Intelligence assessments for children with cerebral palsy: a systematic review

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AIM Cerebral palsy (CP) is defined as a primary disorder of posture and movement; however, approximately 45% of children with CP also have an intellectual impairment. Prevalence estimates are limited by a lack of guidelines for intelligence testing. This systematic review aims to identify and examine intelligence assessments for children with CP.

METHOD Electronic databases (PubMed, PsycINFO, Web of Science, CINAHL, EMBASE, and ERIC) were searched to identify assessments that (1) measured intellectual function, (2) in children aged 4 to 18 years, (3) with CP, and (4) with psychometrics available.

RESULTS Searches yielded 48 assessments, of which nine provided psychometric data for children with CP. The included tests were the Columbia Mental Maturity Scale, the Leiter International Performance Scale, the Peabody Picture Vocabulary Test, the Pictorial Test of Intelligence, the Raven’s Coloured Progressive Matrices, the Stanford–Binet Intelligence Scales, the Wechsler Adult Intelligence Scale, the Wechsler Intelligence Scale for Children, and the Wechsler Preschool and Primary Scale of Intelligence.

INTERPRETATION Intelligence assessments in children with CP lack reliability data, consensus regarding validity data, and population-specific norms. Research is required to establish psychometrics for children with CP. For children with higher motor involvement and/or communication and/or visual impairments, multiple options are required to assess intelligence appropriately.

Although cerebral palsy (CP) is characterized as a disorder ‘of movement and posture [due] to nonprogressive disturbances that occurred in the developing fetal or infant brain’, the impact of associated intellectual impairment in children with CP is gaining more recognition.1 Intelligence (IQ) is critical for independent participation in core activities such as education, self-care, and, in later life, employment and living independently. For this reason, intellectual impairment is an eligibility criterion for services such as school placement, disability support funding, or assistive technologies. It is estimated that about 45% of children with CP have an intellectual impairment,2–4 which is defined as ‘the presence of significantly subaverage intellectual functioning with ‘concurrent deficits or impairments in adaptive functioning’ when assessed ‘on an individually administered intelligence test’.5 A major problem with establishing this diagnosis, however, is that paediatric IQ assessments are generally developed for, and standardized with, typically developing children who do not have any physical impairments.6 The aim of this systematic review is to identify and evaluate IQ assessments used with children with CP to highlight those with suitable psychometric properties and clinical utility for this population.

Measures of ‘Global IQ’ reflect an individual’s overall ‘ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, [and] to overcome obstacles by taking thought’.7 When applying an IQ test, intellectual impairment is commonly diagnosed when a child achieves a Global IQ score more than 2SD below the mean for age-matched typically developing children.8 Areas of strengths and challenges with respect to various components of intelligence can be established by performance on IQ subscales.9 Individual IQ assessments vary in the subscales that they include. Verbal IQ subscales measure a child’s ability to reason using words, which is commonly measured using verbally delivered items requiring a verbal response, such as defining, or finding similarities between, words.10 Verbal IQ is useful when it is necessary to evaluate IQ in children with motor impairment as these subtests often do not include a motor component. Non-verbal IQ subscales measure a child’s ability to reason without using words, which is generally measured using visual items such as symbols and pictures, for example solving a visual pattern.11 Non-verbal assessments of IQ, especially those that use gestures and modelling, rather than words, to provide instruction, can be useful in children with communication impairments.12 Other domains of intelligence measured using IQ assessments include processing speed.10,13
memory, crystallized knowledge, quantitative reasoning, fluid reasoning, and visual–spatial processing. As well as assessments of Global IQ, there are many tests that measure subcomponents of intelligence, such as memory or executive function; however, these will not form part of this review as they do not enable the clinician to determine a Global IQ.

Despite the plethora of IQ assessments, it is difficult to identify those that both (1) report psychometric data for children with CP, and (2) suitably accommodate the heterogeneous range of impairments experienced by this population, in particular impairments of motor (100%), communication (60%), and/or visual function (37%). This is problematic because use of standardized IQ assessments that have been developed for the typical population can result in children with developmental disabilities receiving low IQ scores which are not necessarily a true reflection of their cognitive abilities, but reflect the fact that physical impairments limit their performance on assessment items. It has been reported that up to 42% of children with special needs seen by preschool psychologists are not able to complete standardized IQ assessments. Inappropriate test selection should be avoided because it compromises population estimates of prevalence of IQ impairment. It can also significantly impair services provided for individual children. For example, where education systems use IQ to determine eligibility for service provision, an inaccurate result can affect access to education adjustment programmes, funding support, and placement within a mainstream or special school. In addition, inappropriate labelling of children as having an intellectual impairment may impact on the attitudes, expectations, and behaviour of the child and the people supporting the child, which may adversely affect access to opportunities and the child’s future academic and career opportunities.

The aim of this study, therefore, was to perform a systematic review to identify IQ assessments reported for children with CP, to evaluate the population-specific psychometric properties and clinical utility of each tool, and to use this information to identify tools appropriate for children with CP with a range of motor, communication, and/or visual impairments.

METHOD

Search strategy

Primary searches were performed on literature published from 1970 to 31 July 2012 using six computerized databases: PubMed, PsycINFO, Web of Science, CINAHL, EMBASE, and ERIC. Searches used the MeSH terms and text words for ‘Cerebral Palsy’ AND (‘intelligen’ OR ‘Intelectual Impairment’ OR ‘Intelectual Disability’ OR ‘Mental Retardation’). Follow-up searches were performed using the title and author of all identified assessment tools as search terms. Assessments were included if they (1) measured Global, Verbal, or Non-verbal IQ (as described by the International Classification of Functioning, Disability and Health [ICF] category b117), (2) in children with CP, (3) aged between 4 and 18 years, and (4) for which psychometric properties were available for the CP population. Articles were excluded if they were (1) dated before 1970 or (2) were not in English. Assessments were excluded if (1) there was not an equivalent English version or (2) they were not accessible or out of print.

Data extraction and quality assessment

Two authors reviewed each article by title, then the abstract or full text until it could be determined if the article met the inclusion criteria. Papers were reviewed by a third author if there was disagreement. Papers were included in the review if there was consensus among authors. Psychometric and clinical utility data were extracted for each included IQ assessment using an adapted CanChild Outcome Measures Rating Form (available from http://www.canchild.ca/en/canchildresources/resources/measures.pdf). The quality of the methodology and strength of the psychometric data were calculated for each study using the scoring system of the COnsensus-based Standard for the Selection of Measurement Instruments (COSMIN) Checklist. The methodological quality of each study was rated on a four-point scale (excellent, good, fair, poor). Similarly, a four-point scale (good, intermediate, poor, unknown) was used to grade the psychometric strength of each study. A summary score was then determined based on the methodological quality and psychometric strength of the findings for each psychometric property of each assessment instrument, where 3=strong (consistent findings across multiple good studies or one excellent study); 2=moderate (consistent findings across multiple fair studies or one good study); and 1=limited (consistent findings across multiple poor studies or one fair study), or conflicting (inconsistent findings), or unknown (no findings). The summary scores for each psychometric property were then summed to provide an overall psychometric rating, which is presented in Table S1 (online supporting information), with a total possible maximum score of 18.

RESULTS

Search results

Initial searches yielded 3882 articles. Articles excluded were those that (1) were dated before 1970 (n=171); (2) were not in English (n=20); (3) did not include data collection, e.g. editorials, letters, comments, etc. (n=150); (4) did not report an assessment of global, verbal, or non-verbal IQ (n=2250); (5) did not include children with CP (n=581); (6) were outside the 4- to 18-year age range (n=357); or (7) could not be accessed (n=28) (Fig. S1, online supporting information). This resulted in 325 included articles that contained 48 assessments.

What this paper adds

- Assessments used with children with CP are identified.
- Assessments suitable for children with higher motor involvement and/or communication and/or visual impairment are evaluated.
- A clinical reasoning tool to guide IQ assessment selection is proposed.
Assessments were reviewed and excluded if (1) they did not include psychometrics for children with CP (n=10); (2) they did not include psychometrics for children within the age range (n=6); (3) there was no equivalent English version (n=7); (4) they were not accessible or were out of print (n=9); or (5) they did not provide a measure of Global, Verbal, or Non-verbal IQ (n=7; e.g. provided only an academic assessment or screen of cognitive abilities). The assessments which were excluded are presented in Appendix S1 (online supporting information). Following the exclusion process, nine IQ assessments were included in this review: the Columbia Mental Maturity Scale (CMMS-3), the Leiter International Performance Scale – Revised (Leiter-R), the Peabody Picture Vocabulary Test (PPVT-III), the Pictorial Test of Intelligence (PTI-2), the Raven’s Coloured Progressive Matrices (RCPM), the Stanford–Binet Intelligence Scales (SB-5), the Wechsler Adult Intelligence Scale (WAIS-IV), the Wechsler Intelligence Scale for Children (WISC-IV), and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III).

Characteristics of included IQ assessments
Table I summarizes the characteristics of the included assessments. All of the included IQ assessments were both predictive and discriminative in nature and were standardized using a typically developing population. Only the WISC-IV standardization included a representative proportion of children from special groups, including children with motor impairments. Most of the assessments drew their normative sample from the United States; however, a number of the assessments have been adapted for a variety of languages. All assessments provided an overall score representative of Global, Verbal, or Non-verbal IQ, with the Leiter-R, SB-5, WAIS-IV, WISC-IV, and WPPSI-III also providing component or index scores representing various dimensions of IQ. The age range for the assessments varied considerably, with the CMMS-3, Leiter-R, PPVT-III, PTI-2, SB-5, and WPPSI-III covering the lower end of the target age range (4y) in this study and the Leiter-R, PPVT-III, SB-5, and WAIS-IV covering the upper end of the study age range (18y).

Validity
The evidence for content, concurrent, and predictive validity for the included IQ assessments is summarized in Table SI. Generally, the included IQ assessments showed evidence of strong content validity, with most assessments developed using extensive reviews (expert, user, and literature) and analysis (pilot/try-out studies, item and subtest analysis, and standardization studies). Good agreements between a number of the IQ assessments (CMMS-3, PPVT-III, PTI-2, RCPM, SB-5, Modified SB, WISC-IV, and WPPSI-III) were found, supporting the concurrent validity of these assessments. With respect to predictive validity, many of the IQ assessments were found to predict academic achievement (general, language, and mathematical), school attendance (mainstream compared with special school), memory, motivation and persistence towards tasks, preference for physical activities, measures within the social domain, self-care skills, fine and gross motor skills, access to botulinum neurotoxin treatment, and stability over time. However, other studies found that IQ assessment results were unable to predict language-based academic achievement, school attendance, attention, and stability over time (decrease in WISC-IV Performance IQ).

The most evidence was found for construct validity, particularly for the WISC-IV and WPPSI-III, and is summarized in Table SII (online supporting information). Findings were mixed for Global IQ. For example, 23 studies found that children with CP scored lower on IQ assessments than children with typical development; however, a further nine studies found no difference between these groups. Some studies found that children with other diagnoses (myelomeningocele, pragmatic language impairment, Duchenne muscular dystrophy, or neonatal encephalopathy) scored higher on IQ assessments than children with CP, while other studies found no difference (myelomeningocele, pragmatic language impairment, or intellectual impairment). Whereas some studies found differences between distribution and severity of motor impairment, other studies found no difference between these groups. Further, lower scores on IQ assessments were associated with neural correlates or visual and somatosensory perception difficulties in some studies, but not in others. There were areas where studies agreed. Lower IQ scores were consistently associated with the presence of seizures, metabolic profile (higher creatine–N-acetylaspartate [Cr/NAA] ratios), preterm birth, bladder control (neurogenic detrusor overactivity), learning difficulties, and number of dental cavities. In terms of subscale comparisons, eight studies found that children with CP scored higher on Verbal IQ than on Performance IQ subscale on the WISC-IV and WPPSI-III, although one study found no difference. One study found that children with CP scored higher on the Verbal IQ subtests than on the Arithmetic subtest, on the remaining Performance IQ subtests than on the Block Design subtest, and on Picture Completion than on Coding on combined WISC-IV and WPPSI-III scores.

Reliability
Overall, there was a lack of reliability data available for the included IQ assessments specific to children with CP (Table SIII, online supporting information). Only one article reported test–retest reliability: a significant correlation was found between testing sessions for the SB-5 (r=0.75, p<0.05). Responsiveness studies were reported in five articles. Increases in IQ scores were found following attendance at school (Verbal IQ of WISC-IV and WPPSI-III), neurofeedback training (WISC-IV), and chronic cerebellar stimulation (WAIS-IV). No change was found in IQ scores following intrathecal baclofen therapy (PPVT-III and RCPM) or power wheelchair training (Leiter-R and PPVT-III), an expected finding.
<table>
<thead>
<tr>
<th>Assessment tool</th>
<th>Purpose</th>
<th>Age range</th>
<th>Type of test</th>
<th>Normative sample</th>
<th>Scale/item/description</th>
<th>Language adaptations</th>
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<tbody>
<tr>
<td>CMMS-3</td>
<td>Predictive discriminative</td>
<td>3y 6mo–9y 11mo</td>
<td>Standardized</td>
<td>2600 children aged 3y 6mo–9y 11mo, representative of the US population</td>
<td>Single overall score</td>
<td>German version</td>
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<td>Leiter-R</td>
<td>Predictive discriminative</td>
<td>2y–20y 11mo</td>
<td>Standardized</td>
<td>1719 individuals aged 2y–20y 11mo, representative of the US population</td>
<td>Full-scale IQ comprising: Ages 2–5y: Fluid Reasoning (two subtests) and Fundamental Visualization (two subtests) Ages 6–10y: Fluid Reasoning (two subtests) Ages 11–20y: Fluid Reasoning (two subtests) and Spatial Visualization (three subtests) Nil reported for children with CP</td>
<td>Nil reported for children with CP</td>
</tr>
<tr>
<td>PPVT-III</td>
<td>Predictive discriminative</td>
<td>2y 6mo–90y 11mo</td>
<td>Standardized</td>
<td>2725 individuals aged 2y 6mo–90y 11mo, representative of the US population</td>
<td>Single overall score</td>
<td>Dutch version</td>
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<tr>
<td>PTI-2</td>
<td>Predictive discriminative</td>
<td>3y–8y 11mo</td>
<td>Standardized</td>
<td>970 children with typical development aged 3y–8y 11mo, representative of the US population</td>
<td>Single overall score comprising: Verbal Abstractions Form Discrimination Quantitative Concepts</td>
<td>Nil reported for children with CP</td>
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<tr>
<td>RCPM</td>
<td>Predictive discriminative</td>
<td>5–11y; 55–85y</td>
<td>Standardized</td>
<td>598 children aged 5y 6mo–11y 6mo from Great Britain; includes children attending special schools 531 children aged 6y 6mo–9y from south-east England Children aged 5y 6mo–11y 6mo from USA (number not reported) Children aged 6y–10y from Queensland, Australia (number not reported) 408 children aged 6y–10y from West Germany 1375 children aged 5y 6mo–11y 3mo from Slovakia 617 children aged 6y–10y from Fribourg, Switzerland 1579 children aged 4y 3mo–9y 6mo from Spain 1575 children aged 5y 6mo–10y from East Germany 1920 children aged 4y–10y from the Netherlands 2015 children aged 5y–11y 6mo from Sao Paulo, Brazil 2518 children aged 5y 6mo–11y from Puerto Rico 4382 children aged 8y–11y 6mo from Peru 2821 individuals aged 55–85y from the Netherlands 271 individuals aged 65–85y from Rutherglen, UK</td>
<td>Single overall score</td>
<td>Dutch version</td>
</tr>
<tr>
<td>Assessment tool</td>
<td>Purpose</td>
<td>Age range</td>
<td>Type of test</td>
<td>Normative sample</td>
<td>Scale/item/description</td>
<td>Language adaptations</td>
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<td>SB-5</td>
<td>Predictive discriminative</td>
<td>2y upwards</td>
<td>Standardized</td>
<td>4800 individuals aged 2y upwards, representative of the US population</td>
<td>Full-scale IQ, with five indices: Fluid Reasoning: two subtests (one verbal, one non-verbal) Knowledge: two subtests (one verbal, one non-verbal) Quantitative Reasoning: two subtests (one verbal, one non-verbal) Visual Spatial Processing: two subtests (one verbal, one non-verbal) Working Memory: two subtests (one verbal, one non-verbal)</td>
<td>Japanese versions (Tanaka–Binet and Suzuki–Binet) Turkish version</td>
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<td>WAIS-IV</td>
<td>Predictive discriminative</td>
<td>16y–90 y11mo</td>
<td>Standardized</td>
<td>2200 individuals aged 16y–90y 11mo, representative of the US population</td>
<td>Full-scale IQ, with four indices: Verbal Comprehension Index: three core and one supplemental subtest Perceptual Reasoning Index: three core and two supplemental subtests Working Memory Index: two core and one supplemental subtest Processing Speed Index: two core and one supplemental subtest</td>
<td>Nil reported for children with CP</td>
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<tr>
<td>WISC-IV</td>
<td>Predictive discriminative</td>
<td>6y–16y 11mo</td>
<td>Standardized</td>
<td>2200 children aged 6y–16y 11mo, representative of the US population. A representative proportion of children from special group studies were added to the normative sample including children who are intellectually gifted and children with intellectual impairment, learning disabilities*, attention-deficit–hyperactivity disorder, communication impairments; acquired brain injury, autism spectrum disorders, and motor impairment</td>
<td>Full-scale IQ with four indices: Verbal Comprehension Index: three core and two supplemental subtests Perceptual Reasoning Index: three core and one supplemental subtest Working Memory Index: two core and one supplemental subtest Processing Speed Index: two core and one supplemental subtest</td>
<td>Dutch version Finnish version Japanese version Polish version Turkish version</td>
</tr>
<tr>
<td>WPPSI-III</td>
<td>Predictive discriminative</td>
<td>2y 6mo–7y 3mo</td>
<td>Standardized</td>
<td>1700 children aged 2y 6mo–7y 3mo, representative of the US population</td>
<td>Full-scale IQ comprising: Ages 2y 6mo–3y 11mo: Verbal IQ (two core and one supplemental subtest) and Performance IQ (two core subtests) Ages 4y–7y 3mo: Verbal IQ (three core and two supplemental subtests), Performance IQ (three core and two supplemental subtests), and Processing Speed Quotient (one core and one supplemental subtest; two optional subtests)</td>
<td>Finnish version Indian version</td>
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CMMS-3, Columbia Mental Maturity Scale; Leiter-R, Leiter International Performance Scale – Revised; PPVT-III, Peabody Picture Vocabulary Test; PTI-2, Pictorial Test of Intelligence; RCPM, Raven’s Coloured Progressive Matrices; SB-5, Stanford–Binet Intelligence Scales; WAIS-IV, Wechsler Adult Intelligence Scale; WISC-IV, Wechsler Intelligence Scale for Children; WPPSI-III, Wechsler Preschool and Primary Scale of Intelligence.

*North American usage: mental retardation.
Further research with suitable subgroup power is critical for each of these assessments, to evaluate individual item suitability and performance ranges for children with varied motor, communication, and perceptual abilities.

A significant amount of research has been carried out to determine the validity of individual assessments. However, although the majority of studies agree that, on average, children with typical development have higher IQs than children with CP, and that children with minimal motor involvement have higher IQs than those with severe motor involvement, it is difficult to determine which assessments are most valid. First, this is because many studies do not include a representative sample, or do not adequately describe the physical characteristics of the CP cohort (e.g. motor distribution, type, and severity). Therefore, studies reporting the ability of assessments to discriminate between children with and without CP do not necessarily prove the validity of those assessments if the cohort of children with CP is biased towards those with more severe presentations. Similarly, studies finding no difference between typical and CP populations may have involved children with only mild presentations. Second, confusion over whether increasing severity of motor impairment does or does not correlate with lower IQ may be confounded by the motor demand of the selected IQ test. For example, children with CP tend to score lower on indices and subtests of the Wechsler scales which have a higher motor component, particularly in Performance IQ. Similarly, children with a visual impairment are likely to be disadvantaged on assessments that rely heavily on visual processing, such as the Wechsler Performance IQ, and children who have a communication impairment may be disadvantaged by items that require both receptive and expressive language skills. Finally, some papers have accentuated these problems by utilizing only one IQ assessment with a heterogeneous cohort of children with CP, only to remove participants who could not complete the assessment for physical reasons, or, in the case of children assumed to have severe intellectual impairment, to impose a low estimated IQ score. To avoid perpetuating the notion that increasing physical impairment has a linear relationship with decreasing IQ, studies should include a suite of IQ assessments suitable for the heterogeneous abilities of a representative sample.

In addition to the poor consensus on validity of IQ assessments for children with CP, very little reliability data is currently available. The nine assessments identified in this review provide reliability information based on a typically developing population. The manuals of each assessment provided information on split-half and test–retest reliability, internal consistency, standard error of measurement, and interscorer consistency. Hence, while there is confidence in the reliability and accuracy of IQ results in typically developing children, the same level of confidence cannot be applied to children with CP in light of the limited reliability information currently available.

This review shows that, to achieve a valid assessment, it is critical to understand the motor, communication, and

Clinical utility
The clinical utility of the included IQ assessments is summarized in Table SIV (online supporting information). Generally, the IQ assessments with multiple subtests (Leiter-R, SB-5, WAIS-IV, WISC-IV, and WPPSI-III) took longer to administer, cost more to purchase, required the administrator to be a registered psychologist, and were more complex to administer and score. However, the presence of verbal and non-verbal subscales enabled flexibility when using these assessments with children with, respectively, more severe motor or communication impairments. The remaining IQ assessments were composed of a single task (CMMS-3, PPVT-III, and RCPM) or a smaller number of subtests (PTI-2). These assessments did not take as long to administer, were less expensive, and were easier to administer and score. While training was recommended for most of these shorter assessments, the administrator did not need to be a registered psychologist.

DISCUSSION
The large number of papers identified in this review confirms that IQ is of major importance in understanding the abilities of children with CP. It is used not only as an outcome measure in studies of cognitive function, but also as an eligibility criterion, classification criterion, or covariate, in many studies of other abilities. Despite this, both the population-specific psychometric data for these assessments and the assessment selection process are in need of improvement. Principal concerns are the inadequate standardization of assessments for children with CP, poor consensus on validity of individual assessments, a lack of reliability data, and limitations in clinical utility for the broader population, which are all underpinned by the significant heterogeneity of physical impairments associated with CP. So, while there are standardized IQ assessments available that are potentially suitable for children and young people with CP, at this time individual assessments should be used and interpreted with caution.

Standardization of IQ assessments for children with CP is so burdened by the heterogeneity of the population that no one assessment currently presents a fair assessment of all children. As all standardized assessments have been normed for children with typical physical development, they all include items that inadvertently penalize subgroups of children with CP, as a result of their motor, communication, and/or visual impairments. This may lead to questionable, possibly invalid, results. However, if any item is modified to make it more appropriate for a certain physical impairment, the item may lose standardization, again compromising the overall assessment validity. In the absence of one assessment that can be adopted for the whole CP population, this paper has identified a suite of nine IQ assessments that have been standardized for typically developing children but also have strong potential for use with subgroups of children with CP (Table I). A method of selecting these assessments is proposed later in this paper. Further research with suitable subgroup power is critical for the assessment of group-level differences.
visual function of the child being assessed and to match this with an IQ assessment that does not penalize deficits in these skills. Understanding the child's capabilities will most likely require a multidisciplinary assessment approach. Achieving the best match between the child's physical capabilities and the available assessments can be aided by a clinical reasoning tool that has been developed by the authors and presented in Figure S2 (online supporting information). The first step in the tool considers the child's level of motor involvement, the second step considers the presence or absence of a communication impairment, and the third step the presence or absence of a visual/visual perceptual impairment.

The tool shows that any of the nine assessments identified in this review are potentially suitable for children with minimal upper limb motor involvement (Gross Motor Function Classification System [GMFCS] levels I–III and Manual Ability Classification System [MACS] level I) and typical communication and visual function, because it is less likely that the child's motor, communication, or visual skills will impact on his or her performance. However, it must be noted that the timed subtests in the Wechsler scales may disadvantage some children with CP. For children with an additional communication impairment but typical visual function, a non-verbal or language-free assessment is recommended (i.e. Leiter-R). If the communication difficulty is expressive, with intact receptive communication skills, assessments which require receptive language but a non-verbal response may be appropriate (i.e. CMMS-3, PTI-2, RCPM, and the Perceptual Reasoning Index of the Wechsler scales). For children with minimal motor impairment and a visual impairment, but typical communication function, there is a lack of vision-free items; however, it may be possible to use the Verbal Comprehension Index of the Wechsler scales to obtain an estimate of a child's verbal cognitive abilities. For children with minimal motor involvement, and both communication and visual impairments, there is a lack of appropriate standardized IQ assessments available; thus, other methods of exploring a child's cognitive abilities must be used, such as reports from parents and teachers, observations of the child across environments, and informal assessment procedures. Furthermore, it is good practice to make use of such methods alongside standardized IQ assessments when making decisions about children with CP. Indeed, including sources of information from parents and other professionals increases the reliability of the interpretations made during the assessment process.

For children with more severe upper limb motor involvement (MACS II–V), or postural limitations (GMFCS levels IV and V), it is important to use assessments with minimal motor requirements (i.e. CMMS-3, Leiter-R, PPVT-III, PTI-2, RCPM, and the Verbal Comprehension Index of the Wechsler scales). For children with additional communication impairments, but typical visual function, non-verbal or language-free assessments with minimal motor components are suitable (i.e. Leiter-R). If the communication impairment is expressive, with intact receptive skills, the CMMS-3, PTI-2, and RCPM may also be appropriate as they do not require a verbal response and have minimal motor requirements. For children who have good communication skills, but have a visual or visual–perceptual impairment, the Verbal Comprehension Index of the Wechsler scales may be appropriate because of the minimal motor and visual components. As discussed above, there is a lack of standardized IQ assessments appropriate for children with significant concomitant motor, communication, and visual impairments and so other methods of estimating IQ need to be considered.

It must be stressed that the flow chart developed is a guide to aid clinical decision-making, and these factors should not be the only considerations when deciding on an IQ assessment. Other aspects which may impact on a child's participation and performance include the child's background (such as his or her cultural and ethnic background and general health), personality characteristics (such as motivation and anxiety levels), and the assessment situation (such as the physical condition of the child and environmental influences). Professional and ethical guidelines regarding assessment should be adhered to at all times.

**Future recommendations**

With respect to future research, there is a need for studies to increase the clarity around validity of individual assessments for specific CP subgroups (i.e. those with motor and/or communication and/or visual impairments). Increased consensus is more likely to be achieved through careful selection and description of the participants for the study and consistency across procedures. In particular, although studies frequently use the GMFCS to classify the motor abilities of a study cohort, as most performance scales are predominantly fine motor based, the MACS should also be reported. No study was identified in this review which explored the impact of other sensory systems on IQ, such as a child's hearing or tactile performance. This may be a useful area of further research as 12% of children with CP also have a hearing impairment, and up to 80% of some subgroups of children with CP are known to have tactile impairments. There was a lack of Non-verbal IQ assessments reported for children with CP. Non-verbal assessments are essential for assessing children with communication impairments, therefore further testing and development of these assessments is warranted in light of the high proportion of children with a communication impairment. Information about the ability of IQ assessments to predict adaptive functioning of children with CP would also be very useful in increasing our ability to estimate the cognitive abilities of children who are unable to complete standardized IQ assessments. More reliability data specific to children with CP is also needed to ensure that the IQ assessments used are a reliable measure of cognitive abilities for this population. Development of norms
specific to children with CP would increase confidence in measuring the cognitive abilities of this group of children using standardized IQ assessments. This would ensure that the results are not disadvantaging children with CP in light of their motor, visual, and communication abilities. Finally, developing and standardizing an IQ assessment with sub-tests specifically for subgroups of children with CP may be the best way to ensure that an accurate picture of each child’s cognitive abilities is obtained.6

CONCLUSIONS
Without doubt, IQ is an essential component to be considered when working with children with CP. However, despite the extensive number of studies reporting IQ assessments in children with CP, there is a lack of sound psychometric information specific to this population. Furthermore, the cognitive abilities of children with more severe motor, communication, and/or visual impairments are likely to be underestimated because the standardized procedures of such assessments are not appropriate for the population as a whole. For this reason, it is desirable that a multidisciplinary and multi-method approach to IQ assessment is adopted, with assessment and information regarding children’s motor, communication, and visual skills taken into account. A clinical reasoning tool designed to support selection of the most appropriate IQ assessment for children with CP based on multidisciplinary information is presented in this review. Such information should also be considered when interpreting IQ assessments and interpretation should be supplemented by information from parents and teachers, observations across environments, and informal assessment procedures.15 This approach has been found to increase the reliability of the results obtained for children with special needs.39,40

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SUPPORTING INFORMATION
Additional supporting information may be found in the online version of this article:
- Appendix S1: Excluded intelligence assessments used with children with cerebral palsy.
- Table S1: Content, concurrent and predictive validity of intelligence assessments reported for children with cerebral palsy.
- Table SII: Construct validity of intelligence assessments reported for children with cerebral palsy.
- Table SII: Reliability of intelligence assessments used with children with cerebral palsy.
- Table SIV: Clinical utility of intelligence assessments used with children with cerebral palsy.
- Figure S1: Search strategy for identifying intelligence assessments used with children with cerebral palsy.
- Figure S2: Clinical reasoning tool for assessments of intelligence (IQ) for children with cerebral palsy.
- Data S1: References may be found in the online version of this article.