

Association between, Dermatoglyphic Patterns and Executive Functions in Schoolchildren: Convergent Validation of the BRIEF-2 in the Ecuadorian Context

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ABSTRACT:

The advent of generative artificial intelligence technologies, has Abstract Early detection of neurocognitive variability in resource-limited educational settings requires culturally validated instruments, this study validated the Behavior Rating Inventory of Executive Function-2 (BRIEF-2) through convergent evidence with dermatoglyphics in 193 schoolchildren aged 8-9 years from Loja, Ecuador. After confirming the factorial structure of the BRIEF-2 ($\alpha = 0.89$; CFI = 0.93) and classifying participants according to global executive function score (GEC), dermatoglyphic profiles revealed significant differences, the group with greater neurocognitive variability ($GEC \geq 75$ th percentile) showed higher arch frequency (15.2% vs. 5.1%, $p < 0.001$) and L>A formula (18.0% vs. 8.7%, $p = 0.008$) compared with the no-risk group.

Dermatoglyphic analysis reproducibility was excellent ($\kappa = 0.91$). These findings provide convergent validity evidence for the BRIEF-2 in identifying executive variability and suggest that increased arch presence may constitute an associated vulnerability marker in this population, they must be interpreted as convergent validity evidence and not as diagnostic proof, given the cross-sectional design and absence of reference neuropsychological assessment, justifying longitudinal studies to evaluate predictive capacity

Keywords: dermatoglyphics; learning difficulties; biomarkers; neurodevelopment; educational screening

Introduction

Early detection of neurocognitive variability in school-aged populations constitutes a public health priority in middle- and low-income educational systems, where recent Latin American epidemiological studies document that between 35% and 48% of special educational needs remain

unidentified during the critical years of reading, arithmetic, and self-regulation consolidation (Fernández et al, 2020; Pankhurst et al., 2023).

This underdetection generates standardized adverse academic trajectories, increases school dropout rates reaching 2.8-3.2 times those of the typical population, and heightens probabilities of

subsequent educational exclusions that perpetuate cycles of intergenerational inequity (Reilly & McKean, 2023; Sarmiento, Costas & Méndez, 2023). The severity of this problem is compounded in Andean Ecuadorian contexts, where the gap between service needs and availability of specialized assessment reaches critical proportions, with fewer than 0.3 educational psychologists per 10,000 schoolchildren in marginalized urban areas (Fernández-Aljoe et al., 2020; Olasumbo et al., 2025).

Standardized instruments for identifying neurocognitive variability and neurodevelopmental disorders, such as the NEPSY-II, Leiter-3, or WISC-V, although demonstrating robust predictive validity evidence in North American and European populations, impose insurmountable barriers in resource-limited contexts: they require specialized personnel trained in pediatric neuropsychology, costly equipment exceeding \$2,500-4,000 USD per administration, and extensive administration times (3-5 hours per child), rendering them unfeasible for universal screening or implementation within the educational network (Burns et al., 1974; Plomin & Kovas, 2005). These structural limitations have motivated an active search for brief, contextualized screening instruments applicable by teachers in the regular classroom, with the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2), representing one of the most promising approaches.

The BRIEF-2 is a reference instrument widely used to assess executive functions in school contexts, with accumulated evidence of psychometric validity in North American, European, and more recently, Spanish-speaking Mexican samples (Gómez et al., 2022). However, its status as a validated instrument in those contexts does not imply automatic transfer of psychometric properties to Andean Ecuadorian contexts, where cultural, genetic, and educational factors may alter the distribution of T scores; therefore, its application in the Ecuadorian population requires specific empirical evidence of construct validity before it can be considered a reliable screening tool in this context.

Its eight subscales evaluate critical domains: Inhibition, Shift, Emotional Control, Working Memory, Planning, Organization, Monitoring and

Initiation, which demonstrate greater sensitivity for identifying neurocognitive variability in early school ages. Specifically, the Working Memory subscale has demonstrated 78% sensitivity and 82% specificity for predicting difficulties in calculation and reading at 12 months, whereas the Inhibition scale correlates with behavioral regulation in the classroom ($r = 0.71$, $p < 0.001$) in recent meta-analyses (Shashidhar et al., 2022; Bispo et al., 2024).

Nevertheless, its specific validation in Andean Ecuadorian populations remains insufficient, with only three studies in Latin America reporting psychometric properties, none in the Ecuadorian child population, limiting confidence in its classifications for pedagogical decisions in this culturally and genetically unique context (Gómez et al., 2022; Olasumbo et al., 2025).

To characterize variability in executive functions through teacher report in the Ecuadorian population, dermatoglyphics was employed as an external convergent validation variable; dermatoglyphic patterns (loops, whorls, arches) represent stable biological markers formed during gestational weeks 10-24 under neuroectodermal and genetic control, which remain unaltered postnatally and have demonstrated consistent associations with variability in neurodevelopment in previous population studies (Santana et al., 2021; Covarrubias et al., 2024).

This multi-method approach permits evaluation of whether classifications derived from the BRIEF-2 correspond to measurable biological differences, providing convergent evidence of its construct validity without incurring the biological determinism that contemporary critical literature has cautioned against (Reilly & McKean, 2023; Pankhurst et al., 2023; Ange, 2010). Based on the preceding evidence, this study proposes the directional hypothesis that schoolchildren with elevated BRIEF-2 scores ($GEC \geq 75$ th percentile) will exhibit greater arch dermatoglyphic frequency compared with the low-risk group, considering this pattern as an external convergent validation marker rather than an independent diagnostic tool (Tharay et al., 2020; Sariza, 2021).

Recent meta-analyses in developmental neuroscience report that configurations with arch

predominance are associated with greater neurodevelopmental vulnerability, with effect sizes ranging from $d = -0.25$ to 0.55 in studies with clinical populations (Cohen's d ; small to moderate range according to Cohen, 1988), whereas population studies report more modest correlations ($r = 0.09-0.15$) (de Bruin et al., 2014; Tran & Mai, 2022; Saha & Chakraborty, 2022).

Ecuador lacks validated national systems for early detection of neurocognitive variability, and the identification of children with special educational needs depends on subjective criteria without standardized tools, generating high underdetection rates in marginalized urban areas and losing opportunities for neuroeducational intervention during the critical period of cerebral plasticity (Fernández et al., 2020; Olasumbo et al., 2025; Ange, 2010; Adenowo & Dare, 2016; Butterworth, 2010). In this scenario, validation of the BRIEF-2 with convergent dermatoglyphic evidence may function as an inclusive first-level tool, but it requires specific empirical evidence for the Ecuadorian population that substantiates its classifications with independent biological markers.

The primary objective of this study was to evaluate the construct validity of the BRIEF-2 and its convergence with dermatoglyphic profiles as external criterion evidence in schoolchildren aged 8-9 years in Loja, Ecuador, through confirmatory factor analysis, internal consistency, and specific comparison with arch frequency and dermatoglyphic formulas. This approach represents a methodological advance in the validation of screening instruments for resource-limited educational contexts and provides necessary empirical evidence to justify its implementation in universal school detection programs in Andean populations, contributing to transcultural neuroscience and educational equity in Latin America.

Methodology

A convergent validation study with an analytical cross-sectional design was conducted in a school-aged child population from the city of Loja, Ecuador. The design combined BRIEF-2 construct validity analysis with external criterion validation through dermatoglyphics; concurrent criterion

validity was evaluated through comparison of dermatoglyphic profiles between groups identified by the BRIEF-2, whereas construct validity was confirmed via confirmatory factor analysis (CFA). This methodological design permitted evaluation of concordance between BRIEF-2 classifications and independent dermatoglyphic markers, overcoming the limitations of previous studies that relied exclusively on self-reports or subjective criteria.

Participants

The study sample comprised 193 students (32.1 ± 4.3 per institution).

Inclusion criteria:

Students aged 8 to 9 years at the time of the study, enrolled in participating institutions, whose legal representatives signed informed consent, and for whom teacher-reported information on academic performance and classroom behavior was available through the institution.

Specifically, we included both children identified by teachers as "at risk for LD" (performance < 25 th percentile in literacy or mathematics, reported attentional difficulties) and children considered without apparent risk, with the objective of contrasting dermatoglyphic profiles.

Exclusion criteria:

Active dermatological pathologies (eczema, psoriasis) that would impede fingerprint capture, recent traumatic injuries (< 3 months) to the hands, partial/total finger amputations, formal prior diagnosis of developmental disorder or neurological condition (autism, ADHD, epilepsy, cerebral palsy) to avoid bias from known pathologies, or lack of informed consent from legal representatives.

The sample size calculation was based on the estimation of an expected loop proportion of 60% (according to pilot data, $n = 30$ with children without identified LD), with absolute error $\leq 7\%$ and 95% confidence level; the minimum required value was $n = 174$. The final sample ($n = 193$) exceeded this threshold, providing 85% statistical power to detect proportion differences of 15% between risk and no-risk groups, with $\alpha = .05$.

Procedure

The study universe comprised 647 schoolchildren aged 8-9 years, enrolled in six private educational institutions in the city of Loja, Ecuador. Non-probability convenience sampling was applied, stratified by institution type and sector socioeconomic level, selecting two high-socioeconomic-level institutions, two mid-level, and two from vulnerable sectors to ensure variability in environmental exposures and educational resources.

The final sample comprised 193 students (52.2% girls, 47.8% boys) with a mean age of 8.4 years ($SD = 0.48$), representing a 29.8% response rate from the universe. This sample size exceeds the statistical power calculation based on the CFA model, which required a minimum $n = 180$ to detect convergent validity effects with power = 0.85, $\alpha = 0.05$, and medium effect size ($f^2 = 0.25$) according to criteria by Hair et al. (2019).

Inclusion criteria:

- Age between 8-9 years at the time of assessment.
- Enrollment in participating institutions with regular attendance $\geq 85\%$ of the academic year.
- No formal prior diagnosis of neurodevelopmental disorder (autism, ADHD, epilepsy, cerebral palsy) reported by parents.
- Signed informed consent from legal representatives and verbal assent from the minor.
- No active dermatological pathologies (eczema, psoriasis) or recent traumatic injuries (< 3 months) to the hands that would compromise dermatoglyphic capture.

Exclusion criteria:

- Partial/total finger amputations.
- History of global developmental delay identified in school records.
- Participation in intensive neurocognitive interventions (> 3 hours/week) during the previous 6 months.
- Incomplete BRIEF-2 data.
- Incomplete informed assent.

Instruments and Measures

Primary Instrument:

The Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2), is a 63-item questionnaire designed to evaluate executive functions in children aged 5-18 years through parent or teacher report. For this study, the teacher version was used, administered by tutors with 4 hours of training in item interpretation and rating bias control.

The instrument evaluates eight subscales: Inhibition (impulse control; ten items), Shift (cognitive flexibility; seven items), Emotional Control (emotional regulation; six items), Working Memory (retention and manipulation of information; eight items), Planning (organization of goals; nine items), Organization (ordering of materials; six items), Monitoring (behavioral self-verification; seven items), and Initiation (motivation to begin activities; six items). Each item is scored on a 3-point Likert scale (1 = never, 2 = sometimes, 3 = very often). The T score is standardized with $M = 50$ and $SD = 10$, where T scores ≥ 65 (75th percentile) indicate clinically significant variability.

Rationale for Focused Analysis:

Although the BRIEF-2 evaluates eight domains, the main analysis focused on three subscales theoretically grounded for LD: Working Memory, Inhibition, and Monitoring. This decision was based on evidence that these subscales demonstrate greater sensitivity ($AUC = 0.82-0.87$) for predicting difficulties in reading, mathematics, and behavioral regulation in recent meta-analyses (Shashidhar et al., 2022; Bispo et al., 2024). The selection of arch frequency as the dermatoglyphic contrast variable was grounded in prior literature that specifically identifies this pattern as associated with greater neurodevelopmental vulnerability (Tharay et al., 2020; Sariza et al., 2021), permitting an a priori directional hypothesis test.

External Validation Variable: Dermatoglyphic Analysis

Fingerprint capture was performed using the Futronic FS50 digital scanner, FBI-validated (compliant with FIPS 201/PIV 071006) with 500 dpi precision. Images were processed with

Dermasoft 2.0® software, which classifies patterns into three fundamental types: loops (pattern with one delta and one core), whorls (with two or more deltas and central circular closure), and arches (without deltas, continuous ridge flow).

Additionally, digital formulas were calculated by comparing total frequencies between types: $L > W$ (loops > whorls), $W > L$ (whorls > loops), $(L+A) > W$, $L > A$ (loops > arches), $10L$ (100% loops), $W=L$, and $W=(L+A)$. The classification phase was performed by two evaluators trained in dermatoglyphics who worked blinded to BRIEF-2 scores to avoid confirmation bias.

Confounding Variables

The following were recorded: (1) exact age in months as a continuous variable; (2) self-reported gender; (3) socioeconomic level via the Unsatisfied Basic Needs Index (UBNI) adapted to the Ecuadorian context (Fernández-Aljoe et al., 2020); (4) institution type (high/medium/low socioeconomic level). These variables were included as covariates in regression models to control for confounding effects.

Data collection was meticulously planned in four phases to ensure precision, validity, and ethical compliance:

- a. Phase 1 (Institutional approvals): a letter of interest was drafted and sent to the six selected educational institutions, obtaining approval from the board of directors and pedagogical committee of each school through administrative resolution.
- b. Phase 2 (Ethics and consent): with approved letters of interest, complete documentation was submitted to the Research Ethics Committee for Human Subjects of the University of Cuenca (CEISH-UC), which issued approval under code CEISH-UC-2025-015EO-IE, verifying compliance with the Declaration of Helsinki and the Organic Health Law of Ecuador. Informed consent was drafted in accessible language, and an informational meeting was held with parents and teachers where the protocol, benefits, and minimal risks were shared. Consent was obtained from 214 families (33.1% response rate), of which 193 met inclusion criteria and 21

were excluded based on pre-established exclusion criteria (active dermatological pathologies, formal prior diagnoses of neurodevelopmental disorders, or incomplete BRIEF-2 data).

- c. Phase 3 (BRIEF-2 administration): tutor teachers applied the BRIEF-2 during one week of systematic observation, recording executive behaviors in the regular classroom. A double-check system was implemented: each tutor reviewed two questionnaires for quality control.
- d. Phase 4 (Dermatoglyphic capture): a visit was coordinated to each institution in a quiet space with ambient lighting and temperature to optimize impression quality. Both hands of each participant were scanned by evaluator 1; subsequently, a random subsample ($n = 19$, 10%) was rescanned by evaluator 2 in a blinded manner for reproducibility calculation. Capture included all 10 fingers using a complete roll technique, ensuring that the third phalanx was fully recorded.

Data Analysis

The analysis was structured in four sequential phases:

- a. Phase 1: BRIEF-2 construct validity analysis. A confirmatory factor analysis with robust maximum likelihood estimation was performed to evaluate the instrument's eight-factor structure. The following fit indices were reported: comparative fit index > 0.90 ; root mean square error of approximation < 0.08 ; and standardized root mean square residual < 0.06 , following the fit criteria recommended in the literature (Hair et al., 2019). Internal consistency was evaluated using Cronbach's alpha coefficient for each subscale and for the total questionnaire score, establishing $\alpha \geq 0.80$ as the acceptance criterion.
- b. Phase 2: group classification and criterion validity. The total T score for Executive Functions (Global Executive Composite, GEC) was calculated, and participants were classified into: (a) Neurocognitive Variability Group if $GEC \geq P75$ ($T \geq 65$, n

= 89, 46.1%), and (b) Control Group if $GEC < P75$ ($n = 104, 53.9\%$). This cutoff is justified because $T \geq 65$ identifies the upper 7% of the distribution, capturing significant variability while maintaining sensitivity in a non-clinical population (Gioia et al., 2015). Dermatoglyphic profiles were compared between groups using Pearson's χ^2 for fingerprint types and digital formulas, with Bonferroni correction for multiple comparisons (adjusted $\alpha = 0.05/7 = 0.007$). Odds Ratios (OR) with 95% CIs were reported.

- c. Phase 3: dermatoglyphic reproducibility. Cohen's Kappa index (κ) was calculated for concordance in fingerprint type classification between two independent evaluators in a subsample of 19 participants ($\kappa > 0.80$ = excellent). Additionally, the intraclass correlation coefficient (ICC) was calculated for ridge count.
- d. Phase 4: confounder control. A multivariate logistic regression was performed in which the dependent variable was membership in the neurocognitive variability group, and independent

variables included arch frequency, age, gender, and institution type. This allowed estimation of the specific value of dermatoglyphics while controlling for sociodemographic factors.

Results

The confirmatory factor analysis of the eight BRIEF-2 subscales revealed adequate goodness of fit of the theoretical model to the observed data ($\chi^2 = 412.3$; $df = 224$; $p < 0.001$). The comparative fit index (CFI = 0.93) and approximation error (RMSEA = 0.062; 95% CI: 0.051-0.074) exceeded the recommended thresholds for complex structure models in child populations, indicating that the eight-factor structure is adequately replicated in the study population. Internal consistency was excellent for both the global score ($\alpha = 0.89$; 95% CI: 0.86-0.92) and the analytical subscales: Working Memory ($\alpha = 0.87$), Inhibition ($\alpha = 0.85$), and Monitoring ($\alpha = 0.83$). The remaining subscales showed acceptable values (α between 0.78-0.81), exceeding the 0.70 threshold for screening scales in educational contexts.

Table 1. Psychometric Properties of the BRIEF-2 and Sample Distribution

Subscale	No. of Items	Mean (SD)	Cronbach's Alpha	Factor Loading	Communality
Inhibition	10	13.21 (3.45)	0.85	0.71-0.82	0.54-0.68
Shift	7	9.87 (2.91)	0.78	0.65-0.76	0.48-0.61
Emotional Control	6	8.34 (2.56)	0.80	0.68-0.79	0.52-0.65
Working Memory	8	15.62 (4.12)	0.87	0.74-0.85	0.58-0.73
Planning	9	16.45 (4.67)	0.84	0.70-0.83	0.56-0.71
Organization	6	10.23 (3.11)	0.81	0.66-0.78	0.49-0.63
Monitoring	7	11.89 (3.34)	0.83	0.69-0.80	0.51-0.66
Initiation	6	9.56 (2.78)	0.79	0.64-0.75	0.47-0.60
Global Score (GEC)	63	95.17 (18.23)	0.89	0.91	0.72

Note: SD = standard deviation. CFI = 0.93; RMSEA = 0.062 (95% CI: 0.051-0.074).

Dermatoglyphic Profiles and Criterion Validity

The distribution of fundamental patterns in the total sample ($n = 193$) revealed a predominance of loops (59.9%; 95% CI: 52.8-66.8), followed by whorls (32.6%; 95% CI: 26.1-39.7) and arches (7.5%; 95% CI: 4.4-11.9). Inter-rater reproducibility was excellent ($\kappa = 0.91$; 95% CI: 0.82-0.98), confirming that dermatoglyphic classification is reliable in educational screening contexts. When participants were classified using the BRIEF-2, the neurocognitive variability group ($GEC \geq P75$, $n = 89$) showed significant differences in

dermatoglyphic profiles compared with the control group ($n = 104$).

The most robust finding was the higher arch frequency in the risk group (15.2% vs. 5.1%; $\chi^2 = 8.7$; $p < 0.001$; OR = 3.42; 95% CI: 1.68-6.95). Additionally, the L>A formula (loops > arches without considering whorls) was significantly more frequent in the risk group (18.0% vs. 8.7%; $\chi^2 = 5.9$; $p = 0.008$; OR = 2.31; 95% CI: 1.08-4.93). No significant differences were observed in loop or whorl distribution between groups ($p > 0.05$), suggesting specificity of the arch pattern as a vulnerability marker.

Table 2. Comparison of Dermatoglyphic Profiles between Neurocognitive Variability Groups

Identified Digital Formulas in the Population

Variable	Risk Group (n=89)	Control Group (n=104)	χ^2 (gl)	p-value	OR (95% CI)
Loops % (n)	58.4% (52)	61.5% (64)	0.31 (1)	0.58	0.88 (0.56-1.39)
Whorls % (n)	26.4% (23)	33.7% (35)	1.42 (1)	0.23	0.72 (0.42-1.23)
Arches % (n)	15.2% (14)	5.1% (5)	8.7 (1)	<0.001	3.42 (1.68-6.95)
L>A Formula % (n)	18.0% (16)	8.7% (9)	5.9 (1)	0.008	2.31 (1.08-4.93)
L>W Formula % (n)	29.2% (26)	26.9% (28)	0.15 (1)	0.70	1.13 (0.61-2.08)
W>L Formula % (n)	27.0% (24)	11.5% (12)	8.3 (1)	0.004	2.89 (1.32-6.35)

Note: of the 23 possible digital formulas according to the Cummins & Midlo (1926) classification, seven were observed in this sample. After applying Bonferroni correction to control Type I error for multiple comparisons (adjusted $\alpha = 0.007$), only the W>L formula maintained statistical significance. The L>A formula showed nominal association ($p =$

0.015) but did not reach corrected significance. The remaining formulas did not differ between groups ($p > 0.05$), confirming that the association is not generalizable to all dermatoglyphic configurations. The high frequency of "other formulas" in the control group (19.2%) reflects greater heterogeneity in low-risk profiles.

Table 3
Identified Dermatoglyphic Profiles

Digital Formula	Risk Group (n=89) n (%)	Control Group (n=104) n (%)	χ^2	p-value
L>W	26 (29.2%)	28 (26.9%)	0.15	0.70
W>L	24 (27.0%)	12 (11.5%)	8.30	0.004
(L+A)>W	16 (18.0%)	19 (18.3%)	0.01	0.94
L>A	16 (18.0%)	9 (8.7%)	5.90	0.015
10L	4 (4.5%)	6 (5.8%)	0.18	0.67
W=L	2 (2.2%)	5 (4.8%)	1.02	0.31
W=(L+A)	1 (1.1%)	3 (2.9%)	0.72	0.40
L=W	0 (0%)	2 (1.9%)	1.72	0.19
Other formulas	0 (0%)	20 (19.2%)	17.8	<0.001
Total	89 (100%)	104 (100%)	-	-

Note: $p < 0.007$ after Bonferroni correction ($\alpha = 0.05/7$ main comparisons). L>A reaches nominal significance ($p = 0.015$) but not corrected significance.

Multivariate Analysis and Confounder Control

To estimate the independent effect of dermatoglyphics on sociodemographic variables, a multivariate logistic regression model was adjusted. The presence of increased arches (>10% of total patterns) maintained a significant association with membership in the neurocognitive variability group after controlling for age, gender, socioeconomic

level, and institution type (adjusted OR = 3.18; 95% CI: 1.52-6.65; $p = 0.002$), whereas low socioeconomic level increased the probability of belonging to the risk group (OR = 2.15; 95% CI: 1.23-3.76; $p = 0.007$). These results confirm that the association between arches and variability in BRIEF-2 scores is real and not attributable to sociodemographic factors.

Table 4.

Multivariate Logistic Regression for Prediction of Neurocognitive Variability

Variable	B (SE)	OR	95% CI	Wald	p-value
Increased arches	1.16 (0.37)	3.18	1.52-6.65	9.87	0.002
Gender (female)	0.21 (0.28)	1.23	0.71-2.14	0.56	0.45
UBNI (low)	0.77 (0.28)	2.15	1.23-3.76	7.54	0.007
Institution (vulnerable)	0.34 (0.31)	1.41	0.76-2.61	1.20	0.27
Constant	-2.45 (1.87)	-	-	1.72	0.19

Note: SE = standard error. Model $\chi^2 = 28.4$; $df = 5$; $p < 0.001$. Nagelkerke $R^2 = 0.31$. The model showed adequate fit according to Hosmer-Lemeshow test ($\chi^2 = 6.8$; $p = 0.56$).

Reproducibility and Metrological Quality

Inter-rater concordance for fingerprint type classification in the blinded subsample ($n = 19$) was excellent ($\kappa = 0.91$; 95% CI: 0.82-0.98). The inter-observer coefficient of variation for total ridge count was 4.2%, indicating adequate metrological

precision for population studies. The distribution of patterns was homogeneous across the six participating institutions ($\chi^2 = 10.2$; $df = 10$; $p = 0.42$), confirming that dermatoglyphic profiles are stable regardless of school context and socioeconomic level.

Table 5.

Inter-rater Concordance and Institutional Homogeneity

Variable	Index	95% CI	Interpretation
Fingerprint type (κ)	0.91	0.82-0.98	Excellent
Total ridge count (ICC)	0.88	0.79-0.94	Excellent
CV inter-observer	4.2%	-	Very good
Institutional homogeneity	$\chi^2=10.2$	$df=10$	$p=0.42$

Discussion

This study represents the first effort to validate the BRIEF-2 in the Ecuadorian population through convergent evidence with dermatoglyphics, providing empirical data on the distribution of executive functions and their biological correlates in schoolchildren aged 8-9 years. The main findings confirm the construct validity of the BRIEF-2 in this cultural context ($CFI = 0.93$; $RMSEA = 0.062$) and reveal that the presence of increased arches is significantly associated with variability in executive functions identified by the instrument, independent of sociodemographic factors. This association, interpreted as convergent validity evidence, justifies future longitudinal studies but does not establish predictive capacity or causality.

The confirmatory fit indices obtained ($CFI = 0.93$; $RMSEA = 0.062$) exceed the minimum acceptable thresholds for complex factorial models (Hair et al., 2019) and are consistent with BRIEF-2 validation studies in Spanish-speaking populations reported by Gómez et al. (2022), who found $CFI = 0.91$ in a Mexican school sample. The global internal consistency ($\alpha = 0.89$) and by subscales ($\alpha = 0.83$ - 0.87 for the three analytical subscales) are comparable to the values reported in the original manual ($\alpha = 0.80$ - 0.90), (Gioia et al., 2015), validating the instrument's psychometric stability in

the Andean Ecuadorian context. This finding is particularly relevant given that cross-cultural literature has documented variability in psychometric properties of executive function instruments in Latin American populations (Olasumbo., 2025), and this study fills an important methodological gap.

The proportion of information from each subscale that is shared with the other analyzed factors of Working Memory (0.68) and Inhibition (0.72) indicates that these subscales load robustly on the general executive functions construct, justifying their use as main analytical variables. The selection of arch frequency as the dermatoglyphic contrast variable was grounded in prior literature that specifically identifies this pattern as associated with greater neurodevelopmental vulnerability (Tharay et al., 2020; Sariza et al., 2021), permitting an a priori directional hypothesis test. The decision to focus the criterion validity analysis on three theoretically grounded subscales, rather than the eight available, was methodologically prudent to avoid multiple comparisons that increase Type I error. This strategy aligns with recommendations by Bispo et al. (2024) on analysis sensitization in convergent validation studies.

The central finding of higher arch frequency in the neurocognitive variability group (15.2% vs. 5.1%;

OR = 3.42) constitutes novel empirical evidence supporting the BRIEF-2 criterion validity. This result must be interpreted as convergent validity evidence, not as indicative of predictive capacity or causality. Dermatoglyphic arches, formed between gestational weeks 10-16 under neuroectodermal control (Santana et al., 2021), have been associated in meta-analyses with lower neuromotor maturity and difficulties in cognitive flexibility (Tharay et al., 2020; Sariza et al., 2021), but these associations are correlational and do not imply biological determinism.

The underlying mechanism of the observed association remains unknown. The formation of dermatoglyphic arches between gestational weeks 10-16 occurs during the period of neuronal migration and early cerebral synaptogenesis (Santana et al., 2021), sharing molecular signals with prefrontal cortex development. There is no direct evidence that dermal ridge morphology reflects specific cortical architecture or postnatal functional connectivity. The observed association could be due to pleiotropic genetic factors influencing both dermatoglyphic development and executive circuit maturation, without implying a direct causal relationship (Rook, 2022; Reilly & McKean, 2023).

This hypothesis requires validation through functional neuroimaging and epigenetic studies that were not feasible in this cross-sectional design. The observed association must be interpreted as: "The BRIEF-2 identifies neurocognitive variability that has a measurable biological correlate (increased arches)," without attributing causality or diagnostic capacity to dermatoglyphics.

The statistical significance maintained in the multivariate model (adjusted OR = 3.18; $p = 0.002$) after controlling for age, gender, socioeconomic level, and institution type strengthens the argument that the association is not attributable to sociodemographic confounders. The effect size (adjusted OR = 3.18) is clinically relevant and comparable to associations reported between neurodevelopmental markers and cognitive variables in population studies (de Bruin et al., 2014; Tran & Mai, 2022).

There is a risk of deterministic interpretation when associating biological traits with cognitive

capacities. This study mitigates this risk through three safeguards: first, by interpreting dermatoglyphics exclusively as convergent validation variable, not diagnostic criterion; second, by explicitly acknowledging that arches represent normal variation, not pathology; and third, by refraining from suggesting curricular or pedagogical decisions based on dermatoglyphic profiles, recognizing that educational intervention efficacy depends on pedagogical quality and curricular contextualization rather than biological markers (Reilly & McKean, 2023; Pankhurst et al., 2023).

The interpretation of the L>A formula as associated with neurocognitive variability (OR = 2.31) also requires caution; this formula was significant before Bonferroni correction ($p = 0.015$) but did not reach the corrected threshold ($p < 0.007$). Its directionality (loops, the most common pattern, exceeding arches) suggests that the relative proportion between these two types may be more informative than the absolute frequency of arches alone. However, given the marginal statistical support, this finding should be considered exploratory and requires replication in independent samples.

The main strengths of this study are: the use of the BRIEF-2 as an internationally validated instrument, instead of ad hoc questionnaires with unproven psychometric properties; the inclusion of an external biological validation variable (dermatoglyphics), which reduces the risk of mono-method bias inherent to exclusive reliance on behavioral reports; the calculation of reproducibility ($\kappa = 0.91$), which supports the reliability of dermatoglyphic classification for school screening purposes; and the control of sociodemographic confounders in multivariate models, strengthening the internal validity of observed associations.

The fundamental limitations of the study stem from its cross-sectional structure, which precludes evaluating predictive capacity of the BRIEF-2 or dermatoglyphic profiles for subsequent academic trajectories. The absence of a reference neuropsychological battery (WISC-V, NEPSY-II) prevents calculation of true diagnostic sensitivity and specificity. The response rate (29.8% of the universe) raises the possibility of selection bias, although the sample exceeded the minimum size

calculated for the planned analyses. Convenience sampling in private urban schools restricts generalization to rural populations or extreme socioeconomic sectors.

Dermatoglyphics and executive neurodevelopment share prenatal and perinatal risk factors that were not controlled in this study (maternal nutritional status, exposure to neurotoxic substances, gestational age at birth). This residual confounding could partially explain the observed association. The absence of direct neuroimaging measures (fMRI, qEEG) or genetic analyses prevents elucidating the biological mechanism underlying the dermatoglyphic-executive association.

Furthermore, the BRIEF-2 evaluates executive functions through teacher behavioral report, not through direct cognitive performance, which could introduce subjectivity in ratings. However, this is the standard approach in school screening contexts where direct neuropsychological assessment is unfeasible. The blinding between BRIEF-2 evaluators and dermatoglyphic technicians minimizes confirmation bias, although the open nature of the study design (teachers knowing they were participating in a validation study) could generate expectation effects.

Finally, while this study provides convergent validity evidence for the BRIEF-2 in Andean Ecuadorian schoolchildren, it does not constitute a complete cross-cultural validation. Replications in other Ecuadorian regions (Coast, Amazon) and comparison with additional biomarkers (cortisol levels, epigenetic markers) are necessary before recommending its implementation in national educational policies.

Future Research Directions

This study opens four priority avenues:

1. Prospective 3-year longitudinal study to evaluate the predictive capacity of the BRIEF-2 combined with dermatoglyphics for formal LD diagnoses according to DSM-5-TR or ICD-11, directly addressing the cross-sectional design limitation.
2. Correlation with neurophysiological biomarkers (quantitative EEG, functional connectivity via fNIRS) to validate hypothetical neurobiological mechanisms.
3. Validation in rural populations and public schools through stratified probability sampling that includes early neurobiological covariates (malnutrition, toxic exposure).
4. Development of specific ethical guidelines for biomarker use in school screening to prevent biological determinism and ensure confidentiality, following recommendations by Pankhurst et al. (2023) on biometric data governance in vulnerable contexts.

Conclusions

The present study provides preliminary evidence of concordance between BRIEF-2 classifications and dermatoglyphic profiles in schoolchildren aged 8-9 years from Loja, Ecuador. The findings suggest that the instrument detects executive differences that have a measurable biomarker correlate, although the absence of an independent neuropsychological gold-standard criterion precludes asserting that the BRIEF-2 identifies "genuine neurocognitive variability" in a diagnostic sense.

The findings confirm, first, that the BRIEF-2 adequately replicates its eight-dimensional factorial structure in the Ecuadorian population (CFI = 0.93; RMSEA = 0.062), with excellent internal consistency ($\alpha = 0.89$) comparable to cross-cultural validation studies. This result extends the instrument's psychometric evidence to Andean contexts, although it does not constitute complete diagnostic validation given the observational design and absence of reference neurocognitive batteries.

Second, the significant association between increased arches and variability in BRIEF-2 scores (OR = 3.18; 95% CI: 1.52-6.65), maintained after controlling for sociodemographic confounders, provides convergent evidence that the instrument detects executive differences with a measurable biomarker correlate. This novel finding positions dermatoglyphics as a viable external variable for screening instrument validation, although not as an independent diagnostic tool. The specificity of the arch pattern, in contrast to the absence of association with loops or whorls, suggests that certain dermatoglyphic configurations may reflect vulnerabilities in cognitive flexibility and

neuromotor maturity, a hypothesis requiring validation through functional neuroimaging.

Third, the excellent reproducibility of the dermatoglyphic method ($\kappa = 0.91$) and its homogeneity across institutions ($p = 0.42$) demonstrate that the technique is robust for implementation in diverse educational contexts, with minimal costs compared to standardized neuropsychological evaluations. This operational characteristic is critical for resource-limited educational systems, where fewer than 15% of schools have access to specialized assessment.

The study limitations delimit the scope of these conclusions. The cross-sectional design precludes establishing the predictive capacity of the BRIEF-2 or dermatoglyphic profiles for future diagnosis of learning difficulties. The absence of a neuropsychological gold-standard criterion (WISC-V, NEPSY-II) precludes calculation of true diagnostic sensitivity and specificity. Convenience sampling in urban private schools restricts generalization to rural populations or extreme socioeconomic sectors.

Finally, the lack of control for early neurobiological variables (intrauterine exposure, malnutrition, prematurity) leaves open the possibility of residual confounding. Nevertheless, this work establishes a methodological precedent for educational neuroscience in Ecuador and grounds three priority developments: the implementation of longitudinal studies evaluating the predictive capacity of the BRIEF-2 with formal neuropsychological follow-

up; validation of the instrument in rural populations and public schools through probability sampling; and the development of ethical protocols for biomarker use in educational contexts that prevent biological determinism.

Dermatoglyphics, far from constituting a diagnostic tool, emerges as a methodological resource for convergent validation of screening instruments in contexts where specialized resources are scarce. In summary, this study provides empirical evidence that the BRIEF-2 is a valid and reliable instrument for identifying executive variability in Ecuadorian schoolchildren, with biological backing that strengthens its utility for initial screening in resource-limited educational systems. The specific association with increased arches opens a research line on early markers of executive vulnerability, always under methodological rigor that recognizes the limits of correlational evidence and the need for longitudinal validation before any widespread educational implementation.

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