceptual and Motor Skills*. 2020;127(4):684-97.
- [75] Law M, Baptiste S, McColl MA, Opzoomer A, Polatajko H, Pollock N. The Canadian Occupational Performance Measure: An Outcome Measure for Occupational Therapy. *Canadian Journal of Occupational Therapy*. 1990;57(2):82-7.
- [76] Cardenas A, Warner D, Switzer L, Graham TCN, Cimolino G, Fehlings D. Inpatient Exergames for Children with Cerebral Palsy following Lower

Extremity Orthopedic Surgery: A Feasibility Study. *Developmental Neurorehabilitation*. 2021;24(4):230-6.

[77] Ryll UC, Krumlinde-Sundholm L, Verhage CH, Sicola E, Sgandurra G, Bastiaenen CHG, et al. Predictive validity of the Hand Assessment for Infants in infants at risk of unilateral cerebral palsy. *Developmental Medicine & Child Neurology*. 2020;63(4):436-43.

[78] Arnould C. Practical Considerations of the Both Hands Assessment (BoHA): A commentary on “Development and Validation of the Both Hands Assessment for Children with Bilateral Cerebral Palsy.” *Physical & Occupational Therapy In Pediatrics*. 2018;38(2):127-9.

[79] Romeo DM, Brogna C, Quintiliani M, Baranello G, Pagliano E, Casalino T, et al. Sleep disorders in children with cerebral palsy: neurodevelopmental and behavioral correlates. *Sleep Medicine*. 2014;15(2):213-8.

[80] Morgan C, Novak I, Dale RC, Guzzetta A, Badawi N. Single blind randomised controlled trial of GAME (Goals - Activity - Motor Enrichment) in infants at high risk of cerebral palsy. *Research in Developmental Disabilities*. 2016;55:256-67.

[81] Bjornson KF, Zhou C, Stevenson R, Christakis DA. Capacity to Participation in Cerebral Palsy: Evidence of an Indirect Path Via Performance. *Archives of Physical Medicine and Rehabilitation*. 2013;94(12):2365-72.