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Neuropsychological maturity and neurological soft signs in preschool children

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Abstract

Introduction: Neurological soft signs have been defined as potential predictors of neuropsychological pathologies in typically developing children, which can give rise to discrepancies in neuromaturational development. These signs can be identified during the school-age period and may serve as indicators of a deficient developmental pattern, which, at times, carries a negative prognostic outlook. **Objective:** This study aims to compare neuropsychological maturity and the presence/absence of neurological soft signs in 5 and 6-year-old school-aged children. **Method**: A comparative study employing a non-experimental, cross-sectional design was undertaken. The Child Neuropsychological Maturity Questionnaire (CUMANIN, for its acronym in Spanish) and the annex of neurological soft signs from the Child Neuropsychological Evaluation (ENI, for its acronym in Spanish) were utilized. **Results**: Statistically significant differences were obtained in the domains of psychomotor skills, visual perception, rhythm, verbal fluency, non-verbal development, overall development, and development quotient. Below-average scores were evident in the group displaying neurological soft signs, specifically in the domains of expressive language, rhythm, verbal fluency, attention, verbal development, and overall development. **Conclusions**: The participants exhibit an average level of neuropsychological maturity, highlighting the impact of neurological soft signs on neuropsychological maturity and their implications for the development of both verbal and non-verbal areas.

Keywords: *neuropsychological maturity, neurological soft signs, preschool age, child neuropsychology.*

Introduction

Child neuropsychology examines the interplay between the maturation process of the central nervous system and behavior in children. This field has raised questions about the functionality and potential developmental discrepancies that may go undetected due to various factors, including genetics, psychology, environment, and physical factors.

Child neuropsychology also investigates the relationship between brain development and the emergence and maturation of higher-order functions, which rely on specialized neuroanatomical circuits that begin during the prenatal stage. This process gives rise to neuropsychological maturity, which is considered a response to evolutionary patterns inherent in normal individual development. The ages between three and six are particularly crucial for the optimal acquisition of higher mental functions.[1-2] During childhood, maturation is closely linked to brain development, underscoring the importance of neurological and neuropsychological maturity as direct determinants of cognitive efficiency in school-aged children. Adequate levels of neuropsychological maturity serve as the foundation for academic success. Conversely, inadequate maturation may lead to discrepancies or difficulties in various developmental domains, influenced by factors such as biology, nutrition, social interaction, academic experiences, and emotional well-being.[3]

Among the factors influencing development, neurological soft signs (NSS) have been identified as predictors of

neuropsychological pathologies in mentally healthy children, potentially resulting in developmental discrepancies. While NSS may exhibit a favorable evolution in some cases, it can lead to developmental stagnation in others.

The presence of NSS or minor impairments is a widespread issue affecting a considerable proportion of school-aged children, with estimates indicating that more than 10% of children exhibit varying degrees of NSS. It is noteworthy that many of these children remain undiagnosed and untreated.[2] In underdeveloped countries, approximately 10% to 15% of children are estimated to experience neurodevelopmental alterations of different degrees, ranging from learning difficulties to conditions like cerebral palsy, which can significantly impact their future development, social relationships, academic performance, and the possible presence of emotional problems.[4]

NSS have been linked to learning disorders, with prevalence rates in Colombia ranging from 16% to 22% among infants.[5] These findings suggest a significant relationship between the presence of NSS and indicators or predictors of learning disorders from an early age.[6] Language difficulties have also been associated with NSS, as demonstrated by a study showing that 50% of the sample exhibited issues in articulation (41%), pronunciation, gait (64%), discriminating between right and left (95%), coordinated finger movements (64%), and hand movements (45%).[7]

Attention deficit hyperactivity disorder (ADHD) has been linked to NSS, with affected children showing motor abnormalities, attentional impairments, and differences in psychomotor speed and cognitive flexibility, such as selective attention, divided attention, sustained attention, and alertness, compared to their healthy counterparts.[8]

In a study on NSS and focal epilepsy, it was found that 90% of children experienced difficulties in digital positional movements, as well as alterations in fine and gross motor coordination.[9] Schizophrenia has also shown correlations with NSS, specifically in memory, psychomotor speed, and cognitive flexibility.[10]

These findings underscore the relevance of neuropsychological maturity in the development of mental processes and indicate that NSS may serve as potential predictors of pathologies or dysfunctions that can manifest in early childhood. Considering these factors, the present study aims to compare the level of neuropsychological maturity in school-aged children, specifically those aged 5 to 6, in relation to the presence or absence of NSS.

Methodology

The research follows an empirical-analytical paradigm, employing a quantitative approach and a descriptive-comparative design. It is a non-experimental cross-sectional study.

Participants

The population consisted of 200 school-aged children between 5 and 6 years old enrolled in a public school. The sample comprised 120 students who met the inclusion criteria, selected through convenience sampling.

Inclusion criteria

- Being 5 or 6 years old.
- Being duly enrolled in the educational institution.
- Having the consent and authorization of parents or legal guardians.
- Voluntarily participating in the study.

Exclusion criteria

- Lack of authorization from parents or legal guardians.
- Diagnosis of intellectual disability.
- Moderate or severe medication for psychiatric or neurological conditions.

Ethical considerations

The study adhered to scientific and technical standards for health research, as outlined in Resolution 008430 of 1993, specifically Chapter 1 of Title II and Articles 5, 6, 8, 10, 14, 15, and 16, which emphasize the dignity of participants and the protection of their rights and well-being.[11] Additionally, the study followed the ethical considerations and guidelines prescribed in the deontological and bioethical code governing the professional practice of psychology in Colombia, as outlined in Law 1090 of 2006. Specifically, Article 33 addresses the psychologist's duties towards clients, while Article 36 outlines their responsibilities towards individuals who are the object of their professional practice. Articles 45, 47, and 48 emphasize the appropriate use of psychological materials, while Articles 49, 52, 55, and 56 pertain to scientific research and intellectual property.[12]

Procedure

- Information for the project proposal was gathered, collected, and classified using databases, digital libraries, books, and journals. The document was subsequently reviewed and approved.

- Fieldwork commenced by contacting a public educational institution in the city of Tunja, Colombia. Meetings were held with parents and guardians, and the instruments were administered in the first semester of 2019 after obtaining informed consent.

- The database was created, and the respective analysis was conducted using the statistical software SPSS 22. The data were observed to have a normal distribution. Sociodemographic data were analyzed, and the scores of the two groups (neuropsychological maturity and NSS) were compared using Student's t-test. Finally, performance categories were analyzed using the chi-square test.

Instruments

Sociodemographic form: Designed to collect information such as gender, education, socioeconomic status, family type, and information related to disabilities or medical conditions.

Child Neuropsychological Evaluation (ENI-2, for its acronym in Spanish): This assessment aims to analyze the neuropsychological development of Spanish-speaking children aged 5 to 6 years. It evaluates nine neuropsychological domains, including three academic areas, and examines neurological soft signs, hand laterality, parent questionnaire, and medical history.[13] The annex of the evaluation is used to assess NSS, which includes evaluations for gait, pencil grip, articulation, visual acuity, auditory acuity, right-left discrimination, visual tracking, extinction, dysdiadochokinesia, and finger opposition movements. Norms were obtained from a sample of 788 children between the ages of 5 and 16 from both public and private schools. Reliability and validity analyses were conducted, including test-retest reliability, inter-rater reliability, and correlations between ENI scales and WISC-R scales.[14]

Child Neuropsychological Maturity Questionnaire (CUMANIN, for its acronym in Spanish): This questionnaire evaluates four basic mental functions in the preschool age range - language, memory, motor skills, and sensory perception - through 13 scales. It also includes lateralization information and five additional scales: attention, verbal fluency, laterality, reading, and writing. The last two scales can be applied from 60 months of age. The instrument was validated with a sample of 803 children, employing item analysis based on classical test theory and item response theory, exploratory factor analysis, and tetrachoric correlations.[15] The Cronbach's alpha coefficient values ranged from 0.71 to 0.92.[16]

Results

The results are presented for a sample of preschool children from a public educational institution. The Kolmogorov-Smirnov test confirmed that the data followed a normal distribution.

Table 1 shows that 60.8% of the sample was male, while 39.2% was female. The socioeconomic strata were distributed with 59.2% in stratum 1 and 37.5% in stratum 2. The most common family type was nuclear (54.2%), followed by single-mother families (26.7%). In terms of handedness, 89.2% of the children were right-handed, 7.5% were left-handed, and 3.3% had mixed-handedness. Regarding birth, 78.3% of the children were born through natural delivery, while 21.7% were born via cesarean section. Among the participants, 77.5% did not experience any difficulties during delivery, 19.2% required an incubator, and 3.3% needed oxygen. Regarding the presence of neurological soft signs (NSS), 75% of the children exhibited NSS, while 25% did not.

Table 2 displays statistically significant differences in the scores of the two groups (presence *vs*. absence of NSS) across the scales of psychomotor skills, visual perception, rhythm, verbal fluency, non-verbal development, total development, and developmental quotient.

Table 3 demonstrates statistically significant differences between the two groups in terms of performance, as evidenced by scores below the mean in the scales of psychomotor skills, rhythm, verbal fluency, non-verbal development, and total development.

Discussion

The study aimed to identify the presence or absence of neurological soft signs (NSS) and their association with the level of neuropsychological maturity. Statistically significant scores were obtained in the areas of psychomotor skills, rhythm, verbal fluency, non-verbal development, total development, and developmental quotient.

In the psychomotor skills scale, the group with NSS exhibited scores below the median. This finding is consistent with the relationship between NSS and sensory integration disorder, dysdiadochokinesia, and coordination disorder.[17] On the other hand, the group without NSS obtained scores above the mean, indicating significant changes and faster growth in the frontal areas of the brain responsible for planning, reasoning, judgment, and organization of actions.[18-19]

Table 1. Socio-demographic characteristics of the sample.

Variables	Categories	Frequency	Percentage	Standard deviation
Gender	Female	47	39.2%	.490
	Male	73	60.8%	
	Total	120	100%	
Age	5 years	75	62.5%	.486
	6 years	45	37.5%	
	Total	120	100%	
Grade	Preschool	52	43.3%	.885
	Transition	26	21.7%	
	First grade	42	35%	
	Total	120	100%	
Socioeconomic stratum	Stratum 1	71	59.2%	.562
	Stratum 2	45	37.5%	
	Stratum 3	4	3.3%	
	Total	120	100%	
Type of family	Nuclear	65	54.2%	1.384
	Paternal single-parent	2	1.7%	
	Maternal single-parent	32	26.7%	
	Extended	11	9.2%	
	Reconstituted	10	8.3	
	Total	120	100%	
Laterality	Right-handed	107	89.2%	.436
	Left-handed	9	7.5%	
	Mixed-handed	4	3.3%	
	Total	120	100%	
Type of delivery	Natural	94	78.3%	.414
	Cesarean	26	21.7%	
	Total	120	100%	
Difficulties during delivery	None	93	77.5%	.510
	Incubator	23	19.2%	
	Oxygen	4	3.3%	
	Total	120	100%	
Activity during the first year	Normal	56	46.7%	1.165
	Hypoactive	17	14.2%	
	Hyperactive	34	28.3%	
	Flaccid	9	7.5%	
	Spastic	4	3.3%	
	Total	120	100%	
Inappropriate caregiver behaviors	Physical punishment	1	0.8%	.512
	Verbal reprimand	27	22.5%	
	Taking things away	87	72.5%	
	Ignoring	5	4.2%	
	Total	120	100%	
Neurological soft signs	Normal	30	25%	.435
	Abnormal	90	75%	
	Total	120	100%	

Note : All tables were made by the authors.

Table 2. Comparison of groups with presence/absence of NSS using t-Student test.

Neuropsychological maturity variables	Neurological soft signs	N	Mean	Standard Deviation	F	t	gl	Two-tailed Sig
Psychomotricity	Normal	30	69.13	23.054	8.952	3.806	118	.000
	Abnormal	90	45.57	31.151				
Articulatory language	Normal	30	54.17	29.916	.027	1.410	118	.161
	Abnormal	90	45.23	30.109				
Expressive language	Normal	30	52.53	30.650	.822	2.310	118	.023
	Abnormal	x90	37.71	30.375				
Receptive language	Normal	30	46.47	23.774	1.204	1.750	118	.083
	Abnormal	90	36.81	26.914				
Spatial structuring	Normal	30	72.23	27.182	4.499	2.497	118	.014
	Abnormal	90	55.68	32.726				
Visuo-perception	Normal	30	78.60	21.973	9.975	3.520	118	.001
	Abnormal	90	56.82	31.378				
Iconic memory	Normal	30	57.63	27.041	.003	-.183	118	.856
	Abnormal	90	58.67	26.797				
Rhythm	Normal	30	26.63	31.070	27.736	3.269	118	.001
	Abnormal	90	13.59	12.669				
Verbal fluency	Normal	30	39.33	29.500	18.208	3.050	118	.003
	Abnormal	90	24.50	20.543				
Attention	Normal	30	28.33	24.994	1.045	-1.597	118	.113
	Abnormal	90	37.24	26.921				
Reading	Normal	30	46.00	21.512	2.198	.635	118	.527
	Abnormal	90	43.39	18.825				
Writing	Normal	30	43.43	22.616	.022	-.666	118	.507
	Abnormal	90	46.56	22.124				
Verbal development	Normal	30	39.00	24.297	.000	2.195	118	.030
	Abnormal	90	27.71	24.433				
Non-verbal development	Normal	30	70.83	26.411	.076	4.278	118	.000
	Abnormal	90	46.44	27.245				
Total development	Normal	30	46.50	24.606	2.413	4.082	118	.000
	Abnormal	90	27.62	20.991				
Development quotient	Normal	30	105.63	12.007	.193	5.385	118	.000
	Abnormal	90	91.84	12.191				

Table 3. Comparison of performances in groups with presence/absence of NSS using Chi-square test.

Neuropsychological maturity variables	Performance	Neurological soft signs		Total	X^2 Value	Two-tailed asymptotic significance
		Normal	Abnorma			
Psychomotricity	Far above mean	16	18	34	19.809	.001
	Above mean	7	20	27		
	Mean	1	0	1		
	Below mean	4	17	21		
	Far below mean	2	35	37		
Articulatory language	Far above mean	10	16	26	3.289	.511
	Above mean	6	21	27		
	Mean	1	5	6		
	Below mean	3	11	14		
	Far below mean	10	37	47		
Expressive language	Far above mean	12	19	31	8.134	.043
	Above mean	0	6	6		
	Below mean	10	22	32		
	Far below mean	8	43	51		
Receptive language	Far above mean	2	9	11	14.213	.007
	Above mean	8	16	24		
	Mean	9	6	15		
	Below mean	3	18	21		
	Far below mean	8	41	49		
Spatial structuring	Far above mean	17	31	48	7.885	.096
	Above mean	6	15	21		
	Mean	1	2	3		
	Below mean	4	17	21		
	Far below mean	2	25	27		
Visuo-perception	Far above mean	16	27	43	10.963	.027
	Above mean	9	20	29		
	Mean	3	10	13		
	Below mean	1	14	15		
	Far below mean	1	19	20		
Iconic memory	Far above mean	11	26	37	2.291	.682
	Above mean	7	28	35		
	Mean	1	2	3		
	Below mean	5	22	27		
	Far below mean	6	12	18		
Rhythm	Far above mean	5	1	6	12.786	.005
	Above mean	0	3	3		
	Below mean	4	9	13		
	Far below mean	21	77	98		
Verbal fluency	Far above mean	4	4	8	22.902	.000
	Above mean	8	3	11		
	Mean	1	2	3		

Continuation. Table 3. Comparison of performances in groups with presence/absence of NSS using Chi-square test.

Neuropsychological maturity variables	Performance	Neurological soft signs		Total	X^2 Value	Two-tailed asymptotic significance
		Normal	Abnormal			
Fluidez verbal	Below mean	1	26	27		
	Far below mean	16	55	71		
Attention	Far above mean	2	9	11	7.957	.047
	Above mean	4	21	25		
	Below mean	2	20	22		
	Far below mean	22	40	62		
Reading	Far above mean	3	9	12	3.356	.500
	Above mean	6	8	14		
	Mean	0	2	2		
	Below mean	18	59	77		
	Far below mean	3	12	15		
Writing	Far above mean	3	10	13	7.368	.118
	Above mean	6	35	41		
	Mean	0	3	3		
	Below mean	17	28	45		
	Far below mean	4	14	18		
Verbal development	Far above mean	3	6	9	8.347	.080
	Above mean	4	6	10		
	Mean	1	5	6		
	Below mean	13	21	34		
	Far below mean	9	52	61		
Non-verbal development	Far above mean	16	15	31	17.285	.002
	Above mean	5	19	24		
	Mean	2	6	8		
	Below mean	5	27	32		
	Far below mean	2	23	25		
Total development	Far above mean	2	2	4	19.109	.001
	Above mean	13	10	23		
	Mean	1	9	10		
	Below mean	5	13	18		
	Far below mean	9	56	65		

Regarding visual perception, children with low scores on this scale may demonstrate immaturity or dysfunction in visual areas, leading to difficulties in copying, spatial disorientation, and figure rotation. Additionally, NSS may be correlated with perceptual signs such as spatial orientation disorder and difficulty in right-left recognition.[17] The group without NSS exhibited scores above the mean, whereas the group with NSS showed average performance. This finding supports previous research by Papalia suggesting that by the age of three, hand preference becomes evident, along with well-defined gross and fine motor coordination.[18]

In the rhythm scale, both groups faced difficulties, with the NSS group performing well below the mean and the group without NSS obtaining scores below the mean as well. Previous studies have reported similar results, with scores not exceeding the 5th and 2nd percentiles. It should be noted that from the age of six, the body begins to develop temporal adaptation, and from the age of five, basic rhythmic notions and motor responses that link various motor tasks are acquired. However, due to the complexity of rhythmic sequences, participants may reproduce them with a high margin of error.[20]

Regarding verbal fluency, individuals may vary in their level of fluency depending on their daily experiences, emotional state, topic mastery, and different speech situations.[21] NSS has been found to have a significant impact on verbal fluency, with a lower presence of NSS associated with higher scores in verbal tests.[6-22] This supports the present findings, as the group with NSS performed well below the mean compared to the group without NSS, which exhibited scores below the mean.

In terms of articulatory language, the group with NSS obtained scores below the mean, while the group without NSS scored at the mean level. This stage marks the beginning of articulatory maturation, with increasing sound discrimination and a nearly complete repertoire of phonemes. At this point, children develop spontaneous speech without any significant difficulty in articulating words.[23]

Similar results were obtained for expressive language, with both groups exhibiting comparable performance. This stage is characterized by metalinguistic properties, where children become aware that phrases are not fixed blocks and can be modified by changing the words that compose them. They can also recognize that words can be varied and divided into syllables and isolated sounds. Previous research by Amado suggests that expressive language develops simultaneously with receptive language, allowing children to identify a greater number of complex actions in an image, identify similarities and differences between two elements, respond to questions related to actions or social activities, and even identify absurdities in short and simple texts. The results of the study confirm these findings, as participants without NSS demonstrated better performance at the mean level compared to those with NSS, who scored lower.[23]

Furthermore, in spatial structure, both groups obtained scores above the mean, indicating that children, starting from the age of 4, can locate their own body in relation to the position of objects in space, as well as to position objects relative to their own body. They also demonstrate an understanding of basic spatial planes, such as up, down, front, back, and more complex concepts such as left and right.[24]

Memory development in children begins at an early age and undergoes several modifications during the preschool stage. Some changes that occur include the number of events they remember, the duration of information retention, and whether children rely on external or internal cues for recall. The results of the study demonstrate superior performance in memory for both groups.[25]

In terms of attentional processes, the group with NSS performed below the mean, while the group without NSS exhibited significantly lower performance. Preschool children typically display intense and sustained attention to their activities; however, their attention can easily be diverted when presented with other objects that capture their interest.[26]

In general, verbal development, including articulatory, expressive, and receptive language, was below the mean in the group without NSS, while in the group with NSS, it was significantly lower. These findings align with previous research that evaluated neuropsychological maturity in children aged 36 to 78 months, which found greater development in the non-verbal domain compared to the verbal domain.[27] These results may be related to a developmental lag in verbal processing, as the dynamic integration between thought and language during this stage facilitates skills that give rise to different learning styles. The level of abstraction demonstrated in preschoolers' oral language reflects objective development of mental processes, and any deviation from its normal course can impede essential acquisitions, particularly those directly related to language.[28]

Regarding non-verbal development, which encompasses processes such as psychomotor skills, spatial structuring, visual perception, iconic memory, and rhythm, significant

differences were observed between the groups. The group without NSS performed above the mean, while the group with NSS exhibited average performance. These findings align with a study that aimed to determine the relationship between neuropsychological maturity and academic performance, which concluded that 71.7% of the participants demonstrated a very high level of non-verbal maturity, while only 32% demonstrated a high level of verbal maturity.[28]

Finally, significant differences were observed in the overall development of neuropsychological maturity, with the group without NSS scoring at the mean level and the group with NSS performing below the mean. This suggests that neuropsychological maturity is relevant to the presence of NSS, particularly impacting areas such as language, psychomotor skills, and spatial orientation.[22] This supports the notion that the presence of NSS influences the development of various neurocognitive and neurobehavioral processes in children, potentially resulting in difficulties in development, learning, perceptual-spatial recognition, delayed speech, delayed lateralization, and slight psychomotor alterations.[28] Similarly, a study examining NSS in school-aged children aimed to characterize the level of neuropsychological maturity achieved in children with these signs, and the results demonstrated an expression of neuropsychological immaturity and limitations in executive functions, manual dexterity, reasoning, and visuospatial skills.[28]

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