

Assessment of Child Development by the Bayley III Scale: A Systematic Review

Orioli PA¹, Johnston C^{2*}, Krebs VLJ³, Francisco RPV⁴ and Carvalho WB⁵

¹Neonatologist, Master's Student in Child Health at the Department of Pediatrics, University of São Paulo (FMUSP), Brazil ²Intensivist Physiotherapist, Assistant Professor of Clinical Research in Neonatology\Intensive Therapy by the Department of Pediatrics, FMUSP, Brazil

³Physician Neonatologist, Full Professor at the Department of Pediatrics at FMUSP, Brazil

⁴Obstetrician, Adjunct Professor, Department of Obstetrics, FMUSP, Brazil

⁵Intensivist Physician, Titular Professor in Neonatology\Intensive Care at the Department of Pediatrics, FMUSP, Brazil

***Corresponding author:** Cíntia Johnston, Pt RRT MBA MsC Phd, Intensivist Physiotherapist, Assistant Professor of Clinical Research in Neonatology\Intensive Therapy by the Department of Pediatrics, FMUSP, SP-Brazil, Tel: 55 -11- 982320542; E-mail: <u>cintia.johnston@hc.fm.usp.br</u>

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Abstract

Objective: To identify the accuracy of the Bayley III Scale to assess the neuropsychomotor development (DNPM) of children, as well as to identify the degree of evidence and the level of recommendation of the selected studies.

Method: This is a systematic literature review using the keyword "Bayley III" in the Medline PubMed digital health database. The following filters were used: Clinical Trial, Controlled Clinical Trial, Meta-Analysis, Randomized Controlled Trial, Review, Scientific Integrity Review, Systematic Review. Studies published in English from January 2020 to November 2021 carried out in the neonatal and pediatric age group evaluated by the Bayley III Scale were included. The PICO method (P=patient; I=intervention; C=comparison; O=outcomes) was used to search for scientific articles in the digital health database, the degree of evidence and the level of recommendation were generated through of the GRADE rating.

Results: 118 studies were found, 12 of which met the inclusion criteria of this study. Most studies (07) were classified as C evidence and low recommendation level, 02 of them were classified as D/very low, 02 as A/high and one of them as B/moderate. The age group included ranged from 6 to 36 months and 4 studies compared the accuracy of the BSID-III with the BSID-II.

Conclusions: The Bayley III Scale has been widely applied in pediatrics to assess DNPM (cognitive, language, gross and fine motor) in the age group between one and 42 months corrected age. It has a mean sensitivity of 33.3% and specificity of 98%, with a level of evidence C and a low degree of recommendation to identify delays in DNPM in pediatrics.

Keywords: Bayley-III; BSID-III; DNPM; Motor development; Child development; Infant; Pediatrics; Neonatology

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1. Introduction

The detection of possible changes in children's development is essential to predict the need to institute early intervention methods, aiming to prevent or minimize cognitive, language, motor, behavioral and social problems throughout the child's life [1-3].

Bayley scales have been applied as an objective measure to identify possible neurodevelopmental delays, both at the clinical/care level and in scientific research. The main objective of these scales is to identify children with developmental delays and provide information for planning interventions that may be necessary in this context [1-4]. They must be applied by qualified and certified health professionals [2]. If of scales that can be applied in preterm newborns (PTNB), provided that the corrected age is used to define the starting point of the analysis of its results, as well as to derive the data [4].

There are no reliable statistical data on the incidence of delay in DNPM in children. The WHO estimates that 10% of the population of any country is made up of people with some degree of disability [5]. Risk factors range from diseases, perinatal complications to adverse socioeconomic conditions. The conjuncture of biological, psychosocial and environmental factors interferes in the development of children throughout their growth. Developmental delay can be a transient, evolutionary or permanent condition, so appropriate tools and trained professionals to perform periodic assessments are necessary [6].

The known scarcity of instruments with cross-cultural validation for the assessment of neuropsychomotor development (DNPM) in children in Brazil makes the Brazilian version of the Bayley-III scale, adapted to the Portuguese language in 2012 (MADASHI) [7], considered the gold standard. for this purpose.

Thus, the main objective of this systematic literature review was to identify the accuracy of the Bayley III Scale to assess the DNPM of children, as well as to identify the degree of evidence/recommendation of the selected studies.

2. Method

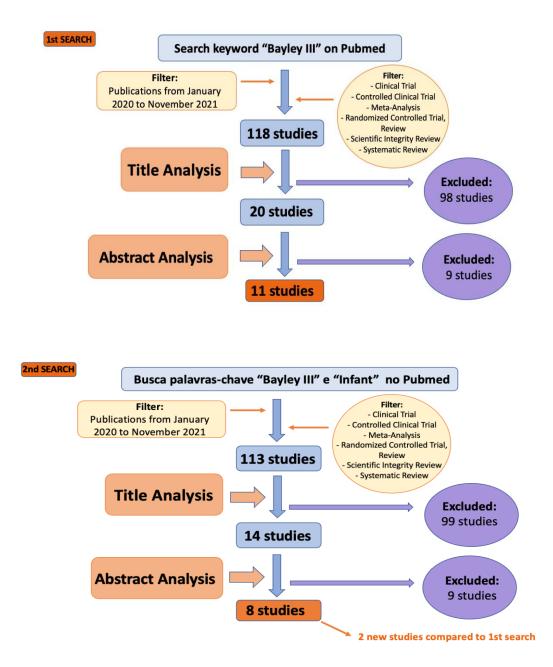
This is a systematic literature review using the keywords "Bayley III" in the Medline Pubmed digital health database. The following filters were used: Clinical Trial, Controlled Clinical Trial, Meta-Analysis, Randomized Controlled Trial, Review, Scientific Integrity Review, Systematic Review. Studies published in English from January 2020 to November 2021 carried out in the neonatal and pediatric age group evaluated by the Bayley III Scale were included.

The PICO method (P=patient; I=intervention; C=comparison; O=outcomes) was used to search for scientific articles in the digital health database [8]. The first researcher searched for scientific articles and selected by title and abstract those that met the inclusion criteria of this systematic review. The second and third researchers classified the degree of evidence/recommendation of the scientific articles found by the GRADE method [9], following the classification: A= well-designed clinical trial, B= clinical trial with mild limitation or well-designed observational study with consistent findings, C= clinical trial with moderate limitations or comparative observational study (cohort and case-control), D= clinical trial with severe limitations or observational study with limitation or non-comparative observational study. A fourth researcher analyzed the GRADE generated by the second/third researchers to verify the agreement of the degree of evidence/recommendation of

each scientific article included in this systematic review. If there was disagreement between the first two researchers, the fourth researcher (with 20 years of experience in scientific research) issued the final graduation for the study. The data are presented in a descriptive way in the form of tables and graphs.

3. Results

During the period of this systematic literature review, 118 studies were found in the digital database, through the analysis of the title, 98 studies were excluded due to not meeting the inclusion criteria (examples: studies with adults, letters to the editor, isolated use of earlier versions Bayley Scales). Thus, 20 studies remained, of which 08 were excluded after reading the abstract, due to analyzing only previous versions of Bayley III (FLOWCHART 1). The 12 studies that met the inclusion criteria are shown in TABLE 1 with their respective levels of evidence/degree of recommendation, after analysis of agreement/disagreement between the researchers involved.



4. Discussion

The first edition of the Bayley Scale of Child Development (BSID) [10] was published in 1969 and evaluated children from two to 30 months of age. The second edition, the BSID-II [11], was published in 1993 and had two assessment indices, the Mental Development Index (MDI) to assess cognitive, language and social skills; and the Psychomotor Development Index (PDI), aiming to assess fine and gross motor skills [1,2,4,12].

Although popular, the BSID and BSID-II, including the MDI, did not differentiate children with selective cognitive delay from children with language delay, just as the PDI did not differentiate children with exclusively fine motor delay from those with selectively gross delay [1,4].

Intending to address the aforementioned issues, the third edition, Bayley Scale III [13], published in 2006, includes subscales, subdivided into five assessments: Cognitive, Receptive Language, Expressive Language, Fine Motor and Gross Motor; aiming to explore more broadly the possible deviations from normality (from typical behavior) and improve the clinical utility of the Bayley scales, enabling more targeted interventions when necessary [1,4,12].

The cognitive scale is applied to assess sensory acuities and the ability to respond to them, as well as memory acquisition, learning, and problem-solving skills. The language scale assesses receptive language skills, expressive vocalizations and the beginning of verbal communication. The motor scale provides a means of assessing postural control, coordination of large muscles, and more refined hand and finger manipulation skills [13].

Unlike the two previous editions, the Bayley-III Scale, aiming at applicability in newborns and infants, was standardized using a mixed sampling procedure, that is, it includes children with typical neurological development and children with some risk factor for delayed development. development (examples: trisomy 21, cerebral palsy, prematurity, among others). With this change, the normative mean was reduced, and the Bayley-III indices were almost 7 points higher than the previous scales. This change brought into question the fact that the Bayley-III Scale underreports delays in relation to previous editions [1,2].

Over time, several studies sought to compare the performance indices of the Bayley Scales. As of 2010 [1], possible causes of the higher rates of the Bayley-III Scale began to be investigated [1]. Most studies [1,2,4,12,13,15] state (see TABLE 1) that the Bayley-III Scale overestimates the DNPM, allowing for higher scores, reports an average of 7 points higher than previous editions [4]. Consequently, studies (see TABLE 1) indicate that the Bayley-III Scale has low sensitivity (33.3%) for detecting later cognitive and motor impairment (in the medium/long term), under-identifying later cognitive and motor impairments, however, maintaining good specificity (98%) [1,3,16,17].

Several of the studies [1,2,4,12] that explored the differences between the BSID-II and the BSID-III have important methodological limitations, which limit comparisons between test versions (See comments in TABLE 1). Thus, it is not possible to conclude whether the change in scores is due to the temporal improvement in the results in the DNPM of the assessed child, since in some studies [4,12] (TABLE 1) Bayley-III was administered in its entirety, followed by the administration of additional items of the BSID-II or estimated performance of the BSID-II based on the overlap of the items. Caution is recommended when comparing results of scientific research carried out in different time periods that used different versions of these scales [2].

TABLE 1. Studies included in the systematic review with their respective authors, type of study, level of scientific evidence, sample, interventions performed, main outcomes analyzed and main results.

A	evidence, sample, interventions performed, main outcomes analyzed and main results.				
Author, Year of Publicati on	Type of study and Level of Scientific Evidence* (GRADE)	Sample	Interventions	Main Outcomes	Main results
Anderson PJ, et al. [1]	Simple literature review D	47 studies	Revised the psychometric properties of the Bayley-III Scale Outcomes analyzed: 1. Is the state of development overestimated? 2. Whether Bayley III is a predictor of long-term functionality?	There is considerable evidence that the Bayley-III overestimates child development, resulting in an incorrect classification of child developmental delays.	A number of strategies have been proposed to deal with inflated Bayley- III scores, none of which are considered ideal. Evidence to date suggests that Bayley-III is a poor predictor for detecting long-term cognitive and motor impairments. The Bayley-III needs new standards or alternatively it may be time for a new edition of the Bayley Scales.
Sharp MA. [2]	Randomize d crossover study C	N=340 eligible =119 enrolled and randomized=77 completed the study being present in 2 assessments GI<32wks, GIc 18-22 months Weight ≤ 2000 g Eligible patients from 4 distinct clinics that are part of the Children's Hospital of Philadelphia Neonatal Care Network.	Bayley II and III were administered integrally (completely), maintaining standard of care at the clinic: - On separate visits - Random, blind, randomized order - Interval of 4 to 8 weeks between assessments - applied by different professionals	Bayley III scores were significantly higher across the range of scores and across all domains. Whether BSID-II underestimates development remains to be seen; Bayley III overestimates development or the two instruments just measure development differently.	The mean difference between the Bayley Cognitive Compound III scores and the BSID-II Mental Development Index (MDI) was nearly 1SD higher (14.1 \pm 12.9 points, p <0.001). The mean difference between the Bayley Motor Compound III scores and the BSID-II Psychomotor Development Index was almost 2/3 SD (9.0 \pm 11.9 p <0.001). When the severity of delay was rated using cutoff points for moderate and severe developmental delay (1 and 2 SDs below the reference norm), 40% of children (n=31/77) were rated as least severely delayed with the Bayley III (p<0.01).

		I			
Griffiths	Systematic	N=37 studies /	Systematically	Identified 7 gross	Bayley III, NSMDA and
A, et al.	review	manuals \Box 7	assess the	motor assessment	MABC-2 have evidence
[3]		instruments met	psychometric	tools suitable for use	of predictive validity.
	Search	the inclusion	properties and	in clinical or research	
	platforms:	criteria	clinical utility of	settings, each with its	The BOT-2, MABC-2,
	MEDLINE,		gross motor	own strengths and	PDMS-2 and TGMD-2
	Embase,	Analyzed	assessment tools for	limitations.	are the most reliable
	CINAHL	instruments:	children aged 2 to		assessments in this age
	and AMED	- Bayley-III	12 years	Most gross motor	group.
		- BOT-2		assessments for	Bayley III has the best
	Period:	- MABC-2	The methodological	children have validity	predictive validity at 2
	between	- SEND	evaluation of the	ranging from good to	years of age for later/long
	May and	- NSMDA	documents was	excellent.	term motor outcomes.
	July 2017	- PDMS-2	completed using the		
		- TGMD-2	four-point scale of		None of the assessment
			the consensus-based		tools demonstrates good
	Α		standards for the		evaluative validity.
			selection of the		
			checklist of health		More research on
			status measurement		evaluative gross motor
			instruments (COSMIN).		assessment tools is needed.
			(COSIVIIIV).		needed.
Reuner	Prospective	N 108 eligible	Compare Bayley-III	Bayley-III scores	- The Bayley Scales
G, et al.	cohort	babies \rightarrow only 55	Bayley-II, with a	were significantly	remain internationally
[4]	study	PT with full	special focus on	higher than the	accepted, although the
[']	Study	assessment	first-year patterns.	previous edition's	third revision raises
			mot jeu paterno.	relevant scores in the	concerns.
		GA All <37wks,	- First, Bayley III	first year of life.	- Although all Bayley-III
	Period:	2/3 PT late, were	was applied in a		scores were higher than
	between	evaluated between	single session.		the relevant scores from
	April 2011	6 months and 16	8		the previous edition, in
	and March	days and 7months	- Raw scores for the		contrast to studies in older
	2012	and 15 days GAc	Bayley-II cognitive		groups, the differences
		(homogeneous	and motor scales		between the two test
	D	group approx. 7	were estimated from		editions in the very young
		months GAc)	Bayley-III items.		study group became more
					obvious with regarding
		Weight 43BP /	- All examinations		motor performance, with
		12MBP or EBP	were performed by a		the greatest difference
			trained psychologist		(ten points) between the
			in approximately 30		motor scales of both
		Clinical situation:	minutes.		editions.
		PT NB treated at			- MBP and EBP had
		the perinatal			significantly lower motor scores than BP in both
		center of the			
		University Hospital of			editions, Interpretation of Bayloy
		Hospital of Heidelberg			- Interpretation of Bayley- III results should be based
		between May			on comparison of groups
		2010 and October			rather than comparison
		2010 and October 2011			with normative data.
		Infants with			with normanye tata.
		severe sensory			
		impairments,			
		cerebral palsy,			
		genetic			
		syndromes,			
L	1	· · · · · · · · · · · · · · · · · · ·		I	

		intracranial hemorrhage (ICH) > grade 1 and periventricular leukomalacia were excluded.			
Acton	Prospective	N 110 survivors	Report Bayley-III	Results suggest that	- The findings suggest that
BV, et al. [12]	and longitudinal	(68% boys) Mean age 21	scores after cardiac surgery and	scores after cardiac surgery at 6 months	the outcomes for children after different heart
,	cohort study	months (SD 4 months) + paired	compare with Bayley-II	of age or younger are generally 4 to 9	surgeries are varied. - Bayley-III scores ranged
	Multicentre	samples	- Children were	developmental quotient points below	from 1.4 (MDI / compared to language
	: 6 locations		assessed with	the normative values	scale) to 10.0 points (MDI
	in the 4 provinces of	Clinical situation: - Children born	Bayley-III and 25 of these children	of the Bayley-III.	/ compared to cognitive scale) higher than similar
	western Canada	June 2004 to December 2007	completed additional items		BSID-II scores.
		who survived complex cardiac	from Bayley-II		
	C	surgery at 6 weeks			
	С	or less - Excluded children with chromosomal alterations/needed ECMO or heart transplantation - All were followed up to 2 years of age			

Campeli SK, [13]Report Gerived from a GA born 29-34 (Gineon32.4)Examine the concertional (Cinical situation: (Gineon32.4) (Gineon32.4) (Gineon32.4) (Gineon32.4) (Gineon32.4)Examine the concertional (Gineon32.4) (Gineon32.4) (Gineon32.4) (Gineon32.4)Ex			1			
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			- Examined associations of problem and competency scores and positive screening rates with USG and MRI		
Martin AJ, et al. [15]	Secondary analysis of a double- blind, randomized , controlled trial Multicentric : Canada and New Zealand C	N 204 babies with suspected or confirmed NNS= 100 girls Weight median weight of 911 g median GA birth 27 weeks Clinical situation: NB with suspected or proven NNS, assessed at 24 months of age	Compare PARCA-R with BSID-III. - PARCA-R was sent to parents to be completed approximately 4 weeks before the child reaches 24 months of age of IGc. - The BSID III was administered by a certified psychologist or other trained evaluator at the time of the scheduled 24- month follow-up visit.	The results support the PARCA-R as a practical tool for the identification of appreciable cognitive and language delay at 24 months among critically ill preterm and LBW infants. Bayley-III reference norms may tend to underestimate cognitive delay.	Spearman's correlation between the PARCA-R and BSID scales was 0.43 for cognition and 0.71 for language. PARCA-R successfully predicted cases of cognitive delay and language delay with the area under the ROC curves ranging from 0.83 to 0.97 depending on the reference norms used.

Kara OK,	Randomize	N 42PT=32	To determine the	Early physical	This study demonstrates
et al. [16]	d controlled	children (16 per	effect of family-	therapy can support	the importance of the role
	and blinded	group)	based intervention	the development of	of family care in the fine
	clinical trial	GI 3 m GIc	on the motor	fine and gross motor	and gross motor
		Weight <or=1500< th=""><th>function of preterm</th><th>function in premature</th><th>development of premature</th></or=1500<>	function of preterm	function in premature	development of premature
	Period:	g	infants	babies in the first	babies.
	between			year of life (with and	Neurodevelopmental
	August 2015		Both groups	without atypical	improvements in fine and
	and	Clinical situation:	received a treatment	movements).	gross motor areas were
	September	- Babies with	program based on a	movements).	not different when
	2016				
	2010	movement.	neurodevelopmental		comparing the family-
		general abnormal	approach during 3 to		based group and the
		- Excluded	12 months of age.		traditional early
	В	congenital	- Study group:		intervention group.
		malformations	physical therapist		
			coach, applied		
		They were divided	2x/week for 60 min		
		into 2 groups:	at the child's home		
		- Family-based	for 9 m		
		intervention,	- Control group: 72		
		consisting of a	routine infant		
		physiotherapeutic	therapy sessions of		
		component and a	1h duration,		
		family component	2x/week, over the 9		
			months		
		- Traditional early	monuns		
		intervention group	TD1		
			The groups were		
			evaluated on 5		
			occasions: at 3 m, 6		
			m, 9 m, 12 m and 24		
			m of age by a		
			pediatric physical		
			therapist=Applied		
			Bayley-III		
dos	Meta-	N 16 studies met	To determine the	The Bayley I, II and	Association between MDI
Santos	analysis	the inclusion	predictive value of	III scales for the later	and cognitive functioning
LES, et	Prism	criteria=1792	the mental and	development of very	was not significantly
al. [17]	Design	children	motor scales of	premature	influenced by BW, GA,
ai. [1/]	Search	GI <or=32 th="" weeks<=""><th>editions I, II and III</th><th>infants/MBP is</th><th>•</th></or=32>	editions I, II and III	infants/MBP is	•
			-		age, interval between
	platforms:	and/or	of the Bayley scale	limited, with the	assessments, date of birth,
	Cochrane	Weight <or=1500< th=""><th>for the later</th><th>Mental Development</th><th>sex, version of the Bayley</th></or=1500<>	for the later	Mental Development	sex, version of the Bayley
	Library,	g	functioning of very	Index (MDI)	scale, PC and study
	PubMed,		premature children /	explaining 37% of	quality.
	PsychINFO		MBP	later cognitive	The predictive value of
	and			functioning and the	the MDI for posterior
	CINAHL	8 studies	- Children were	Psychomotor	motor and language
		investigated	tested using Bayley	Development Index	function was inconsistent
	Period:	Bayley-I, 7	I, II or III and	explaining 12% of	across included studies.
	English	Bayley-II, 1	reassessed later	motor functioning.	The predictive value of
	language	Bayley-III	using another	later.	the Bayley Motor Scale
	studies		standardized test of		for long-term cognitive
	published		any developmental		and language functions
	before		aspect (not the		was inconsistent across
	March 2013		Bayley)		included studies.
	A A		- The predictive		It is debatable to what
	A				
			value of the Bayley		extent clinical practice
			scales was reported		should be based on a
		1	or calculated in		single behavioral

			terms of: sensitivity, specificity, PPV/NPV, RR/OR, correlational and/or regression coefficients, relating the Bayley scales to the follow-up test. - The follow-up time of the children ranged from 3 to 14 years		assessment, such as the Bayley Scales I, II and III. Multiple longitudinal assessments are needed to describe the course of children's development and support expectations for future development.
Pogribna U, et al. [18]	Prospective cohort study C	N 50 EBP and 16 healthy RNT GI PT<1000 g, RNT, AIG Clinical situation: - Excluded with congenital CNS anomalies and those who were ventilated with unstable clinical status / term with perinatal suffering or complications or GA 42 weeks	Investigate: 1) whether regional DTI abnormalities in EBP infants (BW ≤ 1000 g) are predictive of Bayley III scores at 18 to 22 months IGc 2) to compare microstructural white matter development and neurodevelopmental outcomes of EBP infants with healthy term controls. - Were submitted to brain DTI with 38 without IGc or before discharge - Bayley's mental scale score was the main result of interest	DTI microstructural biomarkers at term- equivalent age were independent predictors of cognitive and language development at the corrected age of 18 to 22 months.	Up to 50% of EBP babies develop cognitive impairments by age 2 years.
Atukunda P, et al. [19]	Open trial of random intervention by group C	N 511 mother and child pairs IG recruited at 6-8 months, re- enrolled when children were 24 months Clinical situation: (Intervention n=77, control =78)	Information on nutrition, stimulation and hygiene education was given to mothers in the intervention group, while the control group received routine health care. Developmental results were evaluated with Bayley-III.	The maternal education intervention had positive effects on the child's development and growth at three years but did not change the composition of the gut microbiota.	Up to 50% of EBP babies develop cognitive impairments by age 2 years. The intervention group had higher Bayley-III scores than controls. An improvement in the intervention compared to the control group was obtained for the ASQ and MSEL scores. The mean difference in height-for-age z-score was greater in the intervention

Developmental	compared to the control
outcomes were also	group: 0.50 (0.25-0.75, P
assessed using the	= 0.0001).
Ages and Stages	The composition of the
Questionnaire	gut microbiota did not
(ASQ) and the	differ significantly
Mullen Scales of	between the two study
Early Learning	groups.
(MSEL). Other	
outcomes included	
growth and	
composition of the	
gut microbiota.	
growth and	

LEGEND: *GRADE: classification of the level of evidence in A/B/C/D/E, with respective degrees of recommendation (A = high; B= moderate; C= low; D= very low); N: sample number; GA: gestational age; without: weeks; GAC: gestational age corrected for age; g: grams; BSID-II: Bayley Scales of Infant Development II (BAYLEY II); MDI: Mental Development Index = Mental Development Index; SD: mean standard deviation; BOT-2: Bruininks-Oseretsky Test of Motor Proficiency 2; MABC-2: Movement Assessment Battery for Children-2; MAND: McCarron Assessment of Neuromuscular Development; NSMDA: Sensory Motor Neurodevelopmental Assessment; PDMS-2: Peabody 2 Developmental Motor Scales; TGMD-2: Gross Motor Development Test 2; COSMIN: Consensus-based standards for the selection of health status measurement instruments; EN: premature; BP: low birth weight; MBP: very low birth weight; EBP: extremely low birth weight; ICH: intracranial hemorrhage; ECMO: extracorporeal membrane oxygenation; TIMP: infant motor performance test; PPV: positive predictive value; NPV: negative predictive value; PTe: extreme preterm; USG: ultrasound; MRI: nuclear magnetic resonance; BITSEA: Brief Social Emotional Assessment for Young Children; NNS: neonatal sepsis; PARCA-R: Parents' Report on Children's Abilities - Revised; BSID-III: Bayley III; PN: birth weight; RNT: term newborr; AGA: classification in relation to weight as adequate for gestational age; CNS: central nervous system; DTI: Diffusion tensor imaging, which can predict later development of cerebral palsy; ASQ: Ages and Stages Questionnaire; MSEL: Mullen Scales of Early Learning.

Studies [1,2,4,12] comparing BSID-II with BSID-III include high-risk infants aged between six and 22 months. Thus, it is unclear whether the same effects can be found in newborns and/or younger infants. Due to difficulties related to analyzing performance at young ages, it is recommended to add other sources of information when measuring cognitive functioning throughout childhood [4].

The impact of culture and language on the outcome of assessments must be considered. The use of norms from different populations can mask the level of risk of delay in a child's DNPM. Therefore, overestimating a child's functional capacity compared to a regionally inadequate reference group can result in the child not qualifying for early intervention, which can have a negative impact on their medium/long term development [12].

The Bayley-III Scale is widely applied to assess the infant/child's early developmental status. However, due to the possibility of overestimating the DNPM [1,3,4,12], which may result in an incorrect classification of child development, studies are suggested to assess its sensitivity/specificity in specific pediatric populations.

This study has some limitations, such as: it is a literature review based on a study with samples with different methodologies and cross-cultural versions specific to the countries where the BSID-III was applied; small sample number of included studies; moderate level of evidence/grade of recommendation of included studies.

Despite the studies pointing out limitations in the application of the Bayley-III, the positive aspects of the use of the Scale stand out, such as the possibility of being applied by several professionals in the health area, as long as they are properly trained; it can be used as an instrument for monitoring the DNPM of infants over time; allows comparing gains before versus after the treatment modalities of functional alterations [2,4].

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5. Conclusions

The Bayley III Scale has been widely applied in pediatrics to assess child development issues (cognitive, language, gross and fine motor) in the age group between 6 and 22 months. It has an average sensitivity of 33.3%, specificity of 98%, level of evidence C and a low degree of recommendation to identify delays in DNPM in pediatrics, and there is a need for studies with a greater number of samples to scientifically strengthen its applicability. In clinical practice, it is applied worldwide due to its positive points, especially the fact that the Scale can be applied by several health professionals as a measure to monitor the functional status of children.

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