

Differences in Dermatoglyphic atd Angle as a Biomarker in Children with Autism Spectrum Disorder: A Case - Control Study

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Abstract:

Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition with increasing prevalence. The 'atd' angle, a palmar dermatoglyphic feature formed early in fetal development, may serve as a biomarker for prenatal disturbances. This study aimed to compare the 'atd' angle between children with ASD and typically developing controls, and to assess sex-based differences within the ASD group. **Methods:** A cross-sectional case-control study was conducted in Rangpur, Bangladesh, from January to December 2019. The sample included 100 children aged 5–15 years: 50 with ASD (38 males, 12 females) from two autism centers, and 50 typically developing controls (26 males, 24 females) from a local school. Palm prints were collected using the standard ink method, and the maximal 'atd' angle was measured bilaterally with a protractor. Statistical analysis was performed using SPSS version 23.0, with independent t-tests for group comparisons ($p < 0.05$ considered significant). **Results:** The mean 'atd' angle for children with ASD ($41.31^\circ \pm 6.45^\circ$) was wider than that of controls ($40.83^\circ \pm 5.75^\circ$), but this difference was not significant ($p = 0.275$). Stratified by sex, autistic females had the widest mean 'atd' angle ($45.66^\circ \pm 7.68^\circ$), which was greater than both autistic males ($41.24^\circ \pm 5.77^\circ$; $p = 0.072$) and control females ($40.59^\circ \pm 5.57^\circ$; $p = 0.080$). In the control group, 82% had an 'atd' angle $< 45^\circ$, compared to 75% in the ASD group.

Conclusion: While the 'atd' angle did not show significant differences between the ASD and control groups, a trend toward a wider angle was observed, particularly in autistic females. The 'atd' angle may not serve as a standalone diagnostic biomarker for ASD, but could contribute to a broader dermatoglyphic assessment. Larger studies with standardized methods are needed to further explore these outcomes.

Introduction:

Autism Spectrum Disorder (ASD) is a severe neurodevelopmental condition defined by persistent deficits in social communication and interaction, along with restricted, repetitive patterns of behavior, interests, or activities.¹ The global prevalence of ASD has increased dramatically over recent decades, with current figures indicating that approximately 1 in 160 children worldwide is affected.² In Bangladesh, while comprehensive national epidemiological data are lacking, extrapolations suggest that nearly 1.05 million individuals may have ASD, pointing to the growing

public health concern.³ The etiology of ASD is complex and multifactorial, involving interactions between hereditary predispositions and environmental elements through critical periods of prenatal development.^{4,5} The disorder is thought to result from disruptions in fetal brain development, with abnormalities observed in several brain regions, including the cerebellum, limbic system, and cerebral cortex.^{6,7}

Dermatoglyphics, the scientific study of epidermal ridge configurations on fingers, palms, and soles, gives a unique window into prenatal development.

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These ridges form between the 7th and 21st weeks of gestation and remain unchanged throughout life.^{8,9} Crucially, both the skin (including its ridges) and the central nervous system derive from the same embryological layer – the ectoderm. Therefore, any genetic or environmental insult within this critical developmental window could potentially affect both brain development and dermatoglyphic patterns.^{10,11} Among the various dermatoglyphic parameters, the ‘atd’ angle has received considerable attention in clinical research. This angle is formed by drawing lines from the digital triradius ‘a’ (located at the base of the index finger) to the axial triradius ‘t’ (situated in the hypothenar area), and from ‘t’ to the digital triradius ‘d’ (at the base of the little finger).¹² The position of the axial triradius can vary from proximal to distal on the palm, with a more distal position resulting in a larger ‘atd’ angle. An ‘atd’ angle less than 45° is considered normal (designated ‘t’), angles between 45° and 56° indicate an intermediate position (‘t’), and angles greater than 56° suggest a distally displaced axial triradius (‘t’’).¹³

The ‘atd’ angle has been extensively studied in various genetic and neurodevelopmental disorders. In Down syndrome (trisomy 21), a significantly widened ‘atd’ angle is a well-established characteristic, indicating the distal displacement of the axial triradius.^{14,15} Similarly, alterations in the ‘atd’ angle have been reported in conditions such as schizophrenia¹⁶, cerebral palsy¹⁷, and various chromosomal abnormalities.¹⁸ Given the common ectodermal origin of the skin and brain, and the temporal overlap between ridge formation and critical periods of neurodevelopment, dermatoglyphic traits may serve as indirect markers for early developmental disturbances in ASD. Several studies have investigated the ‘atd’ angle in autistic populations, but the results have been inconsistent. Some researchers have reported significantly wider ‘atd’ angles in individuals with ASD compared to controls^{19,20}, while others have found no significant differences^{21,22} or even smaller angles.²³ These discrepancies may stem from variations regarding sample size, ethnic differences, methodological methods, or the genetic heterogeneity of ASD itself. In the Bangladeshi population, baseline dermatoglyphic data for ASD are lacking. Understanding population-specific dermatoglyphic characteristics is essential, as these patterns display ethnic and racial variations [24]. Therefore, this study aimed to compare

the ‘atd’ angle between Bangladeshi children with ASD and age-matched typically developing controls, and to examine sex-based differences within the ASD group. The findings may add to the growing body of evidence regarding dermatoglyphic markers in neurodevelopmental disorders and provide population-specific reference data for future research.

Materials and Methods

Study Design and Setting

This cross-sectional, analytical case-control study was conducted in the Department of Anatomy, Rangpur Medical College, Rangpur, Bangladesh, from January 2019 to December 2019. The study aimed to compare dermatoglyphic characteristics between children diagnosed with autism spectrum disorder (ASD) and typically developing controls.

Study Population

A total of 100 children aged 5–15 years were enrolled, with 50 children diagnosed with ASD and 50 typically developing controls. ASD participants were recruited from Buddhi Protibondhi Autistic Biddaloy, Dinajpur, and Pyrabond Buddhi Protibondhi Biddaloy, Rangpur, while controls were recruited from Ashirbad- A.G. School, Rangpur. Participants were selected through purposive sampling, with specific inclusion and exclusion criteria.

Inclusion and Exclusion Criteria

- **Inclusion:** Children aged 5–15 years, both sexes, Bangladeshi origin. ASD diagnosis for the ASD group; typically developing children for the control group.
- **Exclusion:** Children with mixed ethnic origin, congenital abnormalities, identifiable neurological disorders, or a history of major trauma or head injury.

Ethical Considerations

The Ethical and Protocol Review Committee of Rangpur Medical College approved the study protocol. Written informed consent was obtained from parents/guardians, and all data were anonymized for research purposes.

Data Collection

Palm Print Acquisition

Palm prints were collected using the ink method as described by Penrose and Cummins. Briefly, the palm was inked and pressed onto an A4 paper. The process

was repeated to guarantee clear, readable prints. Prints were examined under 6× magnification to ensure quality.

Measurement of 'atd' Angle

The 'atd' angle was measured following the standardized method described by Penrose (1954). On each palm print, the digital triradii were identified: triradius 'a' at the base of the index finger, triradius 'b' at the base of the middle finger, triradius 'c' at the base of the ring finger, triradius 'd' at the base of the little finger, and the axial triradius 't' located in the hypothenar area (the fleshy part of the palm below the little finger).

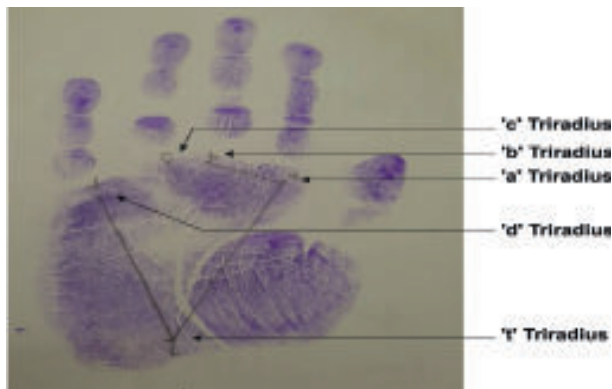


Figure 1: Palm print with 'a', 'b', 'c', 'd' and 't' triradius

Figure 1: Palm print showing the locations of digital triradii 'a', 'b', 'c', 'd' (at the bases of index, middle, ring, and little fingers respectively) and axial triradius 't' in the hypothenar area. These anatomical landmarks are used for dermatoglyphic analysis including the measurement of the 'atd' angle. After identifying these landmarks, two straight lines were drawn: one connecting triradius 'a' to the axial triradius 't', and another connecting triradius 't' to triradius 'd'. The resulting angle at the apex of triradius 't' formed by these two lines—the 'atd' angle—was measured using a standard protractor with 0.5° precision.

Figure 2: Procedure for measuring the 'atd' angle on a palm print. Two straight lines are drawn from triradius 'a' (base of index finger) to axial triradius 't' (hypothenar area), and from 't' to triradius 'd' (base of little finger). The angle formed at the apex 't' is measured using a protractor. The illustrated angle measures approximately 35°. Measurements were



Figure 2: Procedure of measuring 'atd' angle

taken for both right and left hands of each participant. The 'atd' angle was categorized according to the position of the axial triradius:

- <45°: Normal position
- 45°–56°: Intermediate position
- 56°: Distal position

Quality Control

Measurements were performed by a single investigator in duplicate, with the mean recorded. Distorted prints were excluded, and unclear triradii were re-examined.

Statistical Analysis

Data were analyzed using SPSS version 23.0. Descriptive statistics were computed, and normality was assessed using the Shapiro-Wilk test. Comparisons between the ASD and control groups were made using independent t-tests for continuous variables and chi-square tests for categorical data. A p-value of ≤0.05 was considered statistically significant.

Results:

A total of 100 children aged 5–15 years were included in this study. The demographic characteristics of the study population are presented in Table 1. The ASD group comprised 38 males (76%) and 12 females (24%), yielding a male-to-female ratio of approximately 3.2:1, consistent with the known higher prevalence of ASD in males. The control group consisted of 26 males (52%) and 24 females (48%). The mean age was comparable between groups (ASD: 9.4 ± 3.2 years; Control: 9.1 ± 3.0 years; p=0.63).

Table I: Demographic Characteristics of the Study Population

Characteristic	ASD Group (n=50)	Control Group (n=50)
Age (years)		
Mean $\pm$ SD	9.4 $\pm$ 3.2	9.1 $\pm$ 3.0
Range	5–15	5–15
Sex, n (%)		
Male	38 (76%)	26 (52%)
Female	12 (24%)	24 (48%)
Male: Female Ratio	3.2:1	1.1:1

**Figure 3:** Schematic Representation of 'atd' Angle Measurement on the Palm

Figure 3: presents a detailed diagram of the human palm, specifically focusing on the measurement of the 'ATD' angle. The diagram includes various elements of hand anatomy, such as different fingerprint patterns, including left loop (L. Loop), right loop (R. Loop), whorl, and ulnar loop (U. Loop),

each marked on the corresponding fingers. Key anatomical features, including the thenar crease, life line, and proximal transverse crease (DTC), are also indicated. The diagram is oriented to show the radial and ulnar sides of the palm, and arrows point to these sides for reference. The diagram also marks points a, b, c, d, I, II, III, and IV, which serve as reference locations for calculating the 'ATD' angle. This angle is commonly used in dermatoglyphics, the study of skin ridge patterns, to analyze palm prints. The inclusion of these anatomical features and reference points allows for a clear understanding of how the 'ATD' angle is measured on the palm, providing insights into the study of dermatoglyphics and its application in various fields. Comparison of 'atd' Angle Between ASD and Control Groups. The mean 'atd' angle measurements for the right hand, left hand, and both hands combined are presented in Table 2 and illustrated in Figure 2.

For the right hand, the mean 'atd' angle was slightly smaller in the ASD group ($40.00^\circ \pm 6.60^\circ$) compared to controls ($40.68^\circ \pm 4.90^\circ$), but this difference was not statistically significant ($p=0.259$). Conversely, for the left hand, the mean 'atd' angle was wider in the ASD group ($42.62^\circ \pm 6.31^\circ$) than in controls ($40.98^\circ \pm 6.60^\circ$), although this difference also failed to reach statistical significance ($p=0.147$). When both hands were combined, children with ASD demonstrated a wider mean 'atd' angle ($41.31^\circ \pm 6.45^\circ$) compared to controls ($40.83^\circ \pm 5.75^\circ$), but the difference remained non-significant ($p=0.275$). Notably, the ASD group showed greater variability in 'atd' angle measurements (range $28-65^\circ$) compared to controls ($34-55^\circ$), suggesting more heterogeneous palmar configurations within the autistic population.

Table II: Comparison of 'atd' Angle Between ASD and Control Groups

Side	ASD Group (n=50) Mean $\pm$ SD (Range)	Control Group (n=50) Mean $\pm$ SD (Range)	t-value	p-value
Right Hand	$40.00^\circ \pm 6.60^\circ$ (28–65)	$40.68^\circ \pm 4.90^\circ$ (34–55)	1.135	0.259
Left Hand	$42.62^\circ \pm 6.31^\circ$ (29–51)	$40.98^\circ \pm 6.60^\circ$ (38–54)	1.463	0.147
Both Hands Combined	$41.31^\circ \pm 6.45^\circ$ (28–65)	$40.83^\circ \pm 5.75^\circ$ (34–55)	1.299	0.275

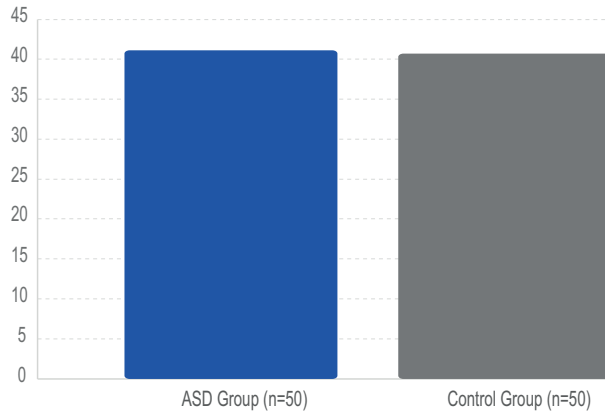


Figure 4: Comparison of Mean 'atd' Angle (Both Hands Combined) Between Autistic Children and Normal Controls

Figure 4: Comparison of mean 'atd' angle (both hands combined) between autistic children and normal controls. Error bars represent standard deviation. The ASD group showed a wider mean angle ($41.31^\circ \pm$

6.45°) compared to controls ($40.83^\circ \pm 5.75^\circ$), but the difference was not statistically significant ($p=0.275$). To explore potential sex differences, we stratified the analysis by sex. Table 3 presents the comparison of 'atd' angles between normal males and autistic males.

Among males, autistic boys exhibited slightly wider 'atd' angles across all measurements compared to normal boys, but none of these differences reached statistical significance ($p>0.05$ for all comparisons). More pronounced differences were observed when comparing females (Table 4).

Autistic females demonstrated consistently wider 'atd' angles compared to their typically developing counterparts, with differences approaching but not reaching statistical significance (p -values ranging from 0.073 to 0.080). The mean 'atd' angle for autistic females ($45.66^\circ \pm 7.68^\circ$) was approximately 5° wider than for normal females ($40.59^\circ \pm 5.57^\circ$). Table 5 compares 'atd' angle measurements between autistic males and autistic females.

Table III: Comparison of 'atd' Angle Between Normal Male and Autistic Male Children

Side	Normal Male (n=26) Mean $\pm$ SD (Range)	Autistic Male (n=38) Mean $\pm$ SD (Range)	t-value	p-value
Right Hand	$40.57^\circ \pm 4.33^\circ$ (36–53)	$40.78^\circ \pm 5.49^\circ$ (28–55)	0.173	0.864
Left Hand	$40.84^\circ \pm 3.67^\circ$ (40–51)	$41.71^\circ \pm 6.06^\circ$ (29–54)	0.706	0.481
Both Hands Combined	$40.70^\circ \pm 4.00^\circ$ (36–53)	$41.24^\circ \pm 5.77^\circ$ (28–55)	0.439	0.578

Table IV: Comparison of 'atd' Angle Between Normal Female and Autistic Female Children

Side	Normal Female (n=24) Mean $\pm$ SD (Range)	Autistic Female (n=12) Mean $\pm$ SD (Range)	t-value	p-value
Right Hand	$40.79^\circ \pm 5.54^\circ$ (34–56)	$45.83^\circ \pm 8.47^\circ$ (36–65)	1.851	0.080
Left Hand	$41.12^\circ \pm 5.60^\circ$ (40–59)	$45.50^\circ \pm 6.90^\circ$ (40–51)	1.90	0.073
Both Hands Combined	$40.59^\circ \pm 5.57^\circ$ (34–59)	$45.66^\circ \pm 7.68^\circ$ (36–65)	2.026	0.080

Table V: Comparison of 'atd' Angle Between Autistic Male and Autistic Female Children

Side	Autistic Male (n=38) Mean $\pm$ SD (Range)	Autistic Female (n=12) Mean $\pm$ SD (Range)	t-value	p-value
Right Hand	$40.78^\circ \pm 5.49^\circ$ (28–55)	$45.83^\circ \pm 8.47^\circ$ (36–65)	1.93	0.073
Left Hand	$41.71^\circ \pm 6.06^\circ$ (29–54)	$45.50^\circ \pm 6.90^\circ$ (40–51)	1.70	0.107
Both Hands Combined	$41.24^\circ \pm 5.77^\circ$ (28–55)	$45.66^\circ \pm 7.68^\circ$ (36–65)	1.93	0.072

Within the ASD group, females exhibited notably wider 'atd' angles than males across all measurements, with differences approaching statistical significance ($p=0.072$ for both hands combined). This pattern was consistent for both right and left hands individually.

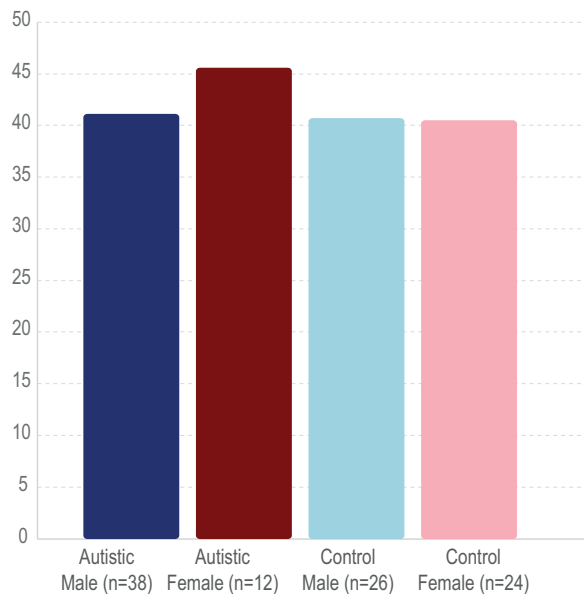


Figure 5: Sex-Based Comparison of Mean 'atd' Angle (Both Hands Combined)

Figure 5: Sex-based comparison of mean 'atd' angle (both hands combined) showing wider angles in autistic females compared to autistic males and control females. Autistic females demonstrated the widest mean angle ($45.66^{\circ} \pm 7.68^{\circ}$), followed by autistic males ($41.24^{\circ} \pm 5.77^{\circ}$), control females ($40.59^{\circ} \pm 5.57^{\circ}$), and control males ($40.70^{\circ} \pm 4.00^{\circ}$). Differences approached statistical significance ($p=0.072$ for autistic females vs. autistic males; $p=0.080$ for autistic females vs. control females). Table 6 presents the classification of 'atd' angles according to the position of the axial triradius (t, t', or t'').

Table VI: Distribution of 'atd' Angle Categories

Angle	Right Hand		Left Hand		Both Hands	
Category	Control	ASD	Control	ASD	Control	ASD
<45° (t)	80%	74%	84%	76%	82%	75%
45°–56° (t')	20%	24%	14%	24%	17%	24%
>56° (t'')	0%	2%	2%	0%	1%	1%

In both groups, the majority of participants exhibited a normal 'atd' angle (<45°), indicating a proximally placed axial triradius. However, the proportion of individuals with a normal angle was higher in the control group (82% vs. 75% for both hands combined). Conversely, a higher percentage of children with ASD fell into the intermediate category (45°–56°; 24% vs. 17% for controls). A distally displaced axial triradius

(>56°) was rare in both groups, observed in only 1% of cases overall.

Discussion:

This study investigated the potential of the palmar 'atd' angle as a dermatoglyphic biomarker for autism spectrum disorder in a Bangladeshi pediatric population. Our findings reveal that, while children with ASD showed a trend toward wider 'atd' angles than typically developing controls, these differences did not reach statistical significance. However, notable sex-specific patterns appeared, with autistic females exhibiting substantially wider angles than both autistic males and control females. The relationship between the 'atd' angle and autism has yielded inconsistent findings among various populations. Our results align with several studies that found no statistically significant difference between autistic and control groups. Milicic, Petkovic, and Bozikov²¹ reported a smaller 'atd' angle in their autistic group compared to controls, though the difference was not statistically significant. Similarly, Sanyaolu et al.²² observed no significant difference in 'atd' angle between autistic and control subjects in their Nigerian study. De Bruin et al.²⁷ also failed to find any difference in the mean 'atd' angle between adolescents with ASD and typically developing boys. In contrast, other researchers have reported significantly wider 'atd' angles in autistic populations. Arrieta et al.¹⁹ found wider angles in their Basque sample of autistic children compared to controls. Stošljevic and Adamovic²⁰ reported significantly increased 'atd' angles in Serbian autistic boys. Haroun²⁸ similarly observed wider 'atd' angles in Egyptian autistic children. The differences indicate the potential influence of ethnic and genetic heterogeneity on dermatoglyphic traits. Walker²³ reported a smaller 'atd' angle in autistic patients, suggesting congenital interference in development. This variation across studies underscores the complexity of dermatoglyphic research and the need for population-specific normative data. An especially intriguing finding of our study was the pronounced difference between autistic males and females. Autistic females demonstrated substantially wider 'atd' angles (mean 45.66°) that approached the threshold for intermediate axial triradius position (t'), while autistic males maintained angles within the normal range (mean 41.24°). This sex-specific pattern has received limited attention in the dermatoglyphic literature. Arrieta et al.¹⁹ examined sex differences in

their autistic sample and found no significant differences between males and females. However, their sample size for females was small, potentially limiting statistical power. The more pronounced dermatoglyphic deviations noted in autistic females in our study may reflect a higher “genetic load” required for females to manifest autistic traits, consistent with the female-protective effect model.²⁹ This hypothesis posits that females require a greater accumulation of genetic risk factors to express the autistic phenotype, which could appear as more pronounced developmental anomalies, including dermatoglyphic alterations. The interpretation of dermatoglyphic findings in ASD must be grounded in embryological principles. Epidermal ridges begin to form during the 7th week of gestation and are completed by the 21st week.^{8,9} This period coincides with important phases of central nervous system development, including neuronal proliferation, migration, and early synaptogenesis.³⁰ The common ectodermal origin of the skin and nervous system provides a biological rationale for using dermatoglyphics as indirect markers of neurodevelopmental disturbances.¹¹ The position of the axial triradius, reflected in the ‘atd’ angle, is determined by the relative growth of the palm during fetal development.¹³ A distally displaced axial triradius (resulting in a wider ‘atd’ angle) may indicate altered growth patterns or developmental delays during the second trimester.³¹ Such disturbances could simultaneously affect brain development, possibly contributing to the pathogenesis of ASD. The genetic architecture of dermatoglyphic traits is complex and polygenic [32]. Family studies have shown significant heritability for various dermatoglyphic parameters, including the ‘atd’ angle.³³ In the context of ASD, which is also highly heritable with estimates ranging from 50–80% [34], common genetic factors influencing both traits could explain observed associations. Milicic, Petkovic, and Bozikov²¹ conducted family analyses and found significant interclass correlations between autistic sons and their parents for various dermatoglyphic traits, suggesting genetic transmission. The sex-specific patterns detected in our study raise the possibility of X-linked influences, consistent with the observation that when a trait is X-linked, mother-son and sister-sister correlations tend to be higher.³⁵ The male predominance in ASD (3.2:1 in our sample) further supports potential X-linked

contributions. While genetic factors play a predominant role in dermatoglyphic development, environmental insults during the critical period of ridge formation can also alter patterns. Maternal factors such as infections, nutritional deficiencies, toxic exposure, and hypoxia during the first and second trimesters have been associated with dermatoglyphic alterations.^{36,37} Many of these same factors have been implicated as risk factors for ASD [38,39]. The greater variability in ‘atd’ angles observed in our ASD group (range 28–65°) compared to controls (34–55°) may reflect the heterogeneous mixture of genetic and non-genetic influences causing autism etiology. Several methodological factors may explain differences between our findings and those of previous studies. First, differences in measurement techniques and the precise definition of triradii can cause variability. We followed the standardized method of Penrose¹³ to ensure consistency, but subtle differences in technique among studies cannot be ruled out. Second, age differences between study populations could influence comparisons, although dermatoglyphic patterns are established prenatally and do not change with age.⁴⁰ The size of the palm increases with age, but the angular relationships between triradii remain constant. Third, and most importantly, ethnic and racial variations in dermatoglyphic traits have been well-documented.^{24,41} Baseline frequencies of various dermatoglyphic parameters differ markedly across populations. Our study provides the first data on ‘atd’ angles in Bangladeshi children with ASD, adding to the global understanding of population-specific variations. The utility of the ‘atd’ angle as a clinical biomarker for ASD must be considered cautiously. While our findings show trends toward wider angles in autistic children, particularly females, the overlap between groups and lack of statistical significance preclude its use as a standalone diagnostic tool. However, when combined with other dermatoglyphic parameters — such as fingerprint patterns (increased arches and radial loops, decreased ulnar loops) and total finger ridge count — the ‘atd’ angle may contribute to a broader dermatoglyphic profile that could help in early screening.^{22,42} Dermatoglyphic analysis has several advantages as a potential screening tool: it is non-invasive, inexpensive, requires no specialized equipment beyond what is available in most clinical settings, and patterns remain stable throughout life.⁴³ However, it must be

emphasized that dermatoglyphics can only serve as an adjunct to comprehensive clinical evaluation, never as a replacement for established diagnostic procedures.⁴⁴

Strengths of The Study:

This study is the first to examine the 'atd' angle in Bangladeshi children with ASD, supplying valuable population-specific baseline data. It uses a rigorous methodology with standardized measurement techniques and includes sex-based analyses, revealing important patterns. Clear inclusion and exclusion criteria help minimize confounding factors.

Limitations of The Study:

The study's limitations include a small sample size, particularly for autistic females (n=12), which affects statistical power. Its single-center design limits generalizability, and the cross-sectional nature prevents establishing causality. Technical issues in obtaining clear palm prints, along with the lack of blinding, may introduce bias. Additionally, focusing only on the 'atd' angle limits the scope of dermatoglyphic profiling.

Recommendations for Future Research

Future studies should include larger, multicenter designs with more participants, particularly autistic females, to validate findings and establish normative data. Family-based studies could provide insights into heritability, while longitudinal research might examine whether prenatal dermatoglyphic changes predict ASD. Expanding the scope of dermatoglyphic parameters and exploring their correlation with ASD severity could offer more thorough insights. Cutting-edge imaging techniques and the combination of genetic and environmental data could further clarify the complex etiology of ASD.

Conclusion:

This study investigated the palmar 'atd' angle as a potential dermatoglyphic biomarker for autism spectrum disorder in Bangladeshi children. While children with ASD demonstrated a trend toward wider 'atd' angles compared to typically developing controls, particularly in the left hand, these differences did not reach statistical significance. However, notable sex-specific patterns appeared, with autistic females exhibiting substantially wider angles that approached the threshold for intermediate axial triradius position, denoting a possible sex-

linked influence on dermatoglyphic development in autism. The findings underscore the complexity of using dermatoglyphic traits as diagnostic markers for neurodevelopmental disorders. The 'atd' angle alone is unlikely to serve as a standalone biomarker for ASD, given the overlap between groups and the influence of ethnic, genetic, and non-genetic factors.

Nevertheless, when interpreted within a comprehensive dermatoglyphic profile that includes fingerprint patterns and ridge counts, the 'atd' angle may provide valuable information for early screening and risk assessment. Our study provides the first baseline data on 'atd' angles in Bangladeshi children with ASD, stressing the importance of population-specific research in dermatoglyphics. The results encourage additional investigation with larger samples, family-based designs, and standardised methodologies to clarify the complex relationships between prenatal development, dermatoglyphic patterns, and autism spectrum disorder.

Declarations

- **Ethics Approval and Consent to Participate:** Approved by IERB, Rangpur Medical College. Informed consent/assent obtained.
- **Consent for Publication:** Not applicable.
- **Availability of Data and Materials:** The datasets used are available from the corresponding author on reasonable request.
- **Competing Interests:** The authors declare no competing interests.
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