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Interventions and Management

1. Decision-making aids for upper limb interventions in neurological rehabilitation: a scoping review

Amelia Tan, Jodie Copley, Jennifer Fleming

Disabil Rehabil. 2021 Jun 14;1-19. doi: 10.1080/09638288.2021.1924881. Online ahead of print.

Purpose: To summarise the range and nature of decision-making aids that guide upper limb (UL) neurorehabilitation. **Methods:** Our scoping review followed Arksey and O'Malley's 6-step framework. Electronic databases were systematically searched; grey literature was hand-searched. Included papers were: (1) published in English; (2) related to UL rehabilitation for people with upper motor neuron conditions; and (3) provided a description of, or research on, a decision-making aid that guides therapists when choosing between two or more intervention approaches, techniques, or applications of a technique. Levels of evidence were rated. An expert panel of occupational therapists working in UL neurorehabilitation was consulted. **Results:** The 24 included articles described 15 decision-making aids with varying breadth and depth of the assessment process and suggested interventions. Six aids had published research, but lacked high quality evidence. The expert panel identified four key decision-making aids as being clinically useful. Preferred aids either included client-centred goal-setting within a holistic assessment or matched specific intervention options to distinct UL assessment results. Prompts to re-evaluate client performance are desirable. **Conclusion:** Few decision-making aids guide therapists to holistically assess and make specific intervention decisions across all domains of UL neurorehabilitation. Their usefulness depends on the purpose, setting, and therapist experience. **Implications for rehabilitation:** Considering the complexity and heterogeneity of upper limb (UL) neurorehabilitation, a selection of evidence-based and purpose-designed decision-making aids may assist therapists across different experience levels and practice settings to choose individualised interventions. Decision-making aids for UL interventions in neurorehabilitation may be more clinically useful if they include a holistic and client-centred information gathering process that focuses on daily life goals. Decision-making aids should illustrate a clear clinical picture based on UL assessment results, with corresponding UL intervention recommendations provided. Inclusion of a cyclic process to re-evaluate client performance and function could also enhance the usefulness of a decision-making aid.

PMID: [34126822](https://pubmed.ncbi.nlm.nih.gov/34126822/)

2. Reliability and validity of a computer game-based tool of upper extremity assessment for object manipulation tasks in children with cerebral palsy

Anuprita Kanitkar, Sanjay T Parmar, Tony J Szturm, Gayle Restall, Gina Rempel, Nilashri Naik, Neha Gaonkar, Nariman Sepehri, Bhavana Ankolekar

J Rehabil Assist Technol Eng. 2021 Jun 2;8:20556683211014023. doi: 10.1177/20556683211014023. eCollection Jan-Dec 2021.

Introduction: A computer game-based upper extremity (CUE) assessment tool is developed to quantify manual dexterity of children with Cerebral Palsy (CP). The purpose of this study was to determine test-retest reliability of the CUE performance measures (success rate, movement onset time, movement error, and movement variation) and convergent validity with the Peabody Developmental Motor Scale version 2 (PDMS-2) and the Quality of Upper Extremity Skills Test (QUEST). **Methods:** Thirty-five children with CP aged four to ten years were tested on two occasions two weeks apart. **Results:** CUE performance measures of five chosen object manipulation tasks exhibited high to moderate intra-class correlation coefficient (ICC) values. There was no significant difference in the CUE performance measures between test periods. With few exceptions, there was no significant correlation between the CUE performance measures and the PDMS-2 or the QUEST test scores. **Conclusions:** The high to moderate ICC values and lack of systematic errors indicate that the CUE assessment tool has the ability to repeatedly record reliable performance measures of different object manipulation tasks. The lack of a correlation between the CUE and the PDMS-2 or QUEST scores indicates that performance measures of these assessment tools represent distinct attributes of manual dexterity.

PMID: [34123406](#)

3. Proximal femoral derotation osteotomy in children with CP : long term outcome and the role of age at time of surgery

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Acta Orthop Belg. 2021 Mar;87(1):167-173.

The femoral derotation osteotomy (FDO) is seen as the golden standard treatment in children with cerebral palsy and internal rotated gait. This study provides quantitative evidence in support of the beneficial effect of FDO after long term follow up. Retrospective clinical and kinematic evaluation of 31 CP patients (55 operated limbs) pre-, 1 and 3 years postoperatively after proximal FDO was conducted for a minimal follow-up of 3 years. This group consisted of 20 men and 11 women, aged 10.68 ± 3.31 years at the time of surgery. Minimum follow up was 3 years (3.16 ± 0.53 years), with 22 patients (38 operated limbs) having an additional follow up at 5 years (5.02 ± 0.49 years). Age at FU3 and FU5 was 14.06 ± 3.52 years and 15.39 ± 3.08 years respectively. A set of clinical and kinematic parameters were analyzed and showed a significant correction of mean hip rotation and femoral anteversion after FDO. Further plotting of individual data comparing 3 or 5 year postoperative values to 1 year postoperative values showed no further significant changes, indicating sustained correction of internally rotated gait until end of our follow up. Plotting mean hip rotation in stance as well as kinematic knee parameters according to age grouped cohorts could not show age at time of surgery to be a significant factor in recurrence of internally rotated gait or preoperative disturbances of knee motion in the sagittal plane. This study provides quantitative evidence on the beneficial effect of FDO, a surgical technique to improve internally rotated gait in cerebral palsy patients with spastic diplegia. Pre- and postoperative clinical and kinematic parameters are compared and results are discussed. Minimum follow up was 3 years with a mean follow up of 4.65 ± 0.83 years. The effect of age at time of surgery on recurrence and kinematic parameters were studied.

PMID: [34129771](#)

4. Mechanical properties of ankle joint and gastrocnemius muscle in spastic children with unilateral cerebral palsy measured with shear wave elastography

Clément Boulard, Vincent Gautheron, Thomas Lapole

J Biomech. 2021 Jun 7;124:110502. doi: 10.1016/j.jbiomech.2021.110502. Online ahead of print.

The aim of this study was to describe passive mechanical and morphological properties of the ankle joint and gastrocnemius medialis (GM) muscle in paretic and contralateral legs in highly functional children with unilateral cerebral palsy (UCP) using shear wave elastography (SWE). SWE measurements on the GM muscle were performed in both paretic and contralateral legs during passive ankle dorsiflexion using a dynamometer in 11 children (mean age: 10 years 6 months) with UCP. Torque-angle and shear modulus-angle relationships were fitted using an exponential model to determine passive ankle joint and GM muscle stiffness respectively. Based on shear-modulus-angle relationship, slack angle and shear modulus of GM muscle were compared between legs. GM and Achilles tendon length were determined at rest using ultrasonography. No significant difference was found between legs for passive ankle joint ($p = 0.26$; 11.2%; 95 %CI: 31.9, -9.4) and GM muscle passive stiffness ($p = 0.62$; -4.4%; 95 %CI: 14.7, -23.4). GM shear modulus at a common angle was significantly higher on the paretic leg ($p = 0.02$; +56.5%; 95 %CI: 100.5, 12.6). GM slack angle on the paretic leg was significantly shifted to a more plantarflexed position ($p = 0.04$; +25.5%; 95 %CI: 49.7, 1.3) and this was associated with a non-significant lower muscle

length compared to the contralateral leg ($p = 0.05$; -4.5% ; $95\%CI: -0.4, -8.7$). Increased passive tension on the paretic leg when compared to the contralateral one may be explained in large part by muscle shortening. The role of altered mechanical properties remains unknown.

PMID: [34126561](#)

5. Method for characterization of dynamic ankle stiffness in patients with spasticity

Stacy R Loushin, Krista A Coleman Wood, Kenton R Kaufman

Gait Posture. 2021 Jun 8;88:247-251. doi: 10.1016/j.gaitpost.2021.06.007. Online ahead of print.

Background: Dynamic ankle stiffness has been quantified as the slope of the ankle joint moment-angle curve over the gait interval of the second rocker, defined explicitly as the period of the gait cycle from the first relative maximum plantar flexion in early stance to maximum dorsiflexion in midstance. However, gastrocnemius spasticity may interfere with the second ankle rocker in patients with spasticity. This gait disruption results in stiffness calculations which are misleading. Current dynamic stiffness metrics need to be modified. Research question: The main goal of this study was to develop and test a new method to better evaluate dynamic ankle stiffness in individuals with pathologic gait who lack a second rocker interval. Methods: Twenty unimpaired ambulators (10/20 female, 26.7 ± 5.0 years, BMI: 23.2 ± 2.2) and 9 individuals with cerebral palsy (5/9 female, 5.7 ± 1.7 years, BMI: 14.6 ± 2.1 , GMFCS Levels: I - 2, II - 5, III - 2) participated in this study. Dynamic ankle stiffness was evaluated using the previous kinematic method, defined by the interval of maximum plantar flexion to maximum dorsiflexion angle in midstance, and the proposed kinetic method, defined by the interval from the maximum dorsiflexion moment to first peak plantar flexion moment. Stiffness was quantified as the linear slope between the sagittal plane ankle angle and moment. Method differences were explored using an equivalence test ($\alpha = 0.05$). Results and significance: There was equivalence between the methods for unimpaired ambulators ($p = 0.000$) and a lack of equivalence for patients with spasticity ($p = 0.958$). The new method was successfully applied to all 9 pediatric ambulators with CP and demonstrated increased stiffness in patients with spasticity as compared to the previous method. The ability to objectively calculate ankle stiffness in pathologic gait is critical for determining change associated with clinical intervention.

PMID: [34130093](#)

6. Feasibility of a real-time pattern-based kinematic feedback system for gait retraining in pediatric cerebral palsy

Xuan Liu, Nuno Oliveira, Naphtaly Ehrenberg, JenFu Cheng, Katherine Bentley, Sheila Blochlinger, Hannah Shoval, Peter Barrance

J Rehabil Assist Technol Eng. 2021 Jun 2;8:20556683211014125. doi: 10.1177/20556683211014125. eCollection Jan-Dec 2021.

Introduction: Visual biofeedback of lower extremity kinematics has the potential to enhance retraining of pathological gait patterns. We describe a system that uses wearable inertial measurement units to provide kinematic feedback on error measures generated during periods of gait in which the knee is predominantly extended ('extension period') and flexed ('flexion period'). Methods: We describe the principles of operation of the system, a validation study on the inertial measurement unit derived knee flexion angle on which the system is based, and a feasibility study to assess the ability of a child with cerebral palsy to modify a gait deviation (decreased swing phase knee flexion) in response to the feedback. Results: The validation study demonstrated strong convergent validity with an independent measurement of knee flexion angle. The gait pattern observed during training with the system exhibited increased flexion in the flexion period with maintenance of appropriate extension in the extension period. Conclusions: Inertial measurement units can provide robust feedback during gait training. A child with cerebral palsy was able to interpret the novel two phase visual feedback and respond with rapid gait adaptation in a single training session. With further development, the system has the potential to support clinical retraining of deviated gait patterns.

PMID: [34123407](#)

7. Quantification of the effects of robotic-assisted gait training on upper and lower body strategy during gait in diplegic children with Cerebral Palsy using summary parameters

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Comput Methods Biomech Biomed Engin. 2021 Jun 14;1-8. doi: 10.1080/10255842.2021.1938009. Online ahead of print.

The effects of robotic-assisted gait training on upper and lower body strategy during gait in diplegic children with Cerebral Palsy (CP) were quantified using summary parameters (Upper Body Profile Score (UBPS) and Gait Profile Score (GPS)). Firstly, the upper body strategy during gait was assessed in 73 children with CP and 15 healthy children (Control Group: CG): patients with CP exhibited higher values of most of the summary parameters of the upper body position than the CG. Then, the effects of a robotic-assisted gait training in a sub-group of 35 children by means of UBPS were evaluated. After robotic-assisted gait training program, no significant differences as for the summary parameters (UBPS and GPS). However, considering the specific variables scores, significant improvements are displayed as for the upper body parameter on the sagittal plane (Upper Body Ant/Pst index) and the lower limbs, in particular pelvis (Pelvic Ant/Pst and Pelvic Int/Ext indices) and as for walking velocity. A sort of reorganization of full-body kinematics, especially at upper body and proximal level (pelvis) seems to appear, with a new gait approach, characterised by a better strategy of the upper body associated with a significant improvement of the pelvis movement.

PMID: [34121521](#)

8. More Than Just Adolescence: Differences in Fatigue Between Youth With Cerebral Palsy and Typically Developing Peers

Laura K Brunton, Elizabeth G Condliffe, Gregor Kuntze, Leticia Janzen, Shane Esau, Clodagh M Toomey, Carolyn A Emery

Ann Rehabil Med. 2021 Jun 14. doi: 10.5535/arm.20250. Online ahead of print.

Objective: To quantify differences in fatigue and disordered sleep between adolescents with cerebral palsy (CP) and their typically developing peers. A secondary aim was to investigate the association between fatigue and disordered sleep in adolescents with CP. Methods: A convenience sample of 36 youth with CP aged 10-18 years was matched for age and sex with 36 typically developing peers. The Fatigue Impact and Severity Self-Assessment (FISSA), the Patient-Reported Outcome Measurement Information System (PROMIS) fatigue profile, and the Sleep Disturbance Scale for Children (SDSC) were collected. Results: Higher fatigue was reported in participants with CP than in their typically developing peers based on the FISSA total score (mean paired difference=19.06; 99% confidence interval [CI], 6.06-32.1), the FISSA impact subscale (mean paired difference=11.19; 99% CI, 3.96-18.4), and the FISSA Management and Activity Modification subscale (mean paired difference=7.86; 99% CI, 1.1-14.6). There were no differences between groups in the PROMIS fatigue profile (mean paired difference=1.63; 99% CI, -1.57-4.83) or the SDSC total score (mean paired difference=2.71; 99% CI, -2.93-8.35). Conclusion: Youth with CP experienced significantly more fatigue than their peers as assessed by a comprehensive measure that considered both general and diagnosis-specific concerns. Sleep did not differ between youth with CP and their typically developing peers. These findings underscore the need to consider the clinical management of fatigue across the lifespan of individuals with CP to prevent the associated deterioration of functional abilities.

PMID: [34126669](#)

9. Determinants of hearing loss in children with cerebral palsy in Kano, Nigeria

Y N Jibril, K A Shamsu, N Bello Muhammad, M G Hasheem, A R Tukur, A D Salisu

Niger J Clin Pract. 2021 Jun;24(6):802-807. doi: 10.4103/njcp.njcp_480_20.

Background: Cerebral palsy (CP) is a commonly occurring disorder of movement and posture that starts in early childhood. It is accompanied by other disturbances including hearing loss which has been shown to worsen the quality of life of the patients due to problems associated with speech and language acquisition. Several factors are responsible for developing hearing loss in CP. Aims: To determine the factors that can help in early diagnosis and treatment of hearing loss in children with cerebral palsy. Methodology: This was a hospital based cross-sectional study conducted among 165 randomly selected children with CP. An interviewer-administered questionnaire was used to obtain relevant sociodemographic and clinical information. The

data collected was analyzed using Statistical Product and Services Solution (SPSS) version 21. Results: The age range of the participants was 1-12 years, with a mean age and standard deviation (SD) of 4.49 ± 2.85 . The male to female ratio was 2:1. The commonest type of CP encountered was of spastic variety seen in 47.3%, while the least encountered variety was of the ataxic type, seen in only 4.2%; 46.7% of the children were reported to have hearing impairment by their guardian. Other comorbidities reported included epilepsy (33.9%), speech impairment (27.3%), mental retardation (17.0%) and visual impairment (8.5%). A statistically significant association was found between the presence of comorbidities ($P = 0.05$) and hearing loss among children with CP. Conclusion: Hearing impairment is common among children with CP. Several factors are associated with the development of hearing loss among children with CP. However, only presence of comorbidities was found to be a significant determinant of hearing loss among children with CP.

PMID: [34121725](#)

10. Assessing IQ in adolescents with mild to moderate cerebral palsy using the WISC-V

Monika Coceski, Darren R Hocking, Susan M Reid, Hisham M Abu-Rayya, Dinah S Reddihough, Jacquie Wrennall, Robyn Stargatt

Clin Neuropsychol. 2021 Jun 14;1-20. doi: 10.1080/13854046.2021.1928290. Online ahead of print.

Objective: To examine the influence of subtests that require fine motor responses on measures of intellectual ability, and compare three approaches to minimizing motor demands while assessing cognitive abilities in adolescents with cerebral palsy (CP) to the traditional method of the Wechsler Intelligence Scale for Children - Fifth edition (WISC-V). **Method:** Seventy adolescents with CP ($M = 14$ years 6 months, $SD = 10$ months) who were able to provide either a verbal or point response were assessed using the WISC-V administered via Q-interactive. The pencil-to-paper version of Coding was also administered. Performance on Block Design and pencil-to-paper Coding was compared to Visual Puzzles and Coding on Q-interactive, respectively. Full Scale IQ (FSIQ) scores derived according to the Traditional method of the WISC-V were compared to alternative estimates of FSIQ derived according to the Q-interactive, Nonmotor, and Motor-free methods, which minimized motor demands. **Results:** An additional 7-12% of participants were able to respond to Visual puzzles and Coding on Q-interactive compared to Block Design and pencil-to-paper Coding, respectively, and performance was marginally but significantly better. For 54 adolescents (Gross Motor Function Classification System (GMFCS) Level I-III) who were able to obtain FSIQ scores, the Traditional method underestimated FSIQ by 3-6 points compared to the alternative methods and the difference was most pronounced for those with more severe CP as measured by the GMFCS. **Conclusion:** Adolescents with CP are at an inherent disadvantage when cognitive ability is assessed using the Traditional method of the WISC-V. Findings suggest clinicians should employ the Nonmotor or Motor-free methods when assessing IQ in adolescents with CP.

PMID: [34126856](#)

11. Single-event multilevel surgery in cerebral palsy: Value added by a co-surgeon

Nickolas J Nahm, Meryl Ludwig, Rachel Thompson, Kenneth J Rogers, Ahmet Imerci, Kirk W Dabney, Freeman Miller, Julieanne P Sees

Medicine (Baltimore). 2021 Jun 18;100(24):e26294. doi: 10.1097/MD.00000000000026294.

The aim of this study was to compare outcomes for single-event multilevel surgery (SEMLS) in cerebral palsy (CP) performed by 1 or 2 attending surgeons. A retrospective review of patients with CP undergoing SEMLS was performed. Patients undergoing SEMLS performed by a single senior surgeon were compared with patients undergoing SEMLS by the same senior surgeon and a consistent second attending surgeon. Due to heterogeneity of the type and quantity of SEMLS procedures included in this study, a scoring system was utilized to stratify patients to low and high surgical burden. The SEMLS events scoring less than 18 points were categorized as low burden surgery and SEMLS scoring 18 or more points were categorized as high burden surgery. Operative time, estimated blood loss, hospital length of stay, and operating room (OR) utilization costs were compared. In low burden SEMLS, 10 patients had SEMLS performed by a single surgeon and 8 patients had SEMLS performed by 2 surgeons. In high burden SEMLS, 10 patients had SEMLS performed by a single surgeon and 12 patients had SEMLS performed by 2 surgeons. For high burden SEMLS, operative time was decreased by a mean of 69 minutes in cases performed by 2 co-surgeons ($P = 0.03$). Decreased operative time was associated with an estimated savings of \$2484 per SEMLS case. In low burden SEMLS, a trend toward decreased operative time was associated for cases performed by 2 co-surgeons (182 vs 221 minutes, $P = 0.11$). Decreased operative time was associated with an estimated savings of \$1404 per low burden SEMLS case. No difference was found for estimated blood loss or hospital length of stay between groups in high and

low burden SEMLS. Employing 2 attending surgeons in SEMLS decreased operative time and OR utilization cost, particularly in patients with a high surgical burden. These findings support the practice of utilizing 2 attending surgeons for SEMLS in patients with CP. Level of Evidence: Level III.

PMID: [34128865](#)

12. Perinatal stroke: mapping and modulating developmental plasticity

Adam Kirton, Megan J Metzler, Brandon T Craig, Alicia Hilderley, Mary Dunbar, Adrianna Giuffre, James Wrightson, Ephrem Zewdie, Helen L Carlson

Review Nat Rev Neurol. 2021 Jun 14. doi: 10.1038/s41582-021-00503-x. Online ahead of print.

Most cases of hemiparetic cerebral palsy are caused by perinatal stroke, resulting in lifelong disability for millions of people. However, our understanding of how the motor system develops following such early unilateral brain injury is increasing. Tools such as neuroimaging and brain stimulation are generating informed maps of the unique motor networks that emerge following perinatal stroke. As a focal injury of defined timing in an otherwise healthy brain, perinatal stroke represents an ideal human model of developmental plasticity. Here, we provide an introduction to perinatal stroke epidemiology and outcomes, before reviewing models of developmental plasticity after perinatal stroke. We then examine existing therapeutic approaches, including constraint, bimanual and other occupational therapies, and their potential synergy with non-invasive neurostimulation. We end by discussing the promise of exciting new therapies, including novel neurostimulation, brain-computer interfaces and robotics, all focused on improving outcomes after perinatal stroke.

PMID: [34127850](#)

13. Timing intrapartum management based on the evolution and duration of fetal heart rate patterns

Anthony M Vintzileos, John C Smulian

J Matern Fetal Neonatal Med. 2021 Jun 13;1-6. doi: 10.1080/14767058.2021.1938531. Online ahead of print.

One of the most important challenges in obstetrics is to determine the appropriate time to deliver the fetus without exposing the mother to unnecessary operative interventions. The use of continuous cardiotocography (cCTG) during labor has resulted in dramatic reductions in intrapartum fetal deaths, but fetal central nervous system (CNS) injury and cerebral palsy (CP) rates have remained relatively unchanged as related to the use of cCTG. In our view, this is due to continuing inability to recognize progressive fetal deterioration and intervene promptly prior to the development of fetal CNS injury. Although the 2008 NICHD workshop proposed a 3-tier classification system, most fetuses born with severe (pathologic) acidemia (cord artery pH < 7.00), as well as those who eventually develop CP, will never reach the stage of NICHD Category III fetal heart rate (FHR) pattern. In the present "Clinical Opinion," we promote a concept derived from observations, that the evolution of the FHR changes of the deteriorating fetus can be visually defined by three color "zones" that are clinically recognizable and, therefore, are actionable. In addition, we will review information regarding how long the fetus may be able to tolerate an abnormal FHR pattern before it suffers an adverse perinatal outcome, an area of investigation that has been rarely addressed before. Based on the available evidence, Category III FHR patterns should not be used as screening criteria because of low sensitivity for either fetal CNS injury (45%) or severe (pathologic) fetal acidemia (36-44%). In addition, the duration of the Category III pattern required for the development of severe fetal acidemia is extremely short to allow for a timely preventative operative intervention. On the contrary, the use of our proposed "red" zone, which includes the most advanced stages in the progressive deterioration of Category II patterns and Category III, will identify the overwhelming majority of fetuses who develop severe (pathologic) acidemia (96%) and/or CNS injury during labor (100%); moreover, the detection of fetal jeopardy by the use of the "red" zone occurs much earlier, as compared to using Category III, thus allowing reasonable amount of time for a timely obstetrical intervention. Further research is needed to determine the false positive rate and positive predictive value for a pre-determined period of time in the red zone.

PMID: [34121585](#)