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Outer and Inner Canthal Distances and their Stature Estimation Potentials among Nigerian Igbos and Ibibios Residing in Rivers State, Nigeria

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Abstract: Both inner (ICD) and outer canthal distances (OCD) are some examples of facial parameters often applicable in forensic anthropology as these differ among ancestries. Despite numerous reports on stature estimation using various facial parameters across several ancestries and ethnic groups including those of Nigeria, paucity of literature on the potentials of ICD and OCD in the estimation of stature among global populations, including Nigeria, remain evident. Thus, the present study was carried out to fill this gap for two Nigerian ethnic groups, the Igbos and Ibibios. A total of 300 adults of 18 years and above (150 Igbos and 150 Ibibios) comprising 75 males and 75 females each were randomly selected. The ICD and OCD were measured between the medial canthi and lateral canthi of the palpebral fissures of the two eyes, respectively using a transparent metric rule. Stature (height) was measured using a stadiometer using a standardized method. From the results, the mean heights for the combined population of males and females were 180.57±0.74 cm and 175.28±0.65 cm respectively. The differences between sexes for height were statistically significant ($p<0.05$) while there was no ethnic difference in heights of both ethnic groups observed. The present study showed that the mean ICD in males and females were 3.31 cm and 3.35 cm respectively. The Ibibio males had mean ICD of 3.32 cm compared to 3.29 cm in their females. However, ICD values of Igbos showed a higher mean in females (3.42 cm) compared to males (3.30 cm). The average OCD in males for both ethnic groups were slightly higher compared to females. Significant correlations between ICD, OCD, and stature were observed in both males and females while linear regression equations for stature

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estimation were derived. For males, it was as follows; Stature = 23.65(ICD) + 102.177, and Stature = 3.44(OCD) + 140.932. For females, it was thus, Stature = 4.38(ICD) + 160.575, and Stature = 2.83(OCD) + 143.518. Conclusively, there were strong associations between both canthal parameters and height in both sexes irrespective of ethnic differences.

Key words: canthal distance, stature, estimation, Ibibios, Igbos, anthropology

Introduction

The identification of individuals using the anthropometry of the human face remains an integral part of biological anthropology. The concept of facial anthropometry in anthropology deals with the measurement of physical components of human face in relation to their racial and ethnic differences (Jahanshahi 2012; Darkwah et al. 2018). Both the inner canthal distance (ICD) and outer canthal distance (OCD) of the canthi (the corners of the eyes where the upper and lower eyelids meet) are important facial measurements that are applicable in both anthropological and forensic studies (Oladipo et al. 2011; Yadav et al. 2019; Bahşi et al. 2021). Furthermore, the understanding of the variations between sexes and ancestries in the assessments of canthal anthropometry could be applied in reconstructive and cosmetic surgeries that usually involve carrying out surgical procedures that are aimed at correcting deformities and enhancing facial aesthetics (Raschke et al. 2013; Bouhadana et al. 2022; Celikoyar et al. 2022). Currently, it is generally accepted that there are morphological differences based on several literature on variations in canthal anthropometry among ethnic groups in Nigeria (Osunwoke et al. 2010; Anibor et al. 2014; Ogoun et al. 2021), and between ancestries globally (Yadav et al. 2019; Bahşi et al. 2021; Radha and Srinivasan 2021; Bouhadana et al. 2022; Ndombolo et al. 2024).

Together with sex, age and ancestry, the estimation of stature is a key biological means of identification in humans (Oladipo et al. 2015; Cunha and Ubelaker 2020). Despite the generalization of knowledge among anthropologists that support the accuracy and reliability of long bones as the most suitable body components for predicting stature across different racial populations (Cunha and Ubelaker 2020), the application of soft tissues in stature prediction has been gaining momentum in recent times. The profiling of unidentifiable human remains by forensic anthropologists to estimate stature using soft-tissue craniofacial measurements has become a common practice by various researchers in the field of biological anthropology (de Acuerdo and de la Cabeza 2015; El-Kelany et al. 2015; Yadav et al. 2019; Bashar et al. 2024). It is worthy of note that there are limited studies on the prediction of stature using canthal anthropometry in non-Negroid populations, and there are arguably none that has been studied using a Nigerian population. In estimating stature from canthal anthropometry, individuals can be positively identified especially in forensic cases where soft tissue remains are incomplete.

In south-southern Nigeria, some of the residents that live in the multilingual city of Port Harcourt (which is in Rivers State) are of Igbo and Ibibio ethnic extractions as the city is bordered by Imo and Akwa-Ibom states, respectively. Arguably regarded as the most populated region within southern Nigeria, Rivers State is not without its challenges that are usually associated with crimes, such drug abuse, human trafficking, and other forms of social vices (Abiodun et al. 2017; Joab-Peterside et al. 2021). These vices could in turn lead to deaths of victims found in such crime scenes thereby posing unique difficulties to local security agencies in trying to identify discovered victims. In high profile forensic cases, local anthropologists are consulted by these security agencies to assist in the forensic identification of the discovered victims – which could be challenging as well due to the lack of forensic databases in the region. Also, in line with studies done by Gao et al. (2024), and Chalkis et al. (2024), surgical outcomes could be affected by anatomical differences in eyelid shape, orbital structure, and overall facial proportions across different racial populations and these variations could in turn impact the selection of techniques and aesthetic consequences in oculoplastic surgeries. The current study was done to investigate the stature estimation potentials of outer and inner canthal distances among Nigerian Igbos and Ibibio adult populations residing in Port Harcourt, Rivers state.

Materials and Methods

A total of 300 adults (150 Ibibios and 150 Igbos) were randomly selected for this study and were limited exclusively to adults of Madonna University, Elele Campus in Rivers State of Nigeria. Minimum sample size was determined using Fisher's formula for infinite population or population larger than 10,000 (Cocharan 1963). The subjects were from Ibibio and Igbo ethnic origins of Nigeria by both parents and genealogies and were between the age of 18 and 30 years. Subjects with outside age range of 18 and 30 years, those with any form of facial anomalies, prior facial surgeries and those from heterogeneous parents were excluded. Subjects were selected in line with the Declaration of Helsinki research ethics protocols for human research. Ethical clearance was obtained from the Research Ethics Committee of the University of Port Harcourt Teaching Hospital, Port Harcourt (with registration number NHREC/UPTHREC/03/2023 and protocol number, UPTH/ADM/90/S.11/VOL.XI/1722). All subjects gave their informed consent, and their personal information were kept confidential.

The measurement of inner canthal distance [ICD] and outer canthal distance [OCD] were carried out with the aid of transparent meter rule and recorded in centimeters (cm). The distance between the lateral canthi of the right and left eyes gave the outer canthal distance while the distance between the medial canthal of the right and left eyes gave the inner canthal distance [Figure1]. Height (stature) was measured with the aid of a stadiometer and recorded in cm. Subjects were barefooted (thin socks were also allowed). Subjects were asked to stand on the base of the stadiometer in an erect position. The heels were placed together and arms relaxed at the sides. The head board of the stadiometer was adjusted to the top of the head (vertex) and readings were taken from the calibrations of the stadiometer. 2) All the measurements were performed twice and average of the two scores were used for precision purpose. Reading was taken to two decimal places.

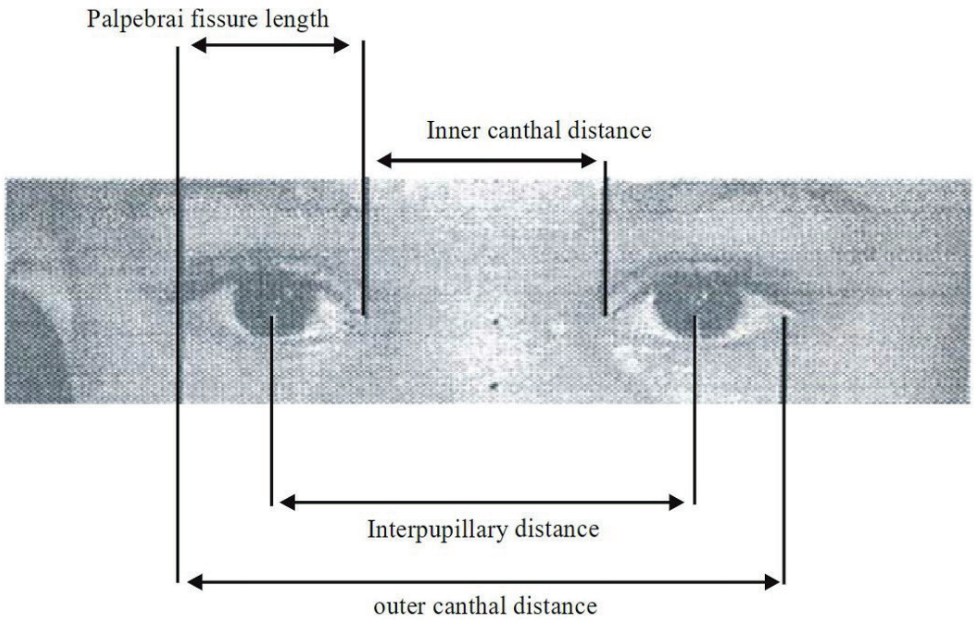

Fig.1. Measurement of inner and outer canthal distances [Oladipo et al. 2011, page 15]

Statistical Analyses

Raw data collected from the subjects were recorded in a Microsoft Excel 2019 version and analyzed using the Statistical Package for Social Sciences (SPSS version 20.0). Differences between sexes and ethnic groups in canthal distances and heights were determined using the independent sample t-test while test of association was done with the aid of Pearson's correlation and regression analyses. Confidence interval was set at 95%.

Results

The results of the various analyses are presented in table 1 to 8. In the general population [Table1], males had a mean height of 180.57±0.74 cm while females had a mean height of 175.28±0.65 cm. The mean ICD in males was 3.31±0.02 cm while in females it was 3.35±0.02 cm. The mean OCD was 11.52±0.04 cm in males and 11.23±0. 04 cm in females.

Using independent sample t-test to compare the above variables between males and females, it was observed that there was a statistically significant difference in the mean height of males and females ($p<0.05$) with males showing significantly higher value than females. Also, there was a statistically significant difference between the mean OCD of males and females ($p<0.05$) with males showing higher mean OCD than females. However, no significant difference was observed between the mean ICD of males and females ($p>0.05$).

Table 2 contains the results of the ethnic comparison of Height, OCD and ICD between Igbos and Ibibios. The mean heights of the Igbo and Ibibio subjects were 177.87±0.69 cm and 177.98±0.76 cm respectively. Those of ICD were 3.36± 0.17 cm and 3.31±0.12 cm respectively while the mean OCD for Igbos and Ibibios were 11.39±0.04 cm and 11.36±0.04 cm respectively. It is worthy of note that the difference in the mean heights of the Igbos and Ibibios were not statistically significant ($p>0.05$). Also, the mean OCD in the Igbos and Ibibios were not statistically significant ($p>0.05$). However, there was a statistically significant difference between the mean ICD of the Igbos and the Ibibios ($p<0.05$) with Igbos showing higher mean value.

Table 3 to 6 show the descriptive statistics for height, ICD and OCD of Igbo males and females, Ibibio males and females, Igbo males and Ibibio males and Igbo and Ibibio females respectively. Regression products of the correlation of height and ICD and OCD are shown in table 7 and 8. It can be observed that Pearson R value for the correlation between height and ICD in males is 0.507. This correlation is statistically significant ($p<0.05$). Although the correlation between height and OCD in males with R value 0.172 is weak, it is however statistically significant ($p<0.05$). On the other hand, no significant correlation was observed between ICD and height ($R=0.121$, $p>0.05$). In females, there was a weak but statistically significant correlation between OCD and height ($R=0.200$ $p<0.05$).

On carrying out the linear regression to obtain the linear relationship between height, OCD and ICD in females, the Pearson constant (C) which indicates the Constant value in a linear equation and the slope (R coefficient) was obtained as shown in table 7. The derived equations follow the linear equation $y = mx+c$ and are represented in table 8. This could be used to determine the height of males and females when the ICD and OCD is measured accurately.

Table 1. Independent T-test Analysis on Height, ICD and OCD in Males and Females

Variables	Min (cm)	Max (cm)	Mean (cm)	P-value
Height				
Male	157	194	180.57±0.74	0.001
Female	157	194	175.28±0.65	
ICD				
Male	3.0	3.7	3.31±0.02	0.06
Female	3.0	4.0	3.35±0.02	
OCD				
Male	10.5	12.0	11.52±0.04	0.001
Female	10.0	12.7	11.23±0.04	

P-value is significant at 0.05 when comparing the means of the different parameters

Table 2. Independent T-test on Height, ICD and OCD of the Igbos and Ibibios

Variables	Min (cm)	Max (cm)	Mean (cm)	P-value
Height				
Igbo	157	195	177.87±0.69	0.91
Ibibio	160	195	177.98±0.76	

Table 2. (cont.)

Variables	Min (cm)	Max (cm)	Mean (cm)	P-value
ICD				
Igbo	3.0	4.0	3.36±0.17	0.03
Ibibio	3.0	3.7	3.31±0.12	
OCD				
Igbo	10.0	12.7	11.39±0.04	0.58
Ibibio	10.5	12.5	11.36±0.04	

P-value is significant at 0.05 when comparing the means of the different parameters

Table 3. Descriptive Statistics of Height, ICD and OCD of the Igbo Males and Females

	Sex	N	Minimum	Maximum	Mean	Standard Deviation
Male	Height (cm)	75	160.00	195.00	180.40	9.41
	ICD (cm)	75	3.00	3.50	3.30	0.17
	OCD (cm)	75	10.50	12.00	11.48	0.44
Female	Height (cm)	75	157.00	194.00	175.35	6.54
	ICD (cm)	75	3.00	4.00	3.42	0.24
	OCD (cm)	75	10.00	12.70	11.30	0.61

Table 4. Descriptive Statistics of Height, ICD and OCD of the Ibibio Males and Females

	Sex	N	Minimum	Maximum	Mean	Standard Deviation
Male	Height (cm)	75	162.00	195.00	180.75	8.62
	ICD (cm)	75	3.00	3.70	3.32	0.21
	OCD (cm)	75	10.50	12.00	11.55	0.46
Female	Height (cm)	75	160.00	194.00	175.21	9.26
	ICD (cm)	75	3.00	3.60	3.29	0.19
	OCD (cm)	75	10.50	12.50	11.17	0.52

Table 5. Descriptive Statistics of Height, ICD and OCD of Igbo males and Ibibio males

	Ethnicity	N	Minimum	Maximum	Mean	Standard Deviation
Igbos	Height (cm)	75	160.00	195.00	180.40	9.41
	ICD (cm)	75	3.00	3.50	3.30	0.17
	OCD (cm)	75	10.50	12.00	11.48	0.44
Ibibios	Height (cm)	75	162.00	195.00	180.75	8.62
	ICD (cm)	75	3.00	3.70	3.32	0.21
	OCD (cm)	75	10.50	12.00	11.55	0.46

Table 6. Descriptive Statistics of Height, ICD and OCD of Igbo and Ibibio Females

Ethnicity		N	Minimum	Maximum	Mean	Standard Deviation
Igbos	Height (cm)	75	157.00	194.00	175.35	6.54
	ICD (cm)	75	3.00	4.00	3.42	0.24
	OCD (cm)	75	10.00	12.70	11.30	0.61
Ibibios	Height (cm)	75	160.00	194.00	175.21	9.26
	ICD (cm)	75	3.00	3.60	3.29	0.19
	OCD (cm)	75	10.50	12.50	11.17	0.52

Table 7. Correlation Statistics for the of OCD, ICD and Height in Males and Females Subjects

Variables	r	R^2	R Coefficient	R Constant	p-value
Male					
ICD	0.507	0.257	23.65	102.177	0.001
OCD	0.172	0.300	3.44	140.963	0.03
Female					
ICD	0.121	0.015	4.38	160.575	0.01
OCD	0.200	0.040	2.83	143.518	0.01

Key: r = Pearson correlation coefficient, R^2 = coefficient of determination

Table 8. Linear Regression Equations for the Estimation of Height from ICD or OCD in Male and Females

Sex	Variable	Regression Formula
Male	ICD	Y = 23.65(x) + 102.177
	OCD	Y = 3.44(x) + 140.932
Female	ICD	Y = 4.38(x) + 160.575
	OCD	Y = 2.83(x) + 143.518

Note: Y = Height (cm), x = ICD (cm) or OCD (cm)

Discussion

It is true that the understanding of the anatomy of the human face brings to light a myriad of applications in the subject fields of ophthalmic, reconstructive, and plastic surgeries, as well as anthropometric evaluations in both forensic and biological identification. As stated earlier, the anthropometric profiling of human subjects by various anthropologists to estimate stature (height) using soft-tissue craniofacial measurements has become a common practice by various researchers in the field of biological anthropology (de Acuerdo and de la Cabeza 2015; El-Kelany et al. 2015; Yadav et al. 2019; Bashar et al. 2024). However, this study is arguably the foremost research that has been done with regards to the relationship between stature, inner (ICD) and outer canthal distances (OCD) for any given Nigerian population.

The present study showed that the mean ICD in males and females were 3.31 cm and 3.35 cm respectively, while the mean OCD in males and females were 11.52 cm and 11.23 cm, respectively. A related study done to evaluate the ICD in a Saudi population reported from their results that the mean ICD when the sexes were combined was 3.03 cm (ranging from 2.22 cm to 3.78 cm), with a mean ICD of 3.11 cm for males, and a mean ICD of 2.96 cm for females (Hamid et al. 2021). Earlier, a research by Ozturk et al. (2006) on a Turkish population found that the males and females had a mean ICD of 3.07 cm and 3.03 cm, respectively, while El-Sheikh et al. (2010) reported mean ICD values for a Sudanese population to be slightly higher compared to this present study to be 3.34 cm and 3.24 cm for their males and females, correspondingly. Furthermore, studies done using different south Asian populations by Adhikari et al. (2016), and Iqbal et al. (2024) both revealed similar findings to the present study results on Ibibio population that the males had higher ICD values in association with the female subjects. Within Nigeria, Oladipo et al. (2011) had earlier reported from a survey of 800 participants from Ibibio ethnic group that the ICD of males and females were 3.52 cm and 3.36 cm, respectively – which is in line with the present study that showed that the Ibibio males had a mean ICD of 3.32 cm while their female counterparts had a mean of 3.29 cm. However, the ICD values of the Igbo population in this present study showed a higher mean for the females (3.42 cm) compared to the male counterparts (3.30 cm).

As seen in this study, the average OCD in males for both ethnic groups were slightly higher compared to the female counterparts. These results were in accordance with the studies done among certain ethnicities in Nigeria by Oladipo et al. (2009), Osunwoke et al. (2010), and Anibor et al. (2014). However, in comparisons to other racial populations, the OCD was higher as the mean OCD for a studied population by Rajput et al. (2022) was 9.23 cm for males and 7.31 cm for females while another related study done by Srivastava et al. (2023) using an Indian population noted from their results that the mean OCD was 8.23 cm for males and 7.22 cm for females. Furthermore, similar research done to evaluate OCD using both Indian and Nepalese undergraduate students (Adhikari et al. 2016) revealed that the males had respective higher OCD values (9.49 cm and 9.35 cm) in association with the female subjects (9.13 cm and 9.15 cm) – which agrees with the current study despite reporting higher values in comparison to the south Asian subjects. It could be explained that a host of diverse factors such as changes in lifestyle and dietary habits have had a direct relation to human growth and development over the years and these factors, which are generally population-specific, can affect the morphology and morphometry of the faces among the studied ethnicities.

Suffice it to say that despite that there are some works that has been done to estimate stature (height) using selected facial and nasal parameters (Kumar and Chandra 2006; Kalia et al. 2008; Agnihotri et al. 2011; Wankhede et al. 2012), it has proven to be a challenge to come across studies that have used periorbital (or canthal) parameters to predict stature talk less of a Nigerian population. The applications of both ICD and OCD in stature prediction were shown to be relevant in this study as there were significant relationships between both canthal parameters and height in both sexes irrespective of ethnic differences using the Pearson correlation. These study observations were followed up by deducing linear regressions for estimating the height in males and females based on the measured ICD and OCD values. Although this study was able to establish the significant relationships between stature, ICD and OCD, the researchers recognize that these observations do not make up for a possible generalization of the total population of Nigerian Igbos and Ibibios due to the limited sample size.

Conclusion

The study concluded that there were significant differences in both sexes despite no ethnic differences in terms of stature, ICD and OCD. Also, there were strong associations between both canthal parameters and height in both sexes irrespective of ethnic differences. These study values could assist local ophthalmic, reconstructive, and plastic surgical practitioners who practice in both ethnic regions in managing surgical issues related to the human face. Also, this study could enable local anthropologists and researchers to digress further on analysing the applications of canthal anthropometry in the prediction of stature across different ethnicities in Nigeria, thereby adding to the growth of physical and forensic anthropology in the country.

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Conflict of interest

All authors declare that there is no form of competing interests.

Authors' contributions

GSO was the lead researcher, conceived the concept of the study and design, critical revision of the article for important intellectual content, provided some materials for the study and wrote the manuscript; BBJ provided some materials for the study, performed the data collection, compilation and statistical analysis. EA and OMA provided some materials for the study and carried out some critical revision of the article. All authors discussed the results and contributed to the final manuscript for publication.

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References

Abiodun AK, George A, Chukwuma AC, Gbenga O, Iluno LU. 2017. Human trafficking: A global challenge reflection on the challenges in Nigeria. J Law Pol Global 61:192.

Adhikari N, Ambekar MN, KC S. 2016. An anthropometric comparison of inner canthal distance, outer canthal distance and canthal index in the Indian and Nepalese undergraduate students of Nepalgunj Medical College. JNGMC 14(2):12–4. https://doi.org/10.3126/jngmc.v14i2.21529

Agnihotri AK, Kachhwaha S, Googoolye K, Allock A. 2011. Estimation of stature from cephalo-facial dimensions by regression analysis in Indo-Mauritian population. J Forensic Leg Med 18(4):167–72. https://doi.org/10.1016/j.jflm.2011.02.006

Anibor E, Omokaro E, Ofere F. 2014. Variations in canthal index of the Isokos in Delta state. Int J Basic Appl Innov Res 3(4):143–6.

Bahşi I, Orhan M, Kervancioğlu P, Karatepe Ş, Sayn S. 2021. Craniofacial anthropometry of healthy Turkish young adults: outer canthal, inner canthal, palpebral fissure, and interpupillary distances. J Craniofac Surg 32(5):1906–9. https://doi.org/10.1097/scs.0000000000007240

Bashar F, Hossain MS, Akhter N, Sharmeen S, Masum MM, Suma SA, Rahman MA. 2024. Anthropometric Study of Correlation between the Selected Craniofacial Measurements with the Stature in Adult Bangladeshi Manipuri Males. MuMCJ 7(1):19–25. https://doi.org/10.3329/mumcj.v7i1.73962

Bouhadana G, Gornitsky J, Saleh E, Trabelsi NO, Borsuk DE. 2022. Expanding the classic facial canons: Quantifying intercanthal distance in a diverse patient population. Plast Reconstr Surg Glob Open 10(4):e4268. https://doi.org/10.1097/gox.0000000000004268

Celikoyar MM, Pérez MF, Akbaş MI, Topsakal O. 2022. Facial surface anthropometric features and measurements with an emphasis on rhinoplasty. Aesthet Surg J 42(2):133–48. https://doi.org/10.1093/asj/sjab190

Chalkias IN, Lokovitis E, Quaranta G, Kamal M, McMullan T. 2024. Factors that affect eyelid show and their importance in upper eyelid blepharoplasty: a systematic review. Orbit 1–10. https://doi.org/10.1080/01676830.2024.2398115

Cunha E, Ubelaker DH. 2020. Evaluation of ancestry from human skeletal remains: a concise review. Forensic Sci Res 5(2):89–97. https://doi.org/10.1080/20961790.2019.1697060

Darkwah WK, Kadri A, Adormaa BB, Aidoo G. 2018. Cephalometric study of the relationship between facial morphology and ethnicity. Transl Res Anat 12:20–4. https://doi.org/10.1016/j.tria.2018.07.001

de Acuerdo PD, de la Cabeza TM. 2015. Prediction of stature according to three head measurements. Int J Morphol 33(3):1151–5.

El-Kelany R, El-Sarnagawy G, Eid G. 2015. Estimation of stature from craniofacial anthropometric measurements in Egyptians and Bengalis samples (a comparative study). Ain-Shams J Forensic Med Clin Toxicol 25(2):24–30. https://doi.org/10.21608/ajfm.2015.18572

Gao T, Guo Y, Rokohl AC, Fan W, Lin M, Ju S, Li X, Ju X, Hou X, Rosenkranz TA, Zhang G. 2024. Racial and sexual differences of eyebrow and eyelid morphology: three-dimensional analysis in young Caucasian and Chinese populations. Quant Imaging Med Surg 15(1):882. https://doi.org/10.21037/qims-24-1113

Iqbal M, Nahar N, Rahman KM, Sultana N, Hossain S, Yeasmin F, Uddin SA. 2024. Anthropometric Study of Orbitonasal Proportion and Their Comparisons in Bangladeshi Buddhist Rakhain Ethnic Males and Females. J Natl Inst Neurosci Bangladesh 10(1):21–5. https://doi.org/10.3329/jninb.v10i1.65450

Jahanshahi M. 2012. Ethnicity and Facial Anthropometry. In Handbook of Anthropometry: Physical Measures of Human Form in Health and Disease (pp. 2535–2542). New York, NY: Springer New York. https://doi.org/10.1007/978-1-4419-1788-1_157

Joab-Peterside S, Nyiayaana K, Jack JT. 2021. Insecurity in Rivers State: The Issues, Actors and Solutions. In: TM Ebiede, CO Bassey, JB Asuni, editors. Insecurity in the Niger Delta: A Report on Emerging Threats in Akwa Ibom, Bayelsa, Cross

River, Delta, Edo and Rivers States. Adonis & Abbey Publishers. 347–433.

Kalia S, Shetty SK, Patil K, Mahima VG. 2008. Stature estimation using odontometry and skull anthropometry. Indian J Dent Res Apr 19(2):150–4. https://doi.org/10.4103/0970-9290.40471

Kumar J, Chandra L. 2006. Estimation of stature using different facial measurements among the Kabui Naga of Imphal Valley, Manipur. The Anthropologist 8(1):1–3. https://doi.org/10.1080/09720073.2006.11890926

Ndombolo GB, Milolo AM, Bushabu FN, Kazadi EK, Ntumba PK, Bukama JM, Tshilumba EL, Isouradi JP. 2024. Relationship between Inter Canine Width and Inter Alar Width, Inter Commissural Width, and Inter Canthal Distance: A Pilot Study. OJST 14(6):279–90. https://doi.org/10.4236/ojst.2024.146022

Ogoun TR, Tobia PS, Aye TT. 2021. A comparative analysis of canthal index of Ekowe indigenes, Bayelsa state. World J Curr Med Pharm Res 157–9. https://doi.org/10.37022/wjcmpr.v3i6.204

Oladipo GS, Fawehinmi HB, Okoh PD. 2009. Canthal indices of Urhobo and Itsekiri ethnic groups. Aust J Basic Appl Sci 3(4):3093–96.

Oladipo GS, Akande PA, Osogba IG, Yorkum KL. 2011. Anthropometric studies of inner canthal distance, outer canthal distance and canthal index of adult Ibibios. Asian J Med Sci 3(1):14–6.

Oladipo GS, Ezi G, Okoh PD, Abidoye AO. 2015. Index and ring finger lengths and their correlation with stature in a Nigerian population. Ann Bioanthrop 3(1):18. https://doi.org/10.4103/2315-7992.160742

Osunwoke EA, Elekwa A, Bob-Manuel IF, Ojeka SO. 2010. A study on the normal values of inner canthal, outer canthal, canthal index, interpupillary distance and head circumference of 23–42 years Igbos. Global J Med Sci 9(1&2):43–8.

Radha K, Srinivasan KR. 2021. Anthropometric assessment of canthal distances and canthal index of South Indian region: A cross-sectional study. Med Legal Update 21(1):794–7. https://doi.org/10.37506/mlu.v21i1.2413

Rajput K, Modi V, Kumar K, Yadav CK, Dhingra S. 2022. Comparative evaluation of Canthal distances and Canthal index in males and females. NeuroQuantology 20(21):503. https://doi.org/10.48049/NQ.2022.20.21.NQ99060

Raschke GF, Rieger UM, Bader RD, Schäfer O, Schultze-Mosgau S. 2013. Objective anthropometric analysis of eyelid reconstruction procedures. J Craniomaxillofac Surg 41(1):52–8. https://doi.org/10.1016/j.jcms.2012.05.011

Srivastava A, Shukla D, Rajput AS. 2023. Comparative evaluation of canthal and cephalic morphomety among males and females. Int J Acad Med Pharm 5(3):192–5. https://doi.org/10.47009/jamp.2023.5.3.42

Wankhede KP, Kamdi NY, Parchand MP, Anjankar VP, Bardale RV. 2012. Estimation of stature from maxillo-facial anthropometry in a central Indian population. J Forensic Dent Sci 4(1):34–7. https://doi.org/10.4103/0975-1475.99161

Yadav AB, Kale AD, Mane DR, Yadav SK, Hallikerimath S. 2019. Stature estimation from regression analysis of facial anthropometry in Indian population. J Oral Maxillofac Pathol 23(2):311. https://doi.org/10.4103/jomfp.jomfp_140_19

Yadav SK, Malla BK, Srivastava AK, Kumar A. 2019. Anatomical study of canthal index: The morphometrical study. J Kathmandu Med Coll 8(3):136–40. https://doi.org/10.3126/jkmc.v8i3.29718

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A Cross-Sectional Approach in Unveiling the Prevalence, Anthropometric Measurements, and Risk Factors of Eating Disorders among Bengalee Adolescent Females

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ABSTRACT: *Background:* The crucial adolescent period demands greater nutritional needs along with physical maturity where overweight can lead to sensitivity towards body image. Excessive appearance concern results in faulty eating habits and complementary behavioral approaches known as eating disorders (ED).

Aim: Due to inconsistencies in prior information regarding ED on Bengalee adolescent females, the cross-sectional study was conducted on Bengalee school females of rural and urban areas of North 24 Parganas district with the insights of prevalence, anthropometric parameters and risk factors of ED.

Method: The study design consisted of self-reported surveys using standardized questionnaires (Eating disorder examination questionnaire-28; Body shape questionnaire-34) to determine ED, body dissatisfaction (BD), meal skipping (MS) and objective assessments of anthropometric parameters of 396 students aged 13–19 years. Statistical analysis was conducted to interpret the findings.

Result: 14.39% ED and 44.95% BD cases were found in this community with significantly high BMI-for-age (BAZ), hip circumference and subscale values of ED questionnaire among ED participants. After chi-square and binary logistic regression analysis regular MS was found to be the strongest predictor of ED accounting for 14% likelihood of ED followed by fear-of-weight-gain (4.48%) and excessive exercise (3.88%).

Conclusion: The findings highlight a complex interplay of psychological and social factors contributing to ED. Regular MS emerged as the strongest predictor of ED, reflecting an unhealthy coping strategy driven by psychological stressors such as fear of weight gain, excessive exercise and BD. Influence of cultural norms on body image cannot be avoided. Our findings will help healthcare practitioners in designing identification treatment procedures and diet plans in a holistic way during further investigation of ED.

KEY WORDS: BMI-for-age, body dissatisfaction, eating disorder, meal skipping, overweight

Original article

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Introduction

Adolescence is a period of key developmental changes including biological, psychological, social, and cognitive transformation. This period also involves emotional regulation and independency generation that impose the passion of self-regulatory manifestations (Silvers 2022). Brain restructuring and pubertal maturation make sensitive to social environment, psychological distress and long-term unhealthy dietary habits along with nutritional risks (Sisk and Gee 2022; Shawon et al. 2023). Additionally, sedentary lifestyle and rapid alteration in dietary behavior, resulting from globalization are increasing obesity prevalence among adolescents (Bauman 2023). Adiposity is determined during intrauterine phase, but after birth, favorable conditions further contribute to positive weight gain (Orsso et al. 2020). Childhood obesity may promote early pubertal maturation (Shalitin and Yablonski 2022), depression, anxiety, low self-esteem, body weight dissatisfaction (BWD) and irregular dietary habits (Tsekoura et al. 2021); whereas this early development among females can increase the concern on body image (Sicilia et al. 2024). Genetic and biological interplay during obesity contributes to weight stigmatization and behavioural risk patterns, emphasizing the likelihood of psychological complications and ED circumstances (House et al. 2022; Lister et al. 2023).

The multifaceted dimensions of Eating disorders (ED) are emerging as a global health concern (Prnjak et al. 2022; Yu and Muehleman 2023); characterized by faulty eating habits (restrictive or binging), mostly present with complementary behaviors like misuse of laxatives, self-vomiting and intense exercise (Val et al. 2022; Aranda et al. 2023). Body dissatisfaction (BD), the negative self-perception towards current and desired physical appearance stands as a central and crucial accelerator for the onset and maintenance of ED, resulting in a number of detrimental outcomes. American Psychiatric Association 2013 included body image in diagnostic criteria of ED by DSM-V but comprehensive investigation is still lacking (Lantz et al. 2018; Prnjak et al. 2022; Feng et al. 2023). Eating disorders are becoming increasingly common in Western Asia (Alfalahi et al. 2021), especially among females with high body mass index (BMI), disguising the primary symptoms, due to the established norms of beauty concept, putting their life into danger (Gil et al. 2023). Recent prevalences among adolescents include 8.9% in China (Li et al. 2022), 38.3% in India (Ganguly et al. 2018), 9.62% in Taiwan (Chen et al. 2023). This indicates inconsistency in current research among Indian adolescents, making the detection of ED in a community sample as an urgent and challenging task, as skilled supervision is needed to ensure accurate diagnosis.

Presently, community investigations for ED and BD use standardized questionnaires relying on recall by the individual to answer the questions. As per DSM-IV criteria, the behavioral symptoms should be present for at least twice in a week in the last 3 months to be categorized as ED (Almutairi et al. 2023). Thus, community-based investigations are needed to understand the changing behavioral patterns and prevent malnutrition earlier.

The present study was conducted on adolescent females of North 24 Parganas district of West Bengal, addressing inconsistencies in cross-sectional information and aiming to focus the lack of progress in research in India to cover some objectives, including determining the prevalence of ED and BD in rural and urban area, comparing anthropometric parameters between ED and control group, and exploring the association of ED with various parameters and the possible risk factors of ED.

Materials and methods

A cross-sectional study was conducted in North 24 Parganas district West Bengal from May 2022 to January 2023 using zone-wise distribution of schools, in sub-divisions. It aimed at quantitative estimation of nutritional parameters among diverse students of similar age and mentality. Divergence and concentration of heterogenous group of students in schools make it an ideal place of data collection. The district concurrently includes urban and rural areas with the highest density of population per square km area. It is eventually impacted by the customs and culture of Kolkata which surrounds it to the west (Brief industrial profile 2023).

The study was initiated by obtaining ethical clearance from Institutional Ethics Committee (IEC) for Research on Human Subjects (approval no. WBSU/IEC/30/05) in accordance with the 'Ethical Guidelines for Biomedical Research on Human Subjects' of Indian Council of Medical Research (ICMR) revised version of 2006. In view of deficit in prior information about adolescent population size or prevalence rate of ED in the district, sample size was determined from the following Cochran (1975) formula (Singh and Masuku 2014)

$$n_0 = \frac{Z^2 pq}{e^2}$$

[n_0= sample size, Z is the area under the acceptance region in a normal distribution curve which is 1.96 at 95% confidence interval, p= estimated proportion of an attribute in a population, q = (1-p) e = level of precision ±5%]

$$n_0 = \frac{(1.96)^2 \cdot 0.5(1-0.5)}{(0.05)^2} = 384.16 \approx 385$$

A 10% margin was added to the sample size computation to account for anticipated non-responses resulting in a target sample size of 424 people. From list of schools, 96 females and coeducational schools were randomly selected from rural and urban areas of the district. 52 schools granted permission and were recruited for the study.

In the next step, researchers explained the importance and procedure of the study to class IX–XII students and their guardians with inclusion criteria such as age (13–19 years), females, unmarried, cultural trend (Bengalee), physiological condition (apparently healthy and free from any other diseases), place of residence (residing at respective rural or urban setting since birth); collected informed consent declaring their purposeful interest and used a random selection lottery method to gather nine students from each school from the list of willing participants using a mix of self-reported surveys and objective assessments.

Eating disorder was detected using 'Eating Disorder Examination Questionnaire-6.0' as per Fairburn et al. 2014, a validated tool consisting of 28 questions divided into four subscales (restraint, eating, weight, and shape scale) with global score >=4 is recommending 'ED' (Carter et al. 2001) and rests are 'control'. BD was measured using 'Body Dissatisfaction Questionnaire-34' (BSQ-34) comprising of 34 questions on 6 point Likert scale. Higher score indicates higher body image concern and the value >80 is considered to have BD (Laporta-Herrero et al. 2016). The informed consent and questions were translated into Bengalee and further tested for clarity and authenticity and described thoroughly to the participants before the survey interview.

A pilot study was conducted on a 10% sample of the total estimated sample size in the same area to ensure validity and reliability of the questionnaires. Cronbach's alpha values were 0.94 and 0.98 respectively for EDE-Q and BSQ-34 that allowed usage of these tools for this survey.

Then the study proceeded with anthropometric assessments. Standing height and weight were measured with stadiometer and digital weighing machine with bare foot, minimum clothing at flat surface and 2 hours after eating (Das 2016). Age-wise BMI-z-score (BAZ) was calculated using WHO 'Anthro Plus' Software which uses the WHO 2007 Growth reference (Bhargava et al. 2020) and classified accordingly. The BAZ curve obtained from the software was included in result portion. The linear diameter of waist and hip were measured using non stretching measuring tape to determine waist-hip ratio (WHR) by apportioning the waist by hip circumference. Waist circumference (WC) was taken between the lowest part of rib cage and upper part of iliac crest. The widest part of hip bone was rounded to note hip circumference (HC) (Bacopoulou et al. 2015). WHR is a crucial measure of fat movement and potential health risks. Waist-to-height ratio (WHtR) was also calculated. Skinfold thickness at three sites (thigh, suprailiac and triceps) were measured by Harpenden skinfold calipers to obtain body density by Jackson-Pollock formula (Jackson et al. 1980) and used for BFP calculation by Siri equation (Mohammadi and Shakerian 2010). To avoid error value, all the anthropometric measurements were taken thrice and the mean value was taken.

To observe meal skipping (MS) tendency, each individual was asked regarding their consumption of food and drink in a day with help of 24 hours recall questionnaire. This process was continued for 7 days (Locks et al. 2022; Meshram et al. 2024). It was further confirmed by separately asking about it in terms of 'never', 'sometimes', and 'regular'. Participants were asked about how many of them skipped any of three major meals in a day in past week. If someone skipped at regular basis or atleast 6 days then termed as 'regular meal skipper'. If the skipping frequency was less than 6–7 days then 'sometimes meal skipper' and others were taken as 'never' to skip meals (Zahrah et al. 2023). Weight management practice was investigated with emphasis on exercise in any form. Type of exercise done to control weight gain was recorded as 'moderate' and 'excessive', and they were compared with individual having 'no' exercise habit (CDC guideline). Fear-of-weight-gain (FWG) response was collected from EDE-Q.

After gathering all relevant data, some responses were eliminated, such as students from other cultural background, previously diagnosed with any issues like PCOS, diabetes, thyroid, anemia, anxiety, depression, missing/ incomplete data, non-cooperative, living in mess/ hostel, changed their residence any time before the study etc. to maintain data homogeneity. The ultimate sample structure was formed with 396 adolescent females and proceeded for statistical analysis.

Data were entered into Microsoft excel and then transferred to IBM Statistical Packages for Social Sciences (SPSS version 24) for coding and statistical analysis. Categorical variables such as place of residence, MS, fear of weight gain, exercise pattern was coded. BAZ, WHR, WHtR were made into categorical variables and coded accordingly for chi-square analysis. Graph and heatmap correlation matrix were created at excel. Tables were made into Microsoft word using table option as per result obtained from SPSS output. BAZ curves were obtained from WHO Anthro plus software. Group differences of anthropometric parameters and sub-scale scores were obtained by performing independent-t test. Chi-square and binary logistic regression functions were run to evaluate the association and contribution of each factor on development of ED. In logistic regression odds ratio (OR) was calculated to estimate risk factors. The relationship between ED and BD in control of anthropometric variables was evaluated by semi-partial correlation analysis. All statistical analysis was done at $p<0.05$.

Results

Table 1 shows prevalence of ED and BD according to place. Figure 1 shows a comparison of ED prevalence rates of adolescents in different Indian studies. A total of 14.39% ED (56.14%, 43.80% from rural and urban area respectively) and 44.95% BD (51.68%, 43.81% from rural and urban area respectively) were found. Prevalence of other studies shown in Figure 1 were taken from Upadhyay and Mishra (2014), Babu and Aroor (2017), Ganguly et al. (2018), Nivedita et al. (2018), and Dikshit et al. (2020).

Table 1. Distribution of ED and BD according to place

	Place of residence		Total (n %)
	Rural (n %)	Urban (n %)	
Eating disorder status			
Present	32 (56.14%)	25 (43.80%)	57 (14.39%)
Absent	179 (52.80%)	160 (47.19%)	339 (85.61%)
Body perception			
Dissatisfied	92 (51.68%)	86 (48.31%)	178 (44.95%)
Satisfied	119 (54.59%)	99 (45.41%)	218 (50.05%)

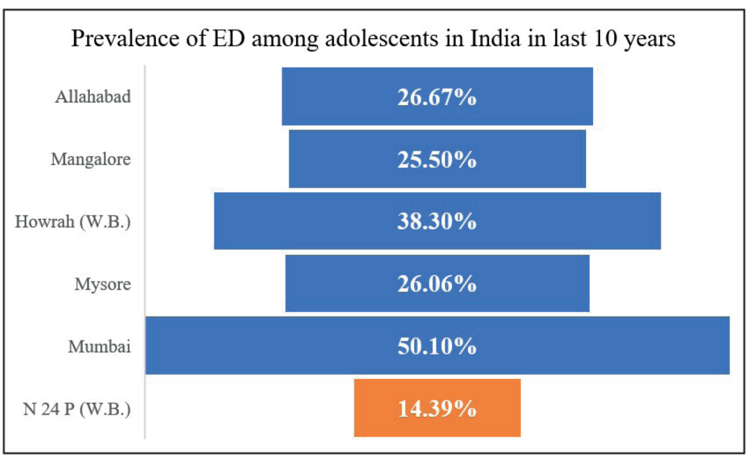

Fig. 1. Comparison of prevalence of eating disorders (ED) among adolescent females in India. The figure shows comparison of ED prevalence rates of different parts of India (blue colored bars) in last ten years with our study (orange colored bar). Our study found the least prevalence till now

Table 2 shows number and percentage of participants in accordance to BAZ. Among total population, 65.15% (ED= 42.10% Control= 69.03%) were in normal category, followed by 21.21% overweight, 8.83% obesity, 2.77% thinness, and 1.26% severe thinness. ED category showed higher cases of overweight and obesity. This community represented very few incidences of undernutrition as overall 2.27% thinness was present both in ED and control group and only 1.26% severe thinness appeared in control group. Despite restrictive eating behavior and weight control approaches, BAZ score of ED participants did not go <-3 SD, affirms inconsistency of ED with undernutrition, but does not ensure optimum health status of them. The comparison of BAZ categories of the study population with compared to WHO reference curve is shown in Figure 2.

Figure 2a shows the right side shifting of z-score curve from WHO standard BMI curve. Figure 2b shows scatterness of the curve in both overweight and underweight categories. The average BAZ value was still very lower than reference curve suggesting presence of malnutrition in overall population. It is visible that overweight or obesity cases are more than undernutrition.

Table 2. Distribution of participants according to BMI z-score (BAZ) status (n=396)

BAZ status	ED {n (%)}	Control {n (%)}	Total {n (%)}
Severe thinness (<-3SD)	0 (0%)	5 (1.47%)	5 (1.26%)
Thinness (<-2SD)	1 (1.75%)	10 (2.95%)	11 (2.77%)
Normal (-2SD to 1SD)	24 (42.10%)	234 (69.03%)	258 (65.15%)
Overweight (>1SD)	23 (40.35%)	61 (17.99%)	84 (21.21%)
Obesity (>2SD)	9 (15.79%)	29 (8.55%)	35 (8.83%)
Total	57	339	396

† BAZ= BAZ= BMI-for-age-z score SD= standard deviation

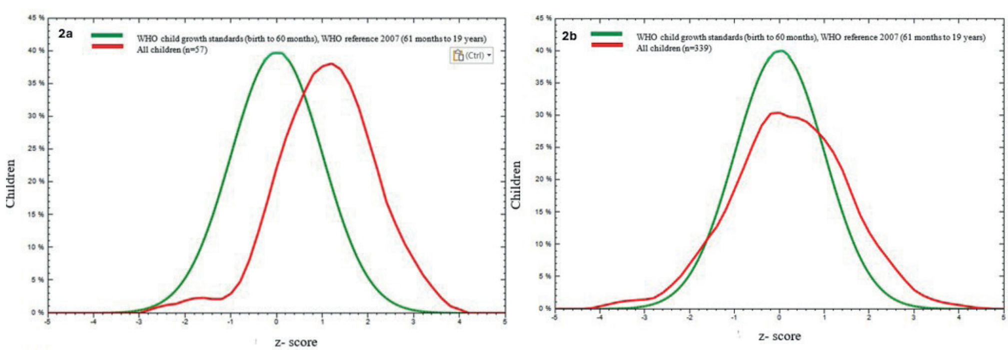

Fig. 2. Comparison of high BMI-for-age (BAZ) of eating disorders (ED) and control group with a WHO reference curve. 2a shows BAZ score curve of ED group, and 2b shows BAZ score curve of control group. The green line is the WHO curve, the red line indicates BAZ of our sample

Table 3 shows significantly higher value (p<0.05) of BAZ, HC, and EDE-Q subscale scores among ED subjects. Normal BAZ category contributed to the most significant difference, indicating general tendency of overweight of ED participants. For subscale variation, the highest concern was observed in 'shape concern' scale, followed by 'weight concern', 'eating' and 'restraint concern'.

Table 3. Difference in anthropometric parameters and subscale scores between ED and control group (n=396)

Parameters		ED (n= 57)	Control (n= 339)	p value
		Mean (± SD)		
Anthropometric parameters				
BAZ	Total	1.09 ± 1.01	0.21 ± 1.30	<0.01**
	Normal	0.29 ± 0.5	-0.18 ± 0.76	<0.01**
	Overweight	1.47± 0.28	1.40 ± 0.27	0.31
	Obesity	2.57±0.38	2.57±0.57	0.99
BFP		27.29 ± 3.93	26.58 ± 4.49	NS
WC		74.80 ± 12.07	72.50 ± 11.20	NS
HC		92.17 ± 11.18	88.72 ± 11.98	0.043*
WHR		0.80 ± 0.06	0.81 ± 0.05	NS
Subscale scores				
Restraint Scale		2.99 ± 1.16	0.07 ± 1.05	<0.01**
Eating concern		3.16 ± 1.21	0.56 ± 0.77	
Weight concern		4.59 ± 1.31	1.25 ± 1.22	
Shape concern		5.06 ± 0.78	1.53 ± 1.34	

† Note= As there was no severe thinness and only one thinness subject in ED group so group difference can't be performed in this case. **p<0.01, *p<0.05, NS= not significant

BAZ= BMI-for-age-z score, BFP= body fat percentage, WC= waist circumference, HC= hip circumference, WHR= waist-hip ratio, SD= standard deviation

Further, the association of different variables with ED was determined by chi-square test for independence at 5% level of significance (p<0.05), that reflected a statistically strong significant association between ED and some parameters except place of residence, age, waist-hip ratio (WHR), and waist-to-height ratio (WHtR). Tables 4,5,6 respectively represented chi-square association of socio-demographic, anthropometric and lifestyle variables with ED.

Significant variables of table 4,5,6 were entered into logistic regression model as predictor variables to observe their likelihood on ED. Chi-square assumption (p=0.922) in Hosmer-Lemeshow goodness of fit data indicates the fitness of model at acceptable level where the variance of predictor variables ranges between 27%- 48% based on Cox and Nagelkerke R^2 [Table 7] and model fitness at 90.4% [Table 8]. Regression analysis shows significant positive association of BD, MS, FWG and excessive exercise with ED. High BAZ did not appear as a significant risk factor of ED [Table 9]. Chi square analysis significant variables may mislead for direct linear relationship and regression analysis confirms their relationship when other variables are present. Contribution of each significant variable on occurrence of ED is presented in Figure 3.

Table 4. Association of socio-demographic variables with ED (n= 396)

Parameters	ED		χ^2 **(Sig. value)**
	Present	Absent	
Place of residence			
Rural	32	179	0.218 (NS)
Urban	25	160	
Age (years)			
13	3	11	1.17 (NS)
14–16	21	146	
17–19	33	182	

[NS= non-significant]

Table 5. Association of anthropometric variables with ED (n= 396)

Parameters	ED		χ^2 **(Sig. value)**
	Present	Absent	
BAZ			
ST	0	5	20.405 (<0.01)**
Thinness	1	10	
Normal	24	234	
Overweight	22	61	
Obesity	10	29	
WHR			
Gynoid (<0.8)	24	132	0.205 (NS)
Android (>0.8)	33	207	
WHtR			
<0.5	32	216	1.197 (NS)
>=0.5	25	123	

[BAZ= BMI z score, ST▪= Severe thinness, WHR= waist-hip ratio, WHtR= Waist-to-height ratio. ** significant p<0.01; *significant p<0.05; NS= not significant]

Table 6. Association of lifestyle behavior with ED (n=396)

Parameters	ED		χ^2 (Sig. value)
	Present	Absent	
BD			
Present	48	130	41.47 (<0.01)**
Absent	9	209	
Fear of weight gain (FWG)			
Yes	42	103	39.42 (<0.01)**
No	15	236	
Exercise pattern			
No	33	241	10.97 (0.004) **
Moderate	16	85	
Excessive	8	13	
Meal skipping (MS)			
Regular	23	22	82.86 (<0.01)**
Sometimes	11	13	
Never	23	304	

[BD= Body dissatisfaction, ** significant p<0.01]

Tabe 7. Model summary and Hosmer-Lemeshow test

Model summery				H-L test		
Step	-2 Log Likelihood	Cox and Snell R square	Nagelkerke R square	Chi-square value	df	p value
1	200.48	0.272	0.485	3.19	8	0.922

Table 8. Model classification table

Observed		Predicted		
		ED		Percentage Correct
		Absent	Present	
Step 1	ED			
	Absent	329	10	97.1
	Present	28	29	50.9
	Overall Percentage		90.4	

Among all the significant variables, 'regular' MS increased the occurrence of ED by 14 times (OR=14.03; 95% CI= 5.82–33.82), followed by 'sometimes' MS to about 10 times (OR=10.18; 95% CI= 3.31–31.30), with compared to reference category (no MS).

Next, significant factor was 'fear of weight gain'. FWG accounted for four times increment in odds of ED (OR=4.48; 95% CI=2.09–9.62). The result for exercise pattern indicated when excessive exercise was done, then the likelihood of ED went around 3.8 times (OR=3.88; 95% CI=1.03–1.04); while for moderate exercise, the odds increased at 1.9 times (OR=1.92; 95% CI=0.85–4.36) than its respective reference category (no).

One unit increase in BD score can increase the probability of ED only one time (OR=1.02; 95% CI= 1.01–1.04) and thus, BD has very less contribution in developing ED than other variables included in the model. Actually, MS and FWG develop primarily which are contributing factors of BD and BD arises at later stage.

Various studies established BD and high BMI as significant risk factors of ED but the concern about physique is very specific to cultural norms and lifestyle approaches and this cross-sectional study tried to seek the strength of BD and BAZ on development of ED among Bengali adolescent females. Here, BD was responsible only one time and BAZ only 1.3 times odds on occurrence of ED.

Table 9. Association of predictor variables with ED and Odds ratio

Predicted variables	Regression coefficient (B)	Standard Error (SE)	Chi-square (Wald) value	p value	Odds ratio	95% CI	
						lower	upper
BD	0.027	0.007	15.25	<0.01**	1.027	1.01	1.04
BAZ	0.278	0.164	2.877	0.09	1.32	0.95	1.80
Meal skipping	–	–	41.89	<0.01**	–	–	–
Regular (ref: never)	2.641	0.449	36.610	<0.01**	14.03	5.82	33.82
Sometimes (ref: never)	2.32	0.573	16.38	<0.01**	10.18	3.31	31.30
FWG Yes (ref: never)	1.50	0.389	14.91	<0.01**	4.48	2.09	9.62
Exercise	–	–	5.48	0.06	–	–	–
Moderate (ref: no)	0.656	0.417	2.46	0.11	1.92	0.85	4.36
Excessive (ref: no)	1.35	0.677	4.02	0.04*	3.88	1.03	1.04
Constant	-6.02	0.73	66.94	<0.01**	0.002	–	–

† Notes: There was no missing data. Odds ratio were determined for predicted variables BD, BAZ, Meal skipping (MS), FWG and Exercise. Dichotomous dependent variable ED was expressed as present and absent. MS, FWG, exercise was converted into categorical variable. Categories of MS: 'regular'– daily at least one major meal in a day for last 7 days; 'sometimes'– at least 3–4 days for last 7 days; 'never'– skip no meal in last 7 days; FWG: yes and no; Exercise: tendency to do at moderate excessive never in a week. The individual value of BD and BAZ of each participant were included for analysis in continuous scale. The significance level is denoted by **= p<0.01 *= p<0.05.

BD= body dissatisfaction, BAZ= BMI-for-age z score, FWG= fear of weight gain

Regression equation:

Logit (P)= -6.02 + 0.02* BD + 0.27* BAZ + 2.64* MS (regular) + 2.32* MS (sometimes) + 1.5* FWG (yes) + 0.65* Exercise (moderate) + 1.35* Exercise (excessive)

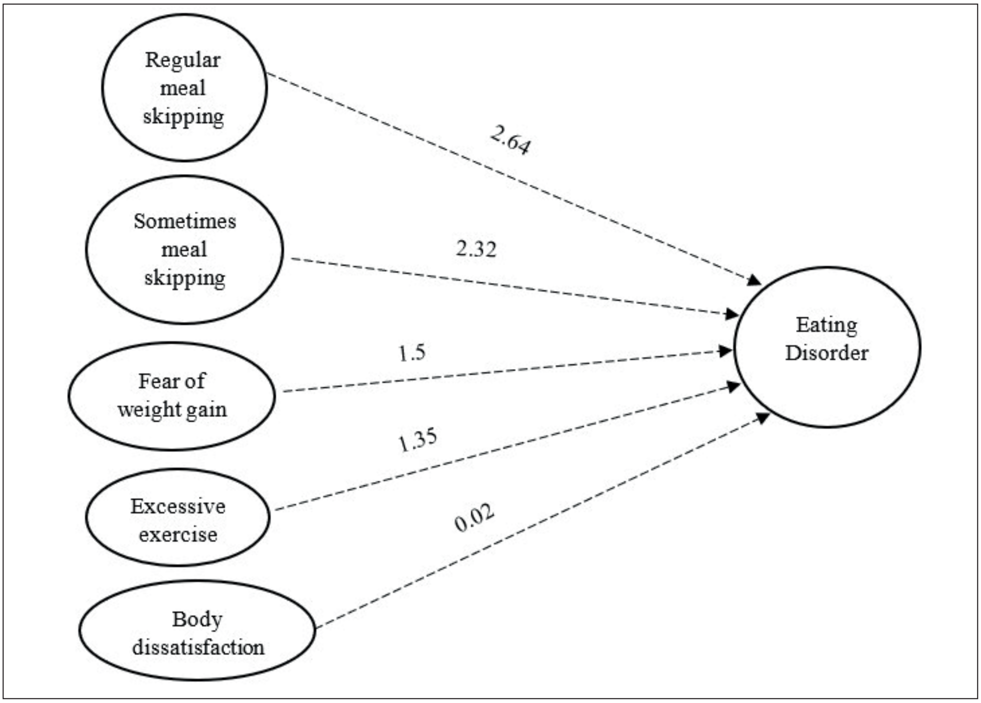

Fig. 3. Impact of predictor factors on development of eating disorders. Effect of significant variables on eating disorders found in our logistic analysis is shown. Regular meal skipping is the strongest predictor, followed by sometimes meal skipping, fear of weight gain, excessive exercise and body dissatisfaction

Among all the anthropometric variables, BAZ had the highest correlation with ED (r=0.37 though the strength of correlation is low). When all other variables were removed except BAZ, then the correlation of BD reduced to 0.53 from 0.63 (model 2). In model 3, the non-significant variables, i.e., HC and BFP were excluded and then the correlation was slightly increased at 0.56 (still at moderate degree of correlation) due to inclusion of WC. Increase in R^2 values and gradual decrease of standardized coefficient beta value from model 1–3 suggest proper exclusion of the particular variables from the model. It indicates that heavy body weight or high BAZ and WC are the main anthropometric factors to initiate BD and in turn ED. The correlation matrix is shown by a heatmap visual chart (Figure 4) where the color intensity has increased from pink to green according to correlation coefficient. Controlling anthropometric parameters on BD and ED in Analysis by Semi-partial correlation can be seen in Tables 10–12.

Table 10. Results from the Pearson's correlation analysis

		BD Score	WC	HC	BFP	BAZ
Pearson Correlation	ED Score	0.636	0.243	0.249	0.184	0.372
Sig. (1-tailed)	ED Score	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**

† BD= body dissatisfaction WC= waist circumference HC= hip circumference BFP= body fat percentage BAZ= BMI-for-age z score. **p<0.01

Table 11. Results from the step-wise exclusion of variables and part correlation analysis

	Model	Standardized Coefficients Beta	Sig.	Zero-order	Part
1	BD Score	0.636	<0.01**	0.636	0.636
2	BD Score	0.577	<0.01**	0.636	0.539
	BAZ	0.167	<0.01**	0.372	0.156
3	BD Score	0.612	<0.01**	0.636	0.561
	BAZ	0.342	<0.01**	0.372	0.226
	WC	-0.251	<0.01**	0.243	-0.163

Table 12. Results from the backward correlation analysis

	Model	Standardized Coefficients Beta	Sig.	Zero-order
1	(Constant)		0.001	
	BD Score	0.614	<0.01**	0.636
	BAZ	0.367	<0.01**	0.372
	WC	-0.211	0.023*	0.243
	HC	-0.038	0.681	0.249
	BFP	-0.048	0.293	0.184

**p<0.01 *p<0.05

	ED score	*BD score*	*BAZ*	*WC*	*HC*	*BFP*
ED score	1.000					
BD score	0.636	1.000				
BAZ	0.372	0.356	1.000			
WC	0.243	0.389	0.748	1.000		
HC	0.249	0.366	0.758	0.908	1.000	
BFP	0.184	0.255	0.551	0.509	0.509	1.000

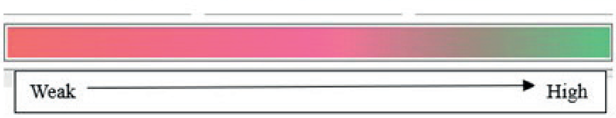

Fig. 4. Heatmap correlation matrix of eating disorders (ED), body dissatisfaction (BD) and anthropometric variables. Regular (MS) is the strongest predictor, followed by sometimes MS, FWG, excessive exercise and BD. The pink color indicates low strength of correlation and green indicates higher correlation. Among anthropometric variables, BD has the highest correlation with ED, the color is indicated a mixture of pink and green

Discussion

The prevalence rates of BD and ED of our study are not limited by geographical location as seen in Table 1. The study found the least prevalence of ED among adolescents in India till now. It is far consistent with 13.6% of Thangaruju et al. (Thangaraju et al. 2020) where same questionnaire was applied on undergraduate students. This variation could be the influence of social media's potency to instill a western philosophy among rural teen minds. Most importantly these prevalence rates can act as documentation for cross-sectional motive of addressing ED behavior among adolescent school females. Body dissatisfaction prevalence of our study came within global prevalence of 19.2–83.8% in various community-based studies (Martini et al. 2022) or 40–60% among adolescent females where 30–60% females preferred to follow inappropriate weight control behaviors (Flament et al. 2015). Further presence of overweight/obesity increased the severity of ED due to weight stigmatization and overestimation (Matthews et al. 2022), predominantly lead to restrictive eating. Therefore, prior weight status poses immense role on severity and progression of ED and metabolic functions of the body (Jhe et al. 2023). Overweight is identified as unacceptable weight status that sometimes raises external pressure of weight loss, thin-body internalization and weight-teasing attitudes (Lin et al. 2023), drive individuals towards improper lifestyle behaviors as seen in ED. It supports the higher chances of overweight and obesity among them [Table 2 and Figure 2a,b]. Consistent presence of ED symptoms such as psychometric properties of body concern, eating and other lifestyle behaviors are confirmed by higher subscale values which distinguish the people having ED from others. Significant difference suggests the presence of symptoms did not appear by chance, but rather developed from indigenous practices in their real lives.

Therefore, cross-sectional studies in different countries even across regions of a single country show variation in prevalence rates due to broad spectrum of cultural differences, social norms, misunderstanding of beauty standards, genetic adaptation, family practices of individual, and questionnaire used. Though the prevalences of BD and ED of this study are not so alarming but still needs to be considered seriously to take timely preventive approach.

Meal skipping and fear-of-weight-gain tendency for intensive exercise, high BAZ, and BD values have been found as significant predictive risk factors of ED. Obesity is not only the sole risk factor of ED, as various studies have reported the development of ED during or after obesity treatment, indicating a complex metabolic interplay between obesity and psychometric allowance for ED behaviors (McMaster et al. 2023). All these factors are inter-related, such as FWG often triggers pervasive feelings of dissatisfaction, leading to emotional disturbance and cognitive regulation on food intake, reinforcing the ED characteristics. Also, persistent ED promotes all these factors in reciprocal way, further increasing the obsession and compulsive behaviors (Nearman et al. 2024). Meal skipping can contribute to emotional eating and unhealthy dietary choices, resulting in binging, poor lifestyle practices, and a surge in obesity (Zahrah et al. 2023). In this study, MS has been found as the most common approach, accounting for almost 10-14 times rise in occurrence of ED.

Therefore, only the psychological freight is not alarming, if it thrives any unscientific practice in regular lifestyle then only it can emerge the severity of ED.

The study suggests that tendency of excessive exercise contributed to about three times increase in risk of ED. Regular physical exercise definitely improves overall quality of life but addiction may trigger for rigid workout schedule for achieving perfect figure. Though the study did not analyze dietary pattern except MS, the findings on exercise pattern and ED was consistent with previous research, that found significant and positive correlation between the healthy dietary pattern with the exercise addiction and shape concern. Apart from dietary pattern, exercise addiction among adolescents can accelerate the risk of ED by promoting psychological distress, sleep disturbances and body image concern particularly among females. Pubertal development of adolescence augments the physiological disillusions or BD and vigorous exercise schedule that take over the charge of dominating lifestyle behaviors for ensuring figure correction; but actually, imposing adverse health effects. A study also mentioned the strongest mediation effect of body image on exercise intensity and ED. So, body image holds the central part of exercise behavior and BD (Ahorsu et al. 2023; Khosro et al. 2024). BD also formed significant positive correlation with ED in presence of BAZ, the most confounding factor, while other anthropometric parameters were in control. A study in Saudi Arab found moderate level of association between ED and BD when the effect of BMI was controlled. BMI can increase due to various causes and not always related to westernization but eventually leading the threat of ED in presence of dissatisfaction and excessive concern on body image (Melisse et al. 2022).

Due to cross-sectional design the study possesses some limitations. Firstly, the eating behaviors, body concern and meal skipping tendency were estimated from the responses given by the participants. So, it was not possible to capture the recall bias, if any, that may underreport these behaviors. The study did not include socioeconomic status and social factors that may influence the above behaviors. Additionally, the changes in anthropometric measurements over time can't be covered at a single point of time that lacks the information about the unhealthy lifestyle choices whether it appear concurrently with or prior to the onset of ED. The cause-relation effect of the variables was also not established. Lastly, the study focused on a specific adolescent population of a district which limited the generalizability of the findings to other adolescents of the state.

Conclusion

This cross-sectional approach was undertaken to shed light on eating-related attitudes of both rural and urban adolescent females of the district. The findings highlight the growing sensitivity towards body image during adolescence, where regular MS has emerged as the strongest predictor of ED, reflecting an unhealthy coping strategy driven by psychological stressors such as FWG, excessive exercise, and BD and socio-cultural norms. Though ED is a widely researched topic, this study recognized a complex interplay of psychological and social factors in the response of ED among Bengalee adolescent females along with their anthropometric indices where limited literature exists in this context. It will undoubtedly help medical practitioners, nutritionists, and policymakers in understanding the health implications and designing the treatment procedure and diet plans. In comparison with other studies, variation exists in prevalence rates due to differences in the survey tool used, participants' type, family and social background, cultural trends, daily habits, etc. High BAZ values among ED participants may be a cause or consequence of ED, and it needs a longitudinal study design to determine the fact. Poor BAZ in participants without ED detection does not mean its absence, but suggests frequent investigations and health care monitoring along with the promotion of mental awareness. However, in regard to ED, the study focuses on the attitudes, anthropometric status, risk factors of ED, and lifestyle choices of young teenagers in West Bengal's North 24 Parganas district, which becomes helpful information for further investigation. At last, the study has found gaps in understanding the effects of social media use, family, friends, and cultural norms on body image; the psychological spectrum and food habits on ED; and any cause-effect pathway of the variables in the Bengalee community.

Ethical approval

Data were collected after getting ethical clearance from West Bengal State University Institutional Ethics Committee (IEC) for Research on Human Subjects (approval no. WBSU/IEC/30/05) in accordance with 'Ethical Guidelines for Biomedical Research on Human Subjects' of Indian Council of Medical Research (ICMR) revised version of 2006.

Consent to participate

Written consent was obtained for participation in the entire survey process from the guardians of the participants prior to data collection.

Consent for publication

Not applicable as no individual's data or image will be used in publication. All the information will be kept confidential. The paper has not been previously published nor under consideration of any journal and it is approved by all authors and the institutions where it was.

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Conflict of interests

The authors declare that they have no conflict of interest.

Authors' contribution

Author SS was involved in data collection. SS and RB both contributed to the study designing data analysis and drafting the manuscript. Both authors read the manuscript and declared that it is their original research work and approved for submission and publication.

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References

Ahorsu DK, Imani V, Potenza MN, Chen HP, Lin CY, Pakpour AH. 2023. Mediating roles of psychological distress insomnia and body image concerns in the association between exercise addiction and eating disorders. Psychol Res Behav Manag 31:2533–42. https://doi.org/10.2147/PRBM.S414543

Alfalahi M, Mahadevan S, Balushi RA, Chan MF, Saadon MA, Al-Adawi S, Qoronfleh MW. 2022. Prevalence of eating disorders and disordered eating in Western Asia: a systematic review and meta-Analysis. Eat Disord 3;30(5):556–85. https://doi.org/10.1080/10640266.2021.1969495

Almutairi R, Azuhairi AA, Mahmud A, Dablool AS. 2023. Eating disorders among adolescent female students in Jeddah Saudi Arabia. Malays J Med Sci 30(1):185. https://doi.org/10.21315/mjms2023.30.1.16

Babu SS and Aroor AR. 2017. Eating disorder among Indian adolescent. Ind J Youth Adol Health 4(1):11–15. https://doi.org/10.24321/2349.2880.201703

Bacopoulou F, Efthymiou V, Landis G, Rentoumis A, Chrousos GP. 2015. Waist circumference waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. BMC Pediatrics 15(1). https://doi.org/10.1186/s12887-015-0366-z

Bauman D. 2023. Impact of obesity on female puberty and pubertal disorders. Best Pract Res Clin Obstet Gynaecol 10:102400. https://doi.org/10.1016/j.bpobgyn.2023.102400

Bhargava M, Bhargava A, Ghate SD, Rao RSP. 2020. Nutritional status of Indian adolescents (15–19 years) from National Family Health Surveys 3 and 4: Revised estimates using WHO 2007 Growth reference. PLOS ONE 15(9):e0239923. https://doi.org/10.1371/journal.pone.0239923

Brief Industrial profile of North 24 Pargana district Ministry of MSME Govt. of India. https://dcmsme.gov.in/old/dips/NORTH%2024-PARGANAS.pdf. Accessed 2.5.2023.

Carter JC, Stewart DA, and Fairburn C. 2001. Eating disorder examination questionnaire: norms for young adolescent girls. Behav Res Ther 39:625–632. https://doi.org/10.1016/s0005-7967(00)00033-4

CDC Physical activity basics. https://www.cdc.gov/physical-activity-basics/measuring/index.html. Accessed Jan 2023.

Chen DR, Lin LY, Levin B. 2023. Differential pathways to disordered eating for immigrant and native adolescents in Taiwan. J Eat Disord 11(1):54. https://doi.org/10.1186/s40337-023-00781-4

Das S. 2016. Textbook of community nutrition. 2nd edition. Academic Publishers. ISBN: 978-93-83420-69-8.

Dikshit R, Karia S, Shah N, Sonavane S, and DeSousa A. 2020. A study on binge eating behavior in urban adolescents. Asian J Psychiatr. 50:101998. https://doi.org/10.1016/j.ajp.2020.101998

Feng B, Harms J, Chen E, Gao P, Xu P, and He Y. 2023. Current Discoveries and Future Implications of Eating Disorders. Int J Environ Res Public Health 20(14):6325. https://doi.org/10.3390/ijerph20146325

Fernández-Aranda F, Granero R, and Jiménez-Murcia S. 2023. Eating Disorders and Addictive Behaviors: Implications for Human Health. Nutrients 15(17):3718. https://doi.org/10.3390/nu15173718

Flament MF, Henderson K, Buchholz A, Obeid N, Nguyen HN, Birmingham M, Goldfield G. 2015. Weight status and DSM-5 diagnoses of eating disorders in adolescents from the community. J Am Acad Child Adolesc Psychiatry 54(5):403–11. https://doi.org/10.1016/j.jaac.2015.01.020

Ganguly N, Roy S, Mukhopadhyay S. 2018. Association of socio-culture factors with disordered eating behavior: An empirical study on urban young girls of West Bengal India. Anthropol Rev 81(4):364–378. https://doi.org/10.2478/anre-2018-0032

House ET, Lister NB, Seidler AL, Li H, Ong WY, McMaster CM, Paxton SJ, Jebeile H. 2022. Identifying eating disorders in adolescents and adults with overweight or obesity: A systematic review of screening questionnaires. Int J Eat Disord 55(9):1171–93. https://doi.org/10.1002/eat.23769

Jackson AS, Pollock ML, Ward A. 1980. Generalized equations for predicting body density of women. Med Sci Sports Exerc 12:175–81.

Jhe GB, Lin J, Freizinger M, Richmond T. 2023. Adolescents with anorexia nervosa or atypical anorexia nervosa with premorbid overweight/obesity: What should we do about their weight loss?. J Child Adolesc Psychiatr Nurs 36(1):55–8. https://doi.org/10.1111/jcap.12394

Khoshro S and Abbasalizad Farhangi M. 2024. Major dietary patterns exercise addiction and eating disorders among a sample of physically active young adults. Nutr Metab Insights 17 11786388241258938. https://doi.org/10.1177/117863882412589

Lantz E, Gaspar M, DiTore R, Piers A and Schaumberg K. 2018. Conceptualizing body dissatisfaction in eating disorders within a self-discrepancy framework: a review of evidence. Eat Weight Disord 23:275–291. https://doi.org/10.1007/s40519-018-0483-4

Laporta-Herrero I, Jáuregui-Lobera I, Barajas-Iglesias B, Santed-Germán MÁ. 2016. Body dissatisfaction in adolescents with eating disorders. Eat Weight Disord 3(3):339–347. https://doi.org/10.1007/s40519-016-0353-x

Li S, Song L, Twayigira M, Fan T, Luo X, Shen Y. 2022. Eating disorders among middle school students in a Chinese population: Prevalence and associated clinical correlates. J Psych Res 154:278–85. https://doi.org/10.1016/j.jpsychires.2022.07.062

Lin JA, Jhe G, Adhikari R, Vitagliano JA, Rose KL, Freizinger M, Richmond TK. 2023. Triggers for eating disorder onset in youth with anorexia nervosa across the weight spectrum. Eat Disord 31(6):553–72. https://doi.org/10.1080/10640266.2023.2201988

Lister NB, Baur LA, Felix JF, Hill AJ, Marcus C, Reinehr T, Summerbell C, Wabitsch M. 2023. Child and adolescent obesity. Nat Rev Disease Prim 18;9(1):24. https://doi.org/10.1038/s41572-023-00435-4

Locks LM, Shah M, Bhaise S, Hibberd PL. Patel A. 2022. Assessing the diets of young children and adolescents in India: challenges and opportunities. Front Pediatr 17(10):725812. https://doi.org/10.3389/fped.2022.725812

Lopez-Gil JF, Garcia-Hermoso A, Smith L, Firth J, Trott M, Mesas AE, Jimenez-Lopez E, Gutierrez-Espinoza H, Tarraga-Lopez PJ, Victoria-Montesinos D. 2023. Global proportion of disordered eating in children and adolescents: A systematic review and meta-analysis. JAMA Pediatr 177(4):363–72. https://doi.org/10.1001/jamapediatrics.2022.5848

Martini MCS, Assumpção D, Barros MBA, Mattei J, Barros Filho AA. 2022. Prevalence of body weight dissatisfaction among adolescents: a systematic review. Rev Paul Pediatr. 41:e2021204. https://doi.org/10.1590/1984-0462/2023/41/2021204

Matthews A, Kramer RA, and Mitan L. 2022. Eating disorder severity and psychological morbidity in adolescents with anorexia nervosa or atypical anorexia nervosa and premorbid overweight/obesity. Eat Weight Disord 27:233–242. https://doi.org/10.1007/s40519-021-01168-7

McMaster CM, Paxton SJ, Maguire S, Hill AJ, Braet C, Seidler AL, Nicholls D, Garnett SP, Ahern AL, Wilfley DE, Lister NB. 2023. The need for future research into the assessment and monitoring of eating disorder risk in the context of obesity treatment. Int J Eat Disord 56(5):914–24. https://doi.org/10.1002/eat.23898

Melisse B, Blankers M, de Beurs E, van Furth EF. 2022. Correlates of eating disorder pathology in Saudi Arabia: BMI and body dissatisfaction. J Eat Disord 24;10(1):126. https://doi.org/10.1186/s40337-022-00652-4

Meshram II, Nagalla B, Kodavanti MR, Avula L, Veera BG. Overweight/obesity pre-diabetes diabetes and its association with hypertension and other factors among rural adults (≥ 18 years) in India. Ind Heart J 2024 May 1;76(3):182–91. https://doi.org/10.1016/j.ihj.2024.06.010

Mohammadi EF and Shakerian SA. 2010. Comparison of body composition assessment in women using skinfold thickness equations bioelectrical impedance analysis and underwater weighing. SPCT 17(3):223–230.

Nivedita N, Sreenivasa G, Rao TS, Malini SS. 2018. Eating disorders: Prevalence in the student population of Mysore South India. Ind J Psych 60(4):433–7. https://doi.org/10.4103/psychiatry.IndianJPsychiatry_97_16

Orsso CE, Colin-Ramirez E, Field CJ, Madsen KL, Prado CM, Haqq AM. 2020. Adipose tissue development and expansion from the womb to adolescence: an overview. Nutr 8;12(9):2735. https://doi.org/10.3390/nu12092735

Prnjak K, Jukic I, Mitchison D, Griffiths S and Hay P. 2022. Body image as a multidimensional concept: A systematic review of body image facets in eating disorders and muscle dysmorphia. Bod Im 42:347–360. https://doi.org/10.1016/j.bodyim.2022.07.006

Ralph-Nearman C, Hooper MA, Hunt RA, Levinson CA. 2024. Dynamic relationships among feeling fat fear of weight gain and eating disorder symptoms in an eating disorder sample. Appet 1;195:107181. https://doi.org/10.1016/j.appet.2023.107181

Shalitin S, Gat-Yablonski G. 2022. Associations of obesity with linear growth and puberty. Horm Res Paediatr 95(2):120–36. https://doi.org/10.1159/000516171

Shawon MS, Jahan E, Rouf RR, Hossain FB. 2023. Psychological distress and unhealthy dietary behaviours among adolescents aged 12–15 years in nine South-East Asian countries: a secondary analysis of the Global School-Based Health Survey data. Brit J Nutr 129(7):1242–51. https://doi.org/10.1017/S0007114522002306

Sicilia Á, Griffiths MD, Martín-Albo J. 2024. A Longitudinal Study of Pubertal Timing and Tempo on Body Shame Among Young Adolescent Girls and Boys. Sex Roles 90(12):1923–36. https://doi.org/10.1007/s11199-024-01537-3

Silvers JA. 2022. Adolescence as a pivotal period for emotion regulation development. Curr Op Psych 1 (44):258–63. https://doi.org/10.1016/j.copsyc.2021.09.023

Singh AS, Masuku MB. 2014. Sampling techniques and determination of sample size in applied statistics research: An overview. Intl J Econom Comm Manag 2(11):1–22.

Sisk LM, Gee DG. 2022. Stress and adolescence: Vulnerability and opportunity during a sensitive window of development. Curr Op Psych 1(44):286–92. https://doi.org/10.1016/j.copsyc.2021.10.005

Thangaraju SI, Karpagalakshmi R, Arumuganathan S, Usaid S, Devi SS, Sethumadhavan V. 2020. A cross-sectional study on prevalence of eating disorder and body image disturbance among female undergraduate medical students. J Mental Health Hum Behav 25:53–6. https://doi.org/10.4103/jmhhb.jmhhb_13_20

Tsekoura E, Kostopoulou E, Fouzas S, Souris E, Gkentzi D, Jelastopulu E, Varvarigou A. 2021. The association between obesity and the risk for development of eating disorders-A large-scale epidemiological study. Europ Rev Med Pharmacol Sci 25(19). https://doi.org/10.26355/eurrev_202110_26883

Upadhyay A and Mishra R. 2014. Prevalence and risk factors for eating disorder in Indian adolescent females. Nat J Physiol Pharm Pharmacol 4(2):153–157. https://doi.org/10.5455/njppp.2014.4.041220131

Val A, Cano M, Ruiz J, Canals J and Martín R. 2022. Characterization epidemiology and trends of eating disorders. Nutr hospital 39:8–15. https://doi.org/10.20960/nh.04173

Yu Z and Muehleman V. 2023. Eating Disorders and Metabolic Diseases. Int J Environ Res Pub Health 20. https://doi.org/10.3390/ijerph20032446

Zahrah NI, Fanani M, Ardyanto TD. 2023. The relationship between emotional eating meal skipping and unhealthy food consumption pattern in adolescent girls. Indonesian J Pub Health 18(1):47–58. https://doi.org/10.20473/ijph.v18i1.2023.47-58

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Relationships between Sociosexuality and Dermatoglyphic Traits

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Abstract: In humans, prenatal development of brain dispositions to sex differences in mating behavior is difficult to study directly. Indirect prenatal markers, including dermatoglyphics, present a viable option.

In this study we tested a hypothesis that some radio-ulnar contrasts in dermatoglyphic ridge counts could be related with human sociosexuality.

Sociosexual Orientation Inventory (SOI) data from 180 young adults, along with fingerprints of their terminal phalanges (via hand scanning) were collected, and relationships between SOI and dermatoglyphics were analyzed.

Typical sex differences in SOI were recorded with higher scores in males and lower in females. Among other results we found that on the index finger lower number of triradii and cores (i.e., mostly in loop type dermatoglyphic patterns) and radial-biased within-finger asymmetry in ridge counts typical for ulnar loops were connected with typical sex differences in SOI (higher in males and lower in females) while in subjects possessing an opposite dermatoglyphic arrangement – higher numbers of cores and triradii and ulnar-biased within-finger ridge count asymmetry typical in radial loops – sex differences in SOI scores disappeared. Recognized significant and systematic trends were mostly connected with variables derived from dermatoglyphic features on the 2nd and 4th fingers.

Possible relationships with prenatal androgen causation are discussed.

Key words: radio-ulnar asymmetry, sex development, prenatal programming, sexual behavior, sex differences

Original article

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Introduction

Sociosexuality and its prenatal dispositions

Sociosexuality has been defined as a variable willingness to have sex outside the committed pair bond (Simpson and Gangestad 1991). Largely applied self-report sociosexual inventories (Simpson and Gangestad 1991; Penke and Asendorpf 2008) contained several items reflecting actually performed sociosexual *behavior* (number of sexual partners, one-night sex occasions), as well as sexual *desire* (internal forces of sex drive and preferences, regardless if realized or not) and *attitudes* to this aspect of sexuality (mostly learned and also culturally forced, but not necessarily without innate influences). Therefore, sociosexuality in a way reflects a complex issue of trade-off between quality and quantity of sexual relations (sexual/reproductive evolutionary strategies) of each subject which is essential from evolutionary (life-history) point of view because it can make reproductive differentials between subjects representing different levels of sociosexuality.

Across human populations, sex differences in sociosexuality are influenced both by biological and social factors (Lippa 2007; 2009). While social factors of sociosexuality are relatively easy to study via questionnaires in surveys, the innate part of variation in sociosexuality is more difficult to investigate even though it is also important (Bailey et al. 2000; Lyons et al. 2004), i.e., the variation people are predisposed to from prenatal development by their genes and/or prenatal programming, which can, genetically or epigenetically, be passed on to the following generations.

Predispositions to sexual behavior in general are developed in the human brain prenatally under an influence of prenatal sex differentiation factors, especially the expression of genes from sex chromosomes locally in each cell (Arnold 2014 for review) in a combination with sex hormones produced centrally by prenatal gonads and secreted to the embryonal/fetal circulation (Cohen-Bendahan et al. 2005 for review), see e.g., Mitsui et al. (2016; 2019) for recent examples. In North American adult men and women, sociosexuality – defined as comparison between monoamorously vs. polyamorously behaved subjects – was related to levels of testosterone (van Anders et al. 2007), even though the relationship between sociosexuality and testosterone might not be so straightforward when long term changes during the partnerships are taken into account (Puts et al. 2015). It is unclear, however, how levels of prenatal testosterone are involved in the predispositions for adult sociosexuality. Results of testing relationships between 2D:4D ratio – as a putative marker of prenatal testosterone – with sexually dimorphic behavioral traits were not unequivocal (Charles and Alexander 2011; DeLecce et al. 2014; Wong and Hines 2016).

Sex differences in dermatoglyphics and relationships to behavior

There are some indications that dermatoglyphics, initiating its development in 10th to 11th weeks *in utero* (Loesch 1983:18–24; Babler 1991), could be used as a potential indirect marker of prenatal sexual differentiation and its prenatal influence on brain predispositions of human behaviour (Bracha et al. 1991; Fatjó-Vilas et al. 2008; Golembo-Smith et al. 2012), including sexual behavior and sociosexuality. The primary argument for such associations is a strong, prenatally fixed sexual dimorphism of many dermatoglyphic traits (Schwidetzky and Jantz 1979; Králík et al. 2019).

Among other sex relationships, in the majority of human samples, genetically normal males have on average higher Total Finger Ridge Count (TFRC) and higher hand asymmetry in the ridge count than genetically normal females of the same population (Kunter and Rühl 1995). Strong negative relationship between TFRC and number (dose) of sex chromosomes has been found; the higher number of sex chromosomes in a genome, the lower TFRC (Penrose 1963; Alter 1965; Penrose 1967; Jantz and Hunt 1986). However, it is not clear whether the origin of this dimorphism is due directly to genetic differences in each cell or is mediated by prenatal differences in the action of steroid sex hormones. Nor do the results of studies of people with normal karyotypes (male 46,XY, female 46,XX) and disorders of sexual development, including congenital adrenal hyperplasia (Qazi and Thompson 1971; Börger et al. 1986), or steroid receptor disorders such as testicular feminization syndrome (Polani and Polani 1979), offer a clearer view. At present, therefore, it is not possible to say unequivocally whether the sex differences in dermatoglyphic traits is purely genetic in origin or caused by prenatal differences in sex steroid hormone levels, or some other mechanism mentioned by Arnold (2014), or a combination of different mechanisms. In any case, however, associations have been found between sexual dimorphism of dermatoglyphic traits and certain types of sexually dimorphic behavior.

Some studies tried to find direct relationships between dermatoglyphics and a "sexually typical behavior" that can be predisposed by a prenatal setting, in particular, if dermatoglyphic features or values non-typical for a given sex are found in subjects with a sexually non-typical behavior (Cohen-Bendahan et al. 2005). There are no clear empirical results for relationship between prenatal testosterone levels and right/left *side asymmetry* in dermatoglyphic features and prenatal testosterone. Females have usually more symmetrical patterns than males. In homosexual males (Hall and Kimura 1994) more symmetrical or even leftward asymmetrical (i.e., more feminine) ridge counts were found but another independent study (Mustanski et al. 2002) did not confirm the result and neither did the study of homosexual transsexuals (Slabbekoorn et al. 2000). Another study of transsexuals (Green and Young 2000) found higher frequency of leftward asymmetry in male homosexual transsexuals than in control heterosexual males and heterosexual transsexuals which is in congruence with the expectation, but they reported no differences between male and female controls in directional asymmetry in the ridge count which is not in congruence with the expectation. In female monozygotic twin pairs discordant in sexual orientation (Hall 2000), lower (i.e., more feminine) ridge count was found in lesbians than in their heterosexual twins which is, however, *not* in congruence with supposed role of testosterone in sexual orientation. Additionally, females with leftward ridge count bilateral asymmetry (more typical for females than males) reached better results in language cognitive tasks (perception, fluency), while females with rightward ridge count asymmetry (more typical for males than females) were better in space orientation and mathematical skills that are usually on average better handled by males (Kimura and Carson 1995; Kimura and Clarke 2001).

To sum up, some relationships between dermatoglyphic variations and sex development have been found (Schwidetzky and Jantz 1977; 1979; Králík et al. 2019), however, empirical evidence linking dermatoglyphics to sexuality other than sexual identity and sexual orientation is scarce. One cause might be an inappropriate methodological nature of dermatoglyphic variables used. So far distinguished, defined and studied dermatoglyphic features (ridge count, right/left directional asymmetry) might not be sufficiently sensitive to hormonal action *in utero*. On the contrary, *within-individual* gradients in dermatoglyphic features (e.g., between fingers) might be crucial for studies of prenatal factors, analogically to the 2D:4D ratio (Manning 2002). According to one piece of supporting evidence (Králík et al. 2019b), sex differences in proportions of dermatoglyphic whorl patterns increases significantly *from radial to ulnar fingers*, i.e., from the thumb to the little finger. It indicates that sexes differ in dermatoglyphic development mostly in the ulnar side of the hand. Although not abundantly studied, radioulnar variations might be sensitive both to internal (genetic) and external (environmental) disturbances of developmental processes. Radio-ulnar asymmetry within fingers reflects the number of sex chromosomes in the karyotype (Jantz and Hunt 1986) and differences between radial and ulnar fingers, e.g., differences between ridge counts on the 1st and the 5th finger, are sensitive to seasonal variations during dermatoglyphic development (Kahn et al. 2001; 2008; 2009).

Recent studies (Polcerová et al. 2022a; 2022b; Polcerová et al. 2023) have found that several radioulnar contrasts (numerically: differences between two ridge counts) on the right hand, involving the radial ridge count on the 2nd finger, were dimorphic in the same sense in all 21 study populations examined. This may indicate that these contrasts are targeted by prenatal sex differentiation factors common to all human populations and could therefore be used as prenatal markers of sexual differentiation, as the 2D:4D ratio is used.

Aims of the study

To our present knowledge, there are no studies on the relationship between dermatoglyphics and sociosexuality. The aim of the study was to describe (innate) sex differences in dermatoglyphic radioulnar patterns on fingers and to find out whether human sociosexuality, as measured by sociosexual orientation inventory (SOI), is related to dermatoglyphics as putative markers of prenatal sexual development. Based on previous studies we hypothesize that radio-ulnar contrasts in dermatoglyphic features will be related to variations in sociosexuality.

Materials and methods

Studied subjects

The studied sample represents 180 young adult people (mean age 23.3 years, range from 18 to 35 years), 87 females (mean age 23.9 years) and 93 males (mean age 22.7 years). The subjects were mostly recruited from students of secondary schools and universities in Brno, Czech Republic. The data were collected within the frame of a project which was approved in advance by the Ethical Committee for Research of our university (protocols: EKV-2017-052 and another one with approval letter) and all subjects signed informed consent with their participation in the study. A preliminary version of this analysis was part of the first author's (P.I.) defended dissertation.

Sociosexual Orientation Inventory Sociosexuality was recorded using local language version of seven-items Sociosexual Orientation Inventory – SOI (Simpson and Gangestad 1991). The inventory is a self-reporting questionnaire composed of seven items. The first three items (1–3) reflect real or perceived sociosexual behavior (number of sex partners over the last 12 months, number of supposed sex partners in the future 5 years, and number of "one-night stands" ever) and the answers are open. Item 4 (frequency of imagination having sex with someone else than the current partner) intended to reflect a hidden sociosexual desire and it is rated on an 8-point ascending heterogeneous scale, from 1 (never) to 8 (at least once a day). Items 5–7 reflect sociosexual attitudes towards casual sex (of the respondent-self and other people/in general; all three are similar but item 7 is formulated with reverse meaning from the remaining two items) and are rated on a 9-point Likert scale from 1 (strongly disagree) to 9 (strongly agree). From the answers to these 7 items, the sociosexuality score (SOI) is calculated according to the formula SOI = (5 × item 1) + (1 × item 2) + (5 × item 3) + (4 × item 4) + [2 × (aggregate of items 5, 6 and reverse values of item 7)]. Despite fact that the final SOI score represents discrete values the scale usually represents relatively wide range of values from a methodologically given lower border to a variable upper tail. Technical Note: In the original publication of SOI method (Simpson and Gangestad 1991) the principle of combination of the last three items of the inventory is described by the term "aggregate". In our opinion, this means "sum", in fact. However, in many studies after the original one, other authors used a procedure of averaging (in fact the arithmetic mean). This is probably true also for the comparative study of many human populations by Schmitt (2005) which involves the only available comparative data on SOI for Czech and Slovak populations known to us. This was the reason we also computed the combination of the last component (attitudes) of the SOI scores as the mean and not a sum.

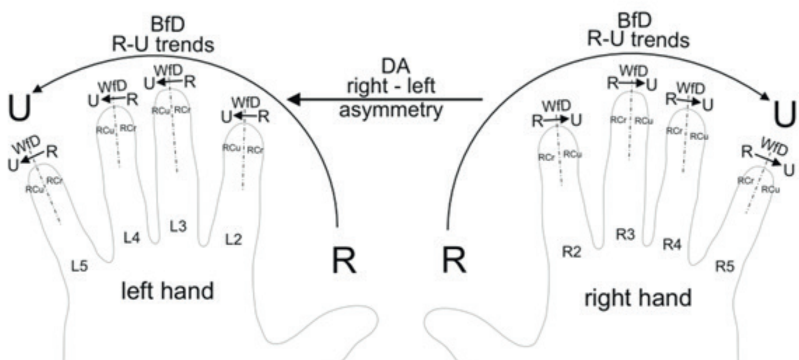

Fig. 1. Studied variables. Schematic illustration of studied positions and ridge-count variables on the human hands: right (R2 – R5) and left (L2 – L5) hand fingers, RCr (radial ridge count) and RCu (ulnar ridge count) on each finger, WfD (within-finger difference) on each finger, BfDs (between finger differences from 2 minus 3 to 4 minus 5) on each hand, and DA (directional asymmetry, right minus left) for RCr and RCu on each finger. The diagram of the hands corresponds to the position of how the handprints look when both hands are printed on paper at the same time in the traditional way, or how we see our own hands from the dorsal side when we scan them on a desktop scanner

Dermatoglyphics

The human hands were scanned by means of 2D flatbed scanner (one type for the whole sample) into color TIFF images using a method adopted for published studies (Králík et al. 2014; 2019a). Since thumbs were recorded from the radial side on scans and their ulnar sides were mostly not available, we studied dermatoglyphic variations in the four fingers only (2nd to 5th finger).

We applied standard dermatoglyphic methodology (Cummins and Midlo 1961) as implemented in open source software *Dermatoglyphix* (Králík et al. 2017). On fingers, all dermatoglyphic points (cores and triradii) were identified according to the methodology standardized by Cummins and Midlo (1961) and subsequent variables for each fingerprint were recorded (see Figure 1 for ridge-count variables).

Number of triradii (nT)

Number of triradii representing in raw form a counting variable ranging from 0 to 2 (Supplementary materials Table S1) were analyzed in the form of two categories (nT): 1 – patterns with 1 or no triradius, 2 – patterns with 2 or more triradii. In the sense of traditional pattern classification, category 1 represents loops, tented arches and arches, i.e., less complicated configurations of ridges, while category 2 represents all whorls and composites (eventually complicated accidentals), i.e., more complex patterns.

Number of cores (nC)

Number of cores representing in raw form a counting variable ranging from 0 to 2 were analyzed in the form of two categories (nC): 1 – patterns with 1 or no core, 2 – patterns with 2 or more cores. In the sense of traditional pattern classification, category 1 represents no-core or simple core patterns (arches, tented arches, loops, simple whorls and central pockets), while category 2 represents double whorl patters (lateral pockets and twin-loops, eventually complicated accidentals with more cores). The variable hence represents a measure of complexity in the center of the pattern.

Radial ridge count (RCr)

Radial ridge count (RCr) was recorded as counted variable: count of ridges between the radial triradius and core, if both present. If a pattern had no core or triradius RCr was zero (0), if number of cores was higher than 1, the radial core (closer to radial triradius) was taken. When counting ridges, endpoints (point of core and point of triradius) were not counted following methodology by Holt (1951; 1961; 1979).

Ulnar ridge count (RCu)

Ulnar ridge count (RCu) was recorded as counted variable: count of ridges between the ulnar triradius and core, if both present. If a pattern had no core or triradius RCu was zero (0), if number of cores was higher than 1, the ulnar core (closer to ulnar triradius) was taken. For this and other ridge counts applied that when counting ridges, endpoints (point of core and point of triradius) were not counted.

Radio-ulnar difference within fingers (WfD)

Radio-ulnar difference of ridge counts within each fingerprint (WfD) was established as a difference between radial (RCr) and ulnar (RCu) ridge count (radial minus ulnar) on each finger. For both hands eight variables were computed, from L2.WfD for the left 2nd finger to

R5.WfD for the right 5th finger similarly to the approach applied in Polcerová et al. (2022a).

Radio-ulnar difference between fingers (BfD)

Radio-ulnar difference in ridge counts between fingers (BfD) was computed as a difference between ridge counts on a radial and an ulnar (radial minus ulnar) finger. In each body side (hand), this was computed for each type of ridge count (RCr, RCu) and each pair of fingers (BfDr, BfDu).

Directional asymmetry between respective fingers

Body side asymmetry (DA) was computed as right-left difference (right minus left) in each type of ridge count (DAr for RCr, DAu for RCu) between respective fingers on right and left hand.

Statistical procedures

All computations with data and statistical methods were performed in the *R software* (R Core Team 2019). Descriptive statistics were computed for each recorded variable. Sex differences in frequencies of triradii (nT) and cores (nC) were tested by means of Pearson's Chi-squared test with Yates' continuity correction. Sex differences in ridge counts (including derived variables) and SOI scores were assessed by means of two sample permutation test (with 100,000 permutes) in the R-package *EnvStats* (Millard 2013). The significance of directional asymmetry was tested by means of one sample permutation test (with 100,000 permutes) of mean DA value against zero (0).

Dermatoglyphic variables were used as independent variables (categorical or continuous factors) and SOI scores as dependent variables (effects) and we tested how SOI scores change in relation to dermatoglyphic variables. To test the effects of categorial variables (nT, nC) on SOI scores we applied two-way nonparametric analysis of variance (so called "robust analysis of variance", RAOV) was applied where obligate Euclidean distance (usual in parametric ANOVA) is replaced by a distance called Jaeckel's (1972) dispersion function based on a rank estimation (Hocking 2003; Hettmansperger and McKean 2011). This method is available for practical usage in the R-package *Rfit* (Kloke and McKean 2012).

For statistical assessment of effect of ridge counts (RCr, RCu), and variables derived from them (WfD, BfD, DA) to SOI we used the same statistical approach. Values of each ridge count variable were divided into two categories (lower, higher) with approximately same sample sizes and the effect of the categories (along sex category and interaction term) was tested by means of the RAOV. In visualization plots, mean values were estimated as Huber M-estimator with Wald-type confidence intervals and they were computed in R-package *rcompanion* (Mangiafico 2015).

Results

Sociosexuality Orientation Inventory

Mean SOI score values were 29.3 (SD = 17.8, N = 69) and 46.3 (SD = 23.8, N = 62) for females and males, respectively. The sex difference was highly statistically significant (two sample permutation test: p-value = 0). Distribution of the values of the SOI scores was not normal in either males or females. For all subsequent tests we used SOI transformed into a form of its natural logarithm (logSOI).

Table 1. Frequencies of nT and nC for each finger and sex separately. Legend: ratio – ratio between count of category 2 and 1 reflecting a proportion of more complex patterns, Chi.sq. – value of Chi-square statistics (degrees of freedom were always equal to 1), p-value – significance of the Chi-square test of the proportion between the frequencies in males and females (two sided hypotheses)

Finger	nT								nC							
	Males			Females			Chi-sq.	p-value	Males			Females			Chi-sq.	p-value
	1	2	ratio	1	2	ratio			1	2	ratio	1	2	ratio		
L2	47	15	0.32	44	22	0.50	0.893	0.34	56	6	0.11	58	8	0.14	0.025	0.87
L3	47	15	0.32	58	11	0.19	0.927	0.34	52	10	0.19	61	8	0.13	0.249	0.62
L4	44	18	0.41	47	21	0.45	0.001	0.97	59	3	0.05	61	7	0.11	0.700	0.40
L5	55	7	0.13	59	8	0.14	0.000	1.00	59	3	0.05	64	3	0.05	0.000	1.00
R2	41	20	0.49	46	20	0.43	0.012	0.91	56	5	0.09	59	7	0.12	0.026	0.87
R3	50	12	0.24	58	10	0.17	0.223	0.64	58	4	0.07	65	3	0.05	0.016	0.90
R4	30	32	1.07	37	31	0.84	0.261	0.61	59	3	0.05	64	4	0.06	0.000	1.00
R5	46	15	0.33	58	8	0.14	2.536	0.11	55	6	0.11	65	1	0.02	2.768	*0.10*

Descriptive statistics and sex differences

Frequencies of nT and nC are available in the Table 1, including results of tests for differences between frequencies in males and females. Sexes did not statistically differ in frequencies of nT and nC (except of borderline significance in nC of R5), however values of ratio between number of cases with complicated patterns (nT=2) and more simple patterns (nT=1) were always higher in males than in females in each right-hand finger (but not in the left-hand fingers). This was not found for nC.

Table 2. Descriptive statistics and sex differences in ridge counts. Descriptive parameters and tests of sex differences of ridge count variables (RCr, RCu) and within-finger ridge count differences (WfD) for each finger and sex separately; N – number of cases, Mean – arithmetic mean, SD – standard deviation, Min – minimum, Max – maximum, Med – median, Q05 – 5% quantile, Q95 – 95% quantile each finger and sex separately; ratio – ratio between count of category 2 and 1 reflecting a proportion of more complex patterns, Chi.sq. – value of Chi-square statistics (degrees of freedom were always equal to 1), p-value – significance of the Chi-square test of the proportion between the frequencies in males and females (two sided hypotheses)

	Females								Males									
Finger	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95	Sex Diff	p-value
									RCr									
L2	91	7.16	6.56	0	20	6	0	18.5	91	8.31	7.28	0	22	8	0	19	1.14	0.27
L3	81	10.62	6.87	0	24	13	0	20	89	12.22	5.82	0	24	13	0	20	1.61	0.10
L4	62	13.35	7.35	0	27	14	0	24	84	15.89	5.79	0	27	17	4	24	2.54	**0.02**
L5	71	11.59	5.87	0	22	12	2.5	20.5	78	13.35	4.83	0	24	14	5.85	21.2	1.75	**0.05**

	Females								Males									
Finger	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95	Sex Diff	p-value
									RCr									
R2	99	7.25	6.37	0	20	8	0	18	92	5.92	6.56	0	21	3	0	17.5	-1.33	0.16
R3	92	11.54	5.87	0	24	12	0	20.5	90	11.40	6.60	0	24	13	0	20.6	-0.14	0.88
R4	69	14.39	7.00	0	26	16	0	23	80	15.36	6.04	0	25	17.5	2	23	0.97	0.37
R5	73	12.41	5.58	1	23	13	3.6	20.4	79	13.11	4.43	3	22	14	6	20.1	0.70	0.39
									RCu									
L2	91	6.29	7.91	0	26	2	0	21	91	6.78	8.33	0	30	2	0	21	0.49	0.69
L3	81	2.48	5.91	0	27	0	0	17	89	2.51	5.66	0	23	0	0	15.6	0.02	0.98
L4	62	4.02	6.57	0	22	0	0	17.9	83	3.47	5.86	0	22	0	0	16.9	-0.55	0.61
L5	70	0.76	2.62	0	13	0	0	6.2	78	0.63	2.34	0	13	0	0	5.45	-0.13	0.77
R2	99	5.83	8.27	0	25	0	0	21	92	8.78	8.64	0	25	8	0	23.5	2.95	**0.02**
R3	92	2.10	6.03	0	27	0	0	18.5	60	2.40	5.98	0	23	0	0	18.6	0.30	0.74
R4	69	4.43	6.44	0	24	0	0	16.6	80	6.04	0.00	0	24	1	0	17.1	1.60	0.15
R5	72	0.86	2.83	0	15	0	0	8.45	79	1.89	4.20	0	16	0	0	12	1.02	*0.08*
									WfD									
L2	91	0.88	9.87	-24	19	0	-18	15	91	1.53	9.64	-24	22	0	-18	17	0.65	0.66
L3	81	8.14	7.43	-11	21	9	-3	18	89	9.72	6.92	-11	24	12	-3	17.6	1.58	0.15
L4	62	9.34	7.12	-2	24	9.5	-1	21	83	12.45	6.81	-10	27	14	1	23.7	3.11	**0.009**
L5	70	10.73	5.20	0	20	11	2.45	19	78	12.72	4.94	-3	23	13.5	4.85	20.2	1.99	**0.02**
R2	99	1.42	9.36	-25	19	0	-15	16	92	-2.86	9.39	-25	19	-1.5	-19	13.5	-4.28	**0.002**
R3	92	9.45	6.43	-6	22	12	-1.5	17	90	9.00	6.96	-5	21	10.5	-1.6	19	-0.45	0.66
R4	69	9.96	7.10	-7	26	9	0	22.6	80	9.33	7.01	-10	23	8	0	21	-0.63	0.59
R5	72	11.50	5.46	-1	23	11.5	2.55	19.5	79	11.23	4.92	1	22	11	2.9	20.1	-0.27	0.75

Descriptive statistics of ridge counts (Table 2) showed systematically higher values of RCr in males on the left hand and the difference was significant on the L4 an L5. On the right hand the sex differences were neither systematic nor significant. On the contrary, mean values of RCu were systematically higher in males on the right hand and the difference was significant on the R2. On the left hand the sex differences were neither systematic nor significant. On the left hand, WfD mean values were always higher in males than in females, while on the right hand, they were always higher in females. The sex difference in WfD was highest on L4 (higher in males) and R2 (higher in females) and significant on fourth and fifth finger of the left hand (L4, L5) and the second finger of the right hand (R2). No significant sex differences were found for BfD (Table 3), except for borderline significance for BfDr of R2-R4 and R2-R5 difference (higher in females) and for BfDu of R2-R3 (higher in males).

Table 3. Descriptive statistics and tests of sex differences in BfD. Descriptive parameters of between-finger ridge count differences (BfD) for each finger and sex separately; for legend see Table 2

	Females								Males									
Difference	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95	Sex Diff	p-value
BfDr																		
L2-L3	70	-2.93	6.25	-20	12	-2	-13	5	82	-4.26	7.17	-23	13	-3	-16	4.95	-1.33	0.23
L2-L4	55	-5.64	6.98	-26	12	-4	-19	2.3	79	-7.67	7.72	-27	15	-6	-21.1	2.1	-2.03	0.12
L2-L5	63	-4.37	5.99	-21	10	-4	-14.9	3.9	73	-4.96	7.42	-18	12	-5	-16.4	5.4	-0.59	0.61
L3-L4	58	-3.34	5.48	-18	13	-2	-13.3	3.15	77	-4.32	5.09	-19	9	-4	-13.2	3	-0.98	0.29
L3-L5	58	-1.64	5.67	-20	8	-0.5	-12.5	6	70	-0.43	5.76	-21	15	0	-9	8	1.21	0.24
L4-L5	58	1.72	4.73	-15	12	2.5	-5.15	8.15	69	3.16	5.05	-13	14	3	-6.6	10	1.44	0.11
R2-R3	80	-4.03	5.65	-18	8	-3	-14.1	4.05	82	-5.79	7.90	-24	15	-3	-18.9	3	-1.77	0.11
R2-R4	67	-7.52	7.00	-25	6	-7	-21	1.7	73	-9.74	7.35	-25	2	-8	-21	0	-2.22	*0.07*
R2-R5	67	-4.81	6.15	-21	10	-5	-15.4	4	68	-6.87	6.29	-19	7	-7.5	-16.7	2	-2.06	*0.06*
R3-R4	64	-3.23	5.12	-20	8	-3	-11.9	3.85	78	-4.76	5.91	-23	8	-4	-13.8	4.15	-1.52	0.11
R3-R5	62	-1.18	5.51	-16	9	-1	-12.9	6	73	-1.41	6.23	-22	8	0	-13.4	5.4	-0.23	0.83
R4-R5	58	2.03	5.01	-13	16	2	-4.3	9.45	69	2.42	5.15	-11	13	3	-6	11	0.39	0.67
BfDu																		
L2-L3	70	3.50	7.37	-11	24	0	-4.55	18	82	3.88	8.39	-20	26	0	-5.9	18.95	0.38	0.77
L2-L4	55	1.89	7.75	-16	19	0	-10.8	15.6	78	3.35	8.54	-15	24	1	-11.2	19	1.46	0.32
L2-L5	62	4.79	6.45	0	20	0.5	0	17	73	6.21	7.96	-3	30	3	0	19	1.42	0.27
L3-L4	58	-1.70	6.44	-22	18	0	-15	6.15	76	-1.70	6.29	-17	23	0	-11.3	7.25	0.00	1.00
L3-L5	57	1.56	5.11	-10	18	0	-4	12.8	70	1.23	5.30	-11	23	0	-4.1	13.1	-0.33	0.74
L4-L5	57	2.84	4.97	-4	16	0	0	12.6	68	2.72	5.15	-5	18	0	0	14.65	-0.12	0.90
R2-R3	80	4.14	7.84	-17	23	0	-2	20	82	6.37	7.97	-13	23	2.5	-0.95	19.95	2.23	*0.07*
R2-R4	67	0.90	6.86	-17	21	0	-9.4	11.7	73	1.67	9.02	-24	24	0	-11.4	16.4	0.78	0.57
R2-R5	66	5.35	8.10	-15	21	0	0	20	68	6.91	7.78	-9	24	3.5	0	20	1.56	0.26
R3-R4	64	-3.17	6.43	-17	22	0	-14.9	0	78	-4.45	6.83	-20	12	0	-16.2	3.15	-1.28	0.26
R3-R5	61	1.21	5.83	-10	23	0	-1	16	73	0.81	5.84	-13	23	0	-8.6	12.8	-0.40	0.70
R4-R5	58	4.00	5.72	0	20	0	0	15.15	69	5.32	6.53	0	24	2	0	16.6	1.32	0.23

In females, directional asymmetry (Table 4) of RCr (DAr) was on average positive (higher values on the right hand) on all fingers but the differences did not significantly differ from zero (except for borderline significance for R4-L4), while in males it was on average negative (higher values on the left hand) in all fingers and the differences were significant on the second fingers (R2-L2). In females, directional asymmetry of RCu (DAu) significantly differed from zero only on the third fingers (R3-L3), while in males the third finger was almost symmetrical but not on the remaining fingers where the DAu differed from zero (significant for R2-L2 and R4-L4 and borderline significant for R5-L5). Sex differences in DAr were negative (i.e., lower – leftward dominated RCr – in males than in females) for all four fingers, while sex differences in DAu were positive (i.e., higher – rightward dominated RCu – in males than in females) in all fingers, and these sex differences were mostly statistically significant, except for the non-significant results for the third fingers (R3-L3) and marginal result of DAu in the fifth finger (R5-L5).

Table 4. Descriptive statistics and sex differences in DA. Descriptive parameters and tests of sex differences in directional asymmetry in ridge counts (DAr, DAu) for each finger and sex separately; DA p-value – significance of the one sample permutation test between mean value of DA and zero (two-sided hypothesis); for legend see Table 2

	Females									Males										
Difference	N	Mean	SD	Min	Max	Med	Q05	Q95	DA p-value	N	Mean	SD	Min	Max	Med	Q05	Q95	DA p-value	Sex Diff	p-value
DAr																				
R2-L2	83	0.22	5.52	-12	19	0	-8.8	9.9	0.74	82	-2.18	7.64	-20	19	-1	-16	12	**0.012**	-2.40	**0.023**
R3-L3	74	0.32	4.67	-12	14	0	-7.35	7	0.57	82	-0.99	5.47	-19	13	0	-10	5	0.11	-1.31	0.11
R4-L4	56	0.95	3.89	-10	14	1.5	-6	6	*0.08*	70	-0.67	4.88	-18	7	0	-9.55	5.55	0.27	-1.62	**0.048**
R5-L5	53	0.64	3.05	-8	10	1	-3.4	4.8	0.14	68	-0.66	3.28	-11	7	-0.5	-5	4.65	0.11	-1.30	**0.028**
DAu																				
R2-L2	83	-0.34	6.73	-20	21	0	-12.8	11.8	0.66	82	2.43	7.27	-19	20	0	-6	15.95	**0.0034**	2.76	**0.012**
R3-L3	74	-1.27	5.38	-22	17	0	-12.7	0	**0.047**	82	0.01	6.27	-23	23	0	-7.95	12.7	1.00	1.28	0.18
R4-L4	56	0.68	5.12	-15	15	0	-7.5	9.25	0.34	69	2.88	6.22	-10	17	0	-7	15.6	**0.00021**	2.21	**0.036**
R5-L5	52	-0.19	2.35	-9	10	0	-2.9	0.45	0.62	68	0.79	3.29	-8	13	0	-1	9	*0.051*	0.99	*0.07*

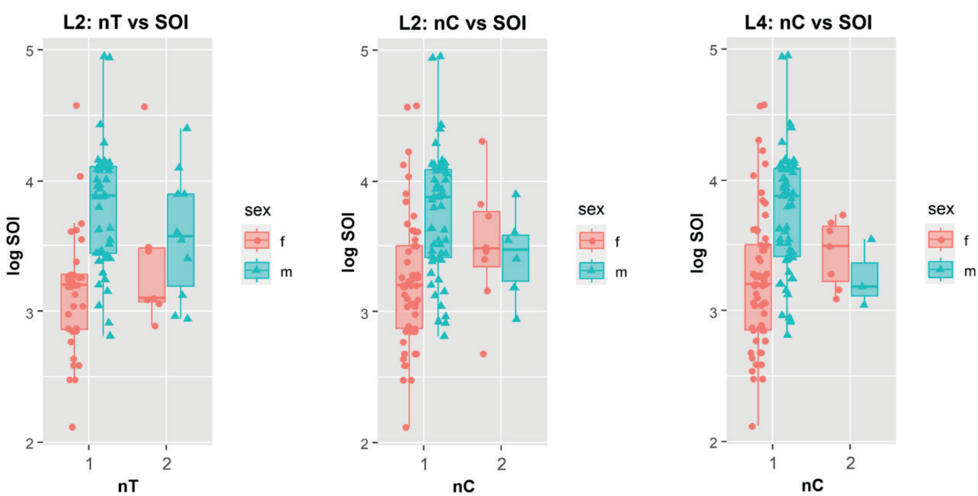

Fig. 2. Significant effects of numbers of triradii and cores. Box-plot visualization of significant effects of nT (number of triradii category) and nC (number of cores category) on logSOI in L2 and L4 fingers; log SOI – natural logarithm of SOI score, 1 – lower number of triradii or cores category, 2 – higher number of triradii or cores category, f – females (red dots), m – males (blue triangles), thick horizontal – median, boxes – lower and upper quartiles, whiskers – non outlier ranges

Relationships between SOI and numbers of triradii and cores

Robust analysis of variance found some significant effects of sex and nT and nC on sociosexuality variables (Table 5). When testing the effect of sex and nT on SOI, the effect of sex was always highly significant, which indicates systematic differences in SOI between sexes. No effects of nT were recorded in any of the fingers but significant interaction between sex and nT was found in the L2 (Figure 2). While in bearers of lower number of triradii on the L2 finger (nT=1) clear sex difference in SOI was evident, in bearers of higher number of triradii (nT=2) on L2 average sex difference was not expressed – males had on average lower SOI than those with lower number of triradii, while females had higher mean SOI than those with lower nT. Such effects were not found on the right hand.

Table 5. Results of the Robust Analysis of Variance (RAOV) for the effect of number of triradii and cores on SOI. Tests of effects of nT (nC) and sex to SOI, including interaction of both factors (nT : sex, and nC : sex); Mean RD – mean reduction in residual dispersion

	nT			sex			nT : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0674	0.313	0.6	3.6054	16.728	**0.0001**	2.2269	10.332	**0.0017**
L3	0.0049	0.020	0.9	3.9575	15.732	**0.0001**	0.2793	1.110	0.3
L4	0.0260	0.103	0.7	6.0322	23.905	**0.00001**	0.0482	0.191	0.7
L5	0.1211	0.494	0.5	2.8935	11.815	**0.0008**	0.0288	0.118	0.7
R2	0.3237	1.330	0.3	6.2225	25.568	**0.00001**	0.1727	0.710	0.4
R3	0.6591	2.818	*0.1*	3.5278	15.084	**0.0002**	0.3102	1.326	0.3
R4	0.0300	0.117	0.7	7.9123	30.842	**0.00001**	0.1156	0.451	0.5
R5	0.1252	0.470	0.5	4.1274	15.490	**0.0001**	0.0025	0.009	0.9
	nC			sex			nC : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0011	0.004	0.9	0.8397	3.530	0.06	1.4770	6.209	**0.014**
L3	0.0824	0.335	0.6	2.9651	12.040	**0.001**	0.1735	0.704	0.4
L4	0.1559	0.679	0.4	0.3935	1.713	0.2	1.4117	6.146	**0.014**
L5	0.1230	0.493	0.5	0.5452	2.184	0.1	0.3469	1.389	0.2
R2	0.1324	0.546	0.5	2.2843	9.413	**0.003**	0.0607	0.250	0.6
R3	0.4897	1.967	0.2	1.4380	5.777	**0.018**	0.0155	0.062	0.8
R4	0.0078	0.033	0.9	0.4571	1.902	0.2	0.7521	3.130	*0.1*
R5	0.1801	0.717	0.4	0.8873	3.531	0.06	0.0025	0.010	0.9

Similar results were found for nC. No simple effect of nC was found in any of the fingers, however, in L2 and L4 significant interactions of nC with sex were found, similar to the nT described above. While in cases with more obvious patterns – those with lower number of cores (nC=1) – average sex difference in SOI was clearly evident, in the group with higher number of cores (nC=2) sex difference in SOI was blurred (females have higher SOI and males lower than those typical for a given sex).

Table 6. Results of the Robust Analysis of Variance (RAOV) for the effect of ridge count on SOI. Tests of effects of ridge count variables (RCr, RCu, and WfD) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion

	RCr			sex			RCr : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0354	0.148	0.70	8.3741	35.037	**0.00001**	0.6002	2.511	0.12
L3	0.0002	0.001	0.98	4.5894	17.689	**0.0001**	0.3838	1.479	0.23
L4	0.7573	3.147	*0.08*	4.5125	18.753	**0.0001**	0.4974	2.067	0.16
L5	0.0146	0.058	0.81	4.1555	16.498	**0.0001**	0.3065	1.217	0.27
R2	0.7108	3.055	*0.08*	8.3507	35.889	**0.00001**	0.9374	4.029	**0.048**
R3	0.0532	0.199	0.66	4.5665	17.107	**0.0001**	0.5787	2.168	0.14
R4	0.0176	0.068	0.80	4.3293	16.763	**0.0001**	0.1725	0.668	0.42
R5	0.0075	0.031	0.86	4.4246	18.040	**0.0001**	0.2078	0.847	0.36
	RCu			sex			RCru : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0435	0.202	0.65	7.5957	35.309	**0.00001**	1.0380	4.825	**0.031**
L3	0.0972	0.372	0.54	3.0799	11.784	**0.001**	0.0227	0.087	0.77
L4	0.0540	0.215	0.64	3.6591	14.586	**0.0003**	0.0534	0.213	0.65
L5	0.0192	0.079	0.78	1.7089	7.043	**0.01**	0.3238	1.334	0.25
R2	0.0186	0.084	0.77	7.7769	34.884	**0.00001**	0.2853	1.280	0.26
R3	0.3725	1.363	0.25	1.9502	7.134	**0.0091**	0.0001	0.000	0.99
R4	0.1306	0.522	0.47	5.1347	20.545	**0.00001**	0.6090	2.437	0.12
R5	0.0000	0.000	1.00	1.0912	4.507	**0.038**	0.0014	0.006	0.94
	WfD			sex			WfD : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.1147	0.543	0.46	8.5122	40.316	**0.00001**	1.1944	5.657	**0.019**
L3	0.0136	0.051	0.82	4.2212	15.735	**0.0002**	0.2777	1.035	0.31
L4	0.6735	3.021	*0.09*	3.8188	17.133	**0.0001**	0.7448	3.342	*0.07*
L5	0.0760	0.290	0.59	4.2065	16.039	**0.0002**	0.1904	0.726	0.40
R2	0.1215	0.525	0.47	8.0434	34.759	**0.00001**	0.6001	2.593	0.11
R3	0.0707	0.273	0.60	4.0687	15.732	**0.0002**	1.0722	4.146	**0.045**
R4	0.5411	2.124	0.15	4.2232	16.575	**0.0001**	0.0162	0.064	0.80
R5	0.0803	0.340	0.56	4.7632	20.174	**0.00001**	0.2057	0.871	0.35

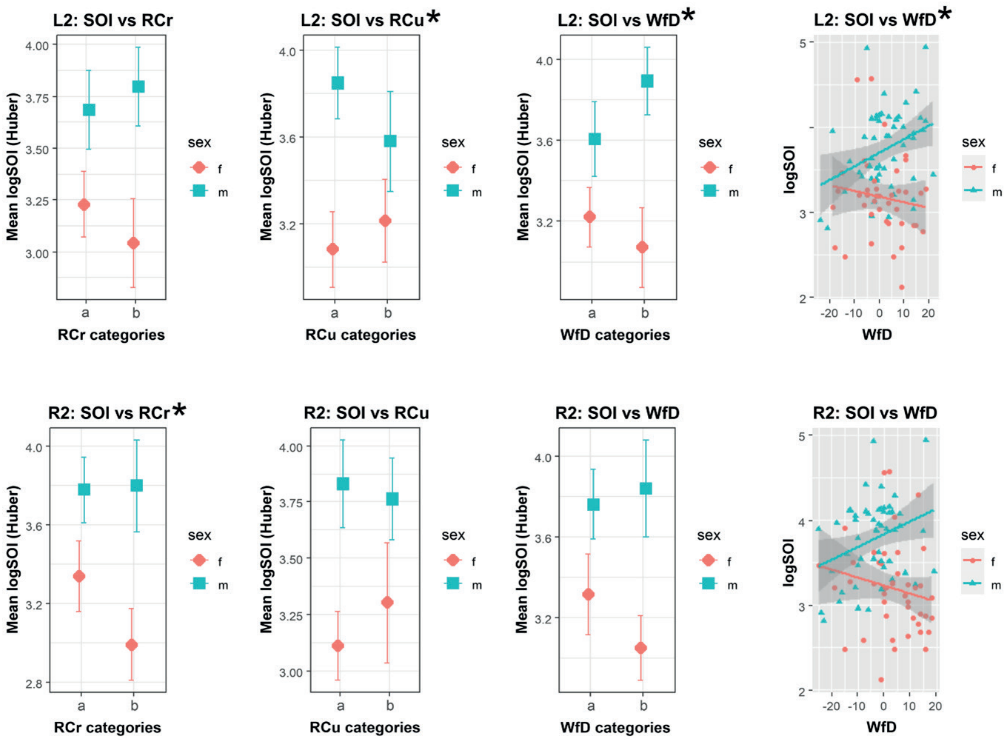

Fig. 3. Significant effects of ridge counts. Plots of effects of RCr, RCu, and WfD categories on logSOI in the second finger (L2 and R2); first three left columns: Huber mean estimates (females – red dots, males – blue squares) augmented with Wald type 95% confidence intervals, a – lower values category, b – higher values category; right column: identical data in raw values of WfD for a comparison (females – red dots, males – blue triangles, lines – ordinary linear least squares regression models, shadow zones – 95% confidence intervals), asterisks – significant interaction between sex and dermatoglyphic variable

Relationships between SOI and ridge counts and within-finger differences in ridge counts

In all tests (Table 6), sex again revealed significant effect on SOI while RCr revealed only borderline effect on L4 (p-value =0.08). However, significant interaction between sex and RCr was found for R2 – the higher was RCr, the higher was SOI difference between sexes. Similarly, significant interaction between sex and RCu was found on L2 for RCu. As can be seen in Figure 3, in both hands, effects of RCu and RCr are similar, but opposite in their direction, which, in connection of both, creates a radioulnar continuum. This is well expressed in WfD variables and more visible on several fingers and significant interactions between WfD and sex was found both on L2 and R2.

Relationships between SOI and between-finger differences in ridge counts

None of the tested relationships between RCr BfDs and SOI was statistically significant (Table 7), except for borderline significance – p-value=0.0951 – of the interaction of both factors (sex : BfD) in L3-L4 difference. In RCu BfD, significant interactions of factors (sex : BfD) on SOI were found in L2-L4 and R3-R4 differences (Figure 4). Similarly, to the WfDs, the higher was the between-finger differences in RCu on the above-mentioned pairs of fingers, the less typical (lower in males and higher in females) the SOI was (Figure 4).

Table 7. Results of the Robust Analysis of Variance (RAOV) for the effect of BfDs on SOI. Tests of effects of between-finger RC differences (BfDr and BfDu) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion; NA – not available (numerical condition not met)

	BfDr			sex			BfDr : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2-L3	0.0358	0.1381	0.7114	4.9372	19.0572	**0.00001**	0.0000	0.0000	1.0000
L2-L4	0.0000	0.0000	1.0000	3.0192	12.3281	**0.0009**	0.0069	0.0283	0.8671
L2-L5	0.1149	0.4624	0.4993	5.0780	20.4311	**0.00001**	0.0549	0.2208	0.6403
L3-L4	0.0721	0.2536	0.6166	3.6202	12.7266	**0.0008**	0.8213	2.8874	*0.0951*
L3-L5	0.1625	0.6994	0.4073	3.9136	16.8401	**0.0002**	0.4473	1.9249	0.1720
L4-L5	0.5128	2.6216	0.1124	5.0871	26.0088	**0.00001**	0.0025	0.0125	0.9114
R2-R3	0.0125	0.0486	0.8262	5.5452	21.5011	**0.00001**	0.2177	0.8442	0.3613
R2-R4	0.0032	0.0129	0.9101	4.1369	16.6641	**0.0001**	0.4128	1.6628	0.2023
R2-R5	0.4118	1.8841	0.1757	3.6669	16.7793	**0.0001**	0.1330	0.6086	0.4388
R3-R4	0.1871	0.6760	0.4143	2.8806	10.4054	**0.0021**	0.0016	0.0058	0.9397
R3-R5	0.2286	0.9324	0.3390	2.8953	11.8087	**0.0012**	0.0003	0.0011	0.9736
R4-R5	0.0769	0.4116	0.5242	5.6775	30.3920	**0.00001**	0.2436	1.3040	0.2591
	BfDu			sex			BfDu : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2-L3	0.1018	0.4082	0.5251	4.6857	18.7803	**0.0001**	0.3351	1.3432	0.2506
L2-L4	0.6057	2.6901	0.1067	3.9779	17.6682	**0.0001**	1.7632	7.8316	**0.0071**
L2-L5	0.0069	0.0305	0.8621	5.2166	23.0112	**0.00001**	0.6944	3.0632	*0.0856*
L3-L4	0.0990	0.3856	0.5373	2.2959	8.9400	**0.0042**	0.0231	0.0898	0.7656
L3-L5	0.4797	1.9548	0.1688	1.1382	4.6382	**0.0365**	0.0868	0.3537	0.5549
L4-L5	0.0188	0.0766	0.7832	4.8364	19.6977	**0.0001**	0.2972	1.2105	0.2771

Table 7 (cont.)

	BfDu			sex			BfDu : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-R3	0.0159	0.0654	0.7990	4.9122	20.2178	**0.00001**	0.0185	0.0763	0.7832
R2-R4	0.5835	2.3458	0.1310	3.9917	16.0473	**0.0002**	0.0105	0.0422	0.8380
R2-R5	0.1366	0.6327	0.4299	5.7145	26.4600	**0.00001**	0.1119	0.5180	0.4749
R3-R4	0.0141	0.0525	0.8196	3.4616	12.9299	**0.0007**	1.1326	4.2306	**0.0442**
R3-R5	NA	NA	NA	NA	NA	NA	NA	NA	NA
R4-R5	0.0107	0.0494	0.8250	6.0558	28.0016	**0.00001**	0.4206	1.9448	0.1696

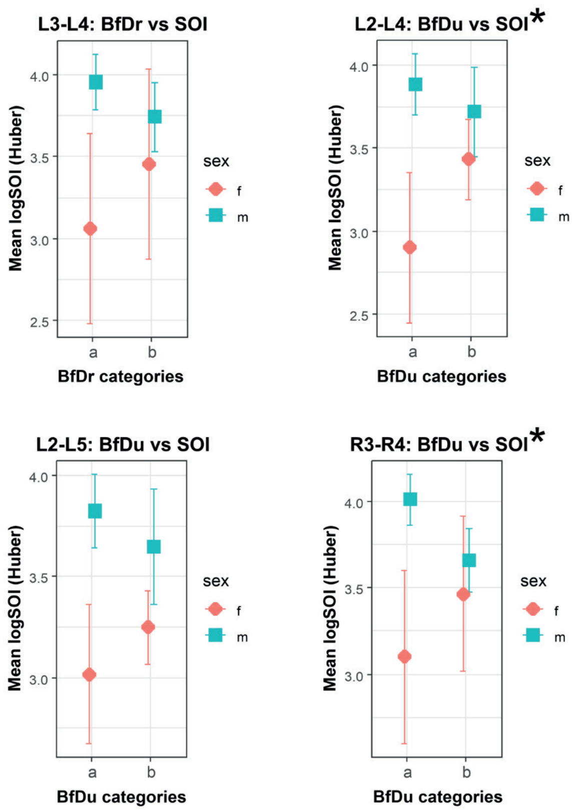

Fig. 4. Significant effects between fingers. Plots of effects of BfD (between-finger differences in ridge count) categories on logSOI the specified finger pair; Huber mean estimates (females – red dots, males – blue squares) augmented with Wald type 95% confidence intervals, a – lower values category, b – higher values category

Relationships between SOI and directional asymmetry in ridge counts

When studying relationships between directional asymmetry (Table 8) of ridge counts and SOI, a statistically significant interaction between the effect of sex and DAr was found on the third fingers (DAr R3-L3), along with borderline significance of interaction between the effect of sex and DAu on third fingers (DAr R3-L3). In both effects, cases with more rightward dominated asymmetry (both DAr and DAu) had more typical sex differences in SOI (higher values in males and lower in females) while leftward asymmetrical patterns belonged to cases in which the sex differences in SOI disappeared.

Table 8. Results of the Robust Analysis of Variance (RAOV) for the effect of DA on SOI. Tests of effects of directional asymmetry (DAr and DAu) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion

	DAr			sex			DAr : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-L2	0.1584	0.7157	0.4001	8.20195	37.0688	**0.00001**	0.1146	0.5179	0.4739
R3-L3	0.2949	1.1475	0.2880	3.4734	13.5140	**0.0005**	1.8598	7.2361	**0.0090**
R4-L4	0.0147	0.0599	0.8077	2.2046	9.0085	**0.0043**	0.3599	1.4707	0.2313
R5-L5	0.0124	0.0549	0.8159	4.3975	19.5095	**0.0001**	0.0875	0.3880	0.5367
	DAu			sex			DAu : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-L2	0.1527	0.6748	0.4138	6.7970	30.0330	**0.00001**	0.0464	0.2049	0.6520
R3-L3	0.0150	0.0528	0.8190	3.0840	10.8790	**0.0016**	0.1064	0.3754	0.5422
R4-L4	0.1759	0.7206	0.4002	3.2135	13.1687	**0.0007**	0.8570	3.5121	*0.0672*
R5-L5	0.0851	0.3769	0.5426	1.8100	8.0122	**0.0071**	0.0320	0.1416	0.7086

Discussion

Main recorded effects

In this study, we attempted to search for dermatoglyphic correlates of human sociosexuality. Inspired with previous promising indications of validity of within-individual (between-fingers) contrast in searching for sex differences (Polcerová et al. 2023; 2022a) and environmental factors (Kahn et al. 2001; 2008) we tested several types within-individual dermatoglyphic differences (within fingers, between-finger within-hand, and between-finger between-hand asymmetry) and their effect on log(SOI) score values. Recorded SOI scores and their sex differences were in congruence with previously published studies for Czech and Slovak population samples (Ingrová et al. 2018; Schmitt 2005). Also, dermatoglyphic variation in pattern frequencies and ridge count values did not exceed obvious limits of typical human variations. Therefore, our analyses are based on common and in no way exceptional data.

We found that males with more complex patterns on the second finger tended to occupy the lower part of the male SOI score distribution, while the opposite was true for females. Other results showed something similar for differences in the number of ridges within and between fingers on (mostly) L2 and L4: the more radial the contrast, the more blurred the sex difference was due to the shift of SOI scores to lower values in males and to higher values in females. Therefore, some sort of mechanism connects dermatoglyphics on fingers with SOI but remarkably often (though not exclusively), the 2nd and 4th fingers appeared in various dermatoglyphic features in which a significant effect was found. This applies both for sex differences and relationships with SOI. A unique nature of the 2nd finger was recognized for a long time in dermatoglyphics since it bears one order (or even more) higher frequencies of radially oriented patterns, mostly radial loops and whorls with radial within-pattern asymmetry compared to other fingers (Cummins and Midlo 1961: 67). The second finger is therefore the most variable finger of all in respect to the complexity and radio-ulnar variation of dermatoglyphic patterns it bears. This underlies a relatively wide range of variations that can express an influence of ontogenetic factors. The 4th finger bears relatively high proportion of central pocket patterns (Cummins and Midlo 1961) – their variable within-finger asymmetry also allows relatively wide variation of within-pattern radioulnar differences.

Interpretation of the results

It has been suggested that dermatoglyphics is associated with sex-specific behavior based on the fact that the brain and dermatoglyphics arise from the same prenatal ectoderm and that nerve cell migration occurs at the time epidermal ridges are formed (Fatjó-Vilas et al. 2008; Vonk et al. 2014). Therefore, prenatal factors, both genetic and environmental, could simultaneously affect both structures – dermatoglyphics and brain substrate for a behavior – and consequently lead to their nonrandom associations. Although other associations between dermatoglyphics and psychological features have been found (Akbarova 2018) our study is the only one known to us where association between SOI and dermatoglyphics has been detected. From the prevalent involvement of the 2nd and 4th fingers we cannot avoid an impression that the results describe an analogous situation to one that can be found in the ratio between the length of the 2nd and 4th fingers, or digit ratio, which is widely studied as a putative marker of prenatal sex steroids (recently e.g., Kasielska-Trojan et al. 2024).

In dermatoglyphics, males have usually on average more complex patterns on fingers (higher nT and nC) and larger patterns (Cummins and Midlo 1961:273), which means higher Total Finger Ridge Count (TFRC) (Holt 1961; 1979). If testosterone is the main factor of masculinization of these dermatoglyphic features and, at the same time, is also responsible for masculinization of brain dispositions for sociosexuality, increasing "masculinity" of the dermatoglyphic features should be positively correlated with increasing "masculinity" (higher scores) of SOI. Our result for numbers of triradii and cores are in congruence with this potential explanation in females but not in males where the opposite is true. It is difficult to discuss a congruence of our results of the ridge-count features (quantitative features) with assumptions about prenatal testosterone and ridge count, since most frequently published TFRC results are sums of ridge counts of all ten fingers and variations between individual fingers as well as within fingers is lost/dissolved in these summary variables (Jantz 2022; Polcerová et al. 2022a). From the published studies, we found no clue or assumption about the possible relationship of RCu or WfD with TFRC. So, we are not able to predict from the previously published studies if the correlation of e.g. RCu on L2 and SOI scores should be expected to be mild or strong, positive or negative. Changes in average radioulnar within-finger asymmetries compared to healthy population is frequently on the list of dermatoglyphic markers of genetic diseases. The frequency of radial loops is increased in many genetic syndromes and their abundance can be shifted to other than the 2^{nd} finger, e.g., in Down syndrome frequently to the 4^{th} finger (Schaumann and Alter 1976: 55), in trisomy of the chromosome 18 to the first, third and fifth fingers (Schaumann and Alter 1976: 165).

We can hypothesize that except for serious pathological variations in dermatoglyphic patterns related to genetic syndromes or harsh environmental factors, radioulnar and body side variation in dermatoglyphic features vary more inconspicuously due to less serious ontogenetic factors even within normal range of variation in an otherwise healthy population. Unfortunately, radio-ulnar asymmetry of whorl patterns is rarely expressed in results of studies following traditional dermatoglyphic methodology. Therefore, in our opinion, many effects related to radio-ulnar asymmetries within fingers remained obscured. The only possible clue can be the frequencies of *radial loops* – their frequencies on 2^{nd} fingers are traditionally published and their abundance on other fingers are so small that even without dividing results into individual fingers frequencies of radial loops in total of all ten fingers (in normal healthy population) reflect almost exclusively the second fingers. However, we found only one study which put radial loops in relation with steroid hormones. In a study of 54 males with sex hormones anomalies (Al-Jumaily et al. 2010), increased frequency of radial loops was found in the studied group compared to controls. Unfortunately, no detailed description of etiologies of these "hormonal anomalies" was available in this study so we cannot discuss it further. Since hormonal anomalies in males are mostly characterized by lower levels of steroid hormones (rather than higher), we can assume that higher frequencies of radial loops were found in a group of subjects with prevalently lower steroid levels which would be in congruence with our results (low WfD related to low SOI) in males. This does not agree, however, with our results in females but these were not involved in the discussed study (Al-Jumaily et al. 2010).

Directional/side asymmetry (right-left) in our sample is in congruence with previous studies (Kunter and Rühl 1995) – males in our sample were generally more asymmetrical than females, except for the third finger which is more symmetrical (in males DA for RCu was effectively zero). However, the male asymmetry was opposite on both sides of fingers – RCr in males was leftward asymmetrical while RCu was rightward asymmetrical. In males, the most asymmetrical RCr were on the second fingers and RCu on the 2^{nd} and the 4^{th} fingers. In females the asymmetry was lower and differently structured between fingers. However, highest sex differences in the side asymmetry were on the 2^{nd} and 4^{th} fingers both for RCr and RCu. Previous studies found a relationship between right-left directional asymmetry of dermatoglyphic

TFRC (i.e., size of patterns and prevalence of large patterns – mostly whorls) and sex-dimorphic cognitive tasks (brain lateralization); the more right directed asymmetry – the better scoring in male-favoring tasks (Kimura and Carson 1995; Kimura and Clarke 2001; Sanders et al. 2002). In our sample and methodology, however, relationships between SOI and DA were different in different fingers (and radial vs. ulnar finger sides) and not significant, except for significant interaction between asymmetry of radial ridge–count on the 3rd finger which was in congruence with the above-mentioned principle (more masculine with more right-directed values) only in males, but not females.

Since we are not aware of any study focusing on the relationship between sociosexuality and dermatoglyphics, we can only compare our results with studies of the relationship between SOI and the 2D:4D ratio (which is *de facto* a radioulnar contrast of the lengths of the respective fingers). Clark (2004) in his second study found a negative correlation between 2D:4D ratio and SOI on both the right and left hands in women (consistent with the prediction from the considered effect of prenatal androgenization), the relationship was statistically significant on the right hand only. He found a similarly significant relationship in his 3rd study (Clark 2004). In a study by Charles and Alexander (2011), in males, SOI did not correlate with the 2D:4D ratio on either the right or left hand (but correlation coefficient values were positive and higher for the left). In females the correlation was significant but positive (the more feminine digit ratio the higher SOI) which contradicts the prediction from the theory of prenatal androgenization. In women in study by DeLecce et al. (2014), SOI did not correlate with the 2D:4D ratio on either the right or left hand. Therefore, the results of these studies (Clark 2004; Charles and Alexander 2011; DeLecce et al. 2014) do not show a clear relationship between 2D:4D ratio and SOI logically predictable by the theory of prenatal androgenization. This is also true more generally for the relationship between 2D:4D ratio and sex-typicality in behavior which has also been discussed previously in some studies (Cohen-Bendahan et al. 2005; Wong and Hines 2016). As in these studies, we can now only speculate that the differences in the results may be due to differences in the relative timing of hand and brain development between the two sexes, body sides, and different human populations. Some studies show a greater effect of androgens on the right side of the body than the left, as well as stronger relationships between behaviors with 2D:4D ratios on the right hand than on the left (e.g., Manning et al. 1998). Studies of ridge-count radioulnar contrasts clearly show significantly greater and more consistent dimorphism on the right hand compared to the left (Polcerová et al. 2022a; 2022b; Polcerová et al. 2023). Our present study of the relationship between radioulnar contrasts and SOI, similar to the 2D:4D ratio studies mentioned above) also suggests ambiguity about which side of the body has a stronger relationship with SOI, but the sense of that relationship is consistent across both hands (see further discussion of stress).

Since direct effects of doses of genes in sex chromosomes was accepted as the cause of dimorphism in dermatoglyphics (Penrose 1967), an alternative explanation of the relationships between dermatoglyphics and SOI as found in our study could be explained exclusively on the genetic level. Some gene variants could predispose their bearers both to specific SOI and, as a side effect, specific dermatoglyphics. Recently, several particular genes have been specified directly (Ho et al. 2016) at the molecular level to be involved in specific finger dermatoglyphics, especially the gene ADAMTS9-AS2 (chromosome 3, locus 3p14.1) was identified as important in the formation of *whorl patterns* (i.e., patterns prevailing in subject with SOI not typical for a given sex). However, relationship of this gene with whorls were recognized not only for the 2nd finger but for other fingers (except for the thumb) and, thus, it does not explain our results dominated with effects on the 2nd and 4th fingers. Moreover, since this gene (and most of other genes recognized as significant in the cited study (Ho et al. 2016)) is not located on sex chromosomes we cannot avoid the need for an additional explanation why the effect of dermatoglyphics on SOI is opposite in each sex. It needs to be clarified whether the same genes also play a role in brain development (and functioning) of neuronal circuits regulating sociosexuality. Since Bailey et al. (2000) found relatively strong within-family additive genetic components in sociosexuality while little effect of shared environmental component on sociosexuality was observed, further searching for common molecular-genetic factors of whorls patterns on fingers and sociosexuality is a potential option.

Finally, we can open another interpretation line concerning prenatal stress. It is well known that prenatal stress and/or various disruptors of prenatal development can compromise fully/optimal expression of many developing processes (Gluckman and Hanson 2006), including testosterone levels and sex differences of stress effects (e.g. Barrett et al. 2014). In rats, for instance, prenatal stress during the late gestational period can lead to demasculinization of male sexual behavior in adulthood (Coll-Andreu et al. 1989; Velazquez-Moctezuma et al. 1993) and masculinization in behavior of affected females (Del Cerro et al. 2015; Kinsley and Bridges 1988). These studies in recent years have flourished within the frame of DOHaD concept (Developmental Origins of Health and Disease) also in humans. For instance, prenatal exposure to *phenol* was negatively associated with umbilical cord serum levels of testosterone (Liu et al. 2016), and, similarly, maternal urinary level of bisphenol A was negatively associated with the left hand 2D:4D ratio of their daughters (Guo et al. 2021). We can therefore assume, that various environmental insults can, more or less – on a continuous scale compromise the sex-typical levels of testosterone (and more generally – typical genes – steroid hormones milieu and interactions for a given sex) and coping with and/or adaptation to these changes might include complex shifts both in morphology and behavior. We can notice only one example of an old evidence mentioned by Cummins and Midlo for two different previously published populations – for associations between dermatoglyphics and schizophrenia which offered results similar to ours for SOI: while typical sex differences in whorls patterns frequencies were found in controls, in schizophrenic patients sex differences were blurred – in males whorl frequencies were lower and in females they were higher (Cummins and Midlo 1961:277). A similar pattern is represented by the effect of birth order (the increase of which can be understood as a worsening of complex prenatal conditions) on the 2D:4D ratio (Králík et al. 2019a), where the greatest dimorphism was observed in first-borns, and as birth order increased (in secondborns and third and higher-borns), there was an increase (feminization) of the 2D:4D ratio in males and a decrease (masculinization) of the 2D:4D ratio in females, which blurred to completely reversed the sexual dimorphism of this trait. Thus, we can speculate that our results of the relationship between dermatoglyphic radioulnar contrasts and SOI show something similar: under normal conditions, a typical dermatoglyphic dimorphism is established while simultaneously setting up a disposition for sex-typical sociosexuality. Alteration of typical prenatal hormone levels for a given sex (e.g., due to stress) alters the timing of fetal pad development on hands and feet, resulting in altered dermatoglyphic traits on them (larger patterns and negative radioulnar contrasts) and concomitant lack of dimorphism in SOI in this group.

Limitations of the study

One of the limitations of our study is the sample size. Despite original sample size (N=180), readability of the dermatoglyphic patterns and/or especially the individual ridges for ridge-counting was limited in some fingers due to sweat produced by skin during scanning and/or excessive pressure imposed to fingers. In a combination with missing data in SOI (all 7 items should be filled for SOI score, which was not always the case) the final sample size in most of the comparisons was usually lower than one hundred subjects.

The results of our study are limited only to this within-population variation and should not be applied to other populations without caution. Human populations differ both in the radioulnar tendencies of the dermatoglyphic patterns on fingers (e.g., in frequencies of radial loops) and SOI scores and there is absolutely no certainty that these within-population relationships apply also in a between-population comparison. In other words, we cannot say that a difference in WfD on the L2 between two populations would be followed with the same change of SOI like the same change of WfD between two groups within our studied population.

Another limitation of our study is the unavailability of data from the 1st finger due to method of hand scanning. The one-off nature of the examination of the volunteers did not allow us to undergo repeated measurements (hand scanning and imprinting) and proceed SOI assessment. Finally, we have not found any reference study of SOI in relationship with dermatoglyphics so far, so we cannot compare our result with any other study.

Conclusions

In our study we found that relationships between finger dermatoglyphics and SOI exist. As hypothesized, these relationships manifested also in radioulnar ridge-count differences (radioulnar contrasts), but not in their whole spectrum. Relationships were observed only in some of the differences related to specific fingers, mostly in the 2nd and 4th fingers. Whatever prenatal factors are involved in the SOI dispositions they should be also somehow involved in development of fetal volar pads and specific coincidence of their regression with onset of histological differentiation of primary dermal ridges (Mulvihill and Smith 1969; Kücken 2007).

Additional information

Supplementary materials [online version].

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Conflict of interests

The authors declare no conflict of interests.

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Authors' contribution

Pavlína Ingrová: study design and conception, data collection, data analysis, manuscript preparation; Miroslav Králík: study design and conception, funding, data analysis, manuscript preparation; Lenka Polcerová: data analysis, manuscript preparation; Věra Pavlíková: data collection, manuscript preparation; Ondřej Klíma: software development, manuscript preparation; Martin Čuta: data analysis, manuscript preparation.

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References

Akbarova SN. 2018. Dermatoglyphics can be as method of behavior genetics. GESJ Educ Sci Psychol. 4(50):26–37.

Al-Jumaily RMK, Lafta FM, Al-Dahiri LKI, Fadhil LZ. 2010. Digital dermatoglyphic characteristics in patients with sex hormones anomalies. J Al-Nahrain Univ. 13(2):164–9. https://doi.org/10.22401/JNUS.13.2.21

Alter M. 1965. Is Hyperploidy of Sex Chromosomes Associated with Reduced Total Finger Ridge Count? Am J Hum Genet. 17(6):473–75.

Arnold AP. 2014. Conceptual frameworks and mouse models for studying sex differences in physiology and disease: Why compensation changes the game. Exp Neurol. 259:2–9. https://doi.org/10.1016/j.expneurol.2014.01.021

Babler WJ. 1991. Embryologic Development of Epidermal Ridges and Their Configurations. Birth Defects Orig. Artic. Ser. 27(2):95–112.

Bailey JM, Kirk KM, Zhu G, Dunne MP, Martin NG. 2000. Do individual differences in sociosexuality represent genetic or environmentally contingent strategies? Evidence from the Australian twin registry. J Pers Soc Psychol. 78(3):537–45. https://doi.org/10.1037/0022-3514.78.3.537

Barrett ES, Parlett LE, Redmon JB, Swan SH. 2014. Evidence for sexually dimorphic associations between maternal characteristics and anogenital distance, a marker of reproductive development. Am J Epidemiol. 179(1):57–66. https://doi.org/10.1093/aje/kwt220

Börger D, Held KR, Lüttgen S. 1986. Dermatoglyphics in Congenital Adrenal Hyperplasia (CAH). Clin Genet. 30(3):173–6. https://doi.org/10.1111/j.1399-0004.1986.tb00591.x

Bracha HS, Torrey EF, Bigelow LB, Lohr JB, Linington BB. 1991. Subtle signs of prenatal maldevelopment of the hand ectoderm in schizophrenia: A preliminary monozygotic twin study. Biol Psychiatry 30(7):719–25. https://doi.org/10.1016/0006-3223(91)90017-G

Charles NE, Alexander GM. 2011. The Association Between 2D:4D Ratios and Sociosexuality: A Failure to Replicate. Arch Sex Behav. 40(3):587–95. https://doi.org/10.1007/s10508-010-9715-z

Clark AP. 2004. Self-perceived attractiveness and masculinization predict women's sociosexuality. Evol Hum Behav, 25(2):113–24. https://doi.org/10.1016/S1090-5138(03)00085-0

Cohen-Bendahan CCC, van de Beek C, Berenbaum SA. 2005. Prenatal sex hormone effects on child and adult sex-typed behavior: Methods and findings. Prenat Program Behav Physiol Cogn. 29(2):353–84. https://doi.org/10.1016/j.neubiorev.2004.11.004

Coll-Andreu M, Ayora-Mascarell L, Trullas-Oliva R, Morgado-Bernal I. 1989. Behavioral evaluation of the stress induced by the platform method for short-term paradoxical sleep deprivation in rats. Brain Res Bull. 22(5): 825–28. https://doi.org/10.1016/0361-9230(89)90025-7

Cummins H, Midlo C. 1961. Finger prints, palms and soles. New York: Dover Publications, Inc.

Del Cerro MCR, Ortega E, Gómez F, Segovia S, Pérez-Laso C. 2015. Environmental prenatal stress eliminates brain and maternal behavioral sex differences and alters hormone levels in female rats. Horm Behav. 73:142–47. https://doi.org/10.1016/j.yhbeh.2015.07.004

DeLecce TL, Polheber JP, Matchock RL. 2014. Sociosexual Orientation and 2D:4D Ratios in Women: Relationship to Men's Desirability Ratings as a Long-Term Pair Bond. Arch Sex Behav. 43(2):319–27. https://doi.org/10.1007/s10508-013-0201-2

Fatjó-Vilas M, Gourion D, Campanera S, Mouaffak F, Levy-Rueff M, Navarro ME, Chayet M, Miret S, Krebs MO, Fañanás L. 2008. New evidences of gene and environment interactions affecting prenatal neurodevelopment in schizophrenia-spectrum disorders: A family dermatoglyphic study. Schizophr Res. 103(1–3):209–17. https://doi.org/10.1016/j.schres.2008.04.015

Gluckman PD, Hanson MA editors. 2006. Developmental origins of health and disease. New York: Cambridge University Press.

Golembo-Smith S, Walder DJ, Daly MP, Mittal VA, Kline E, Reeves G, Schiffman J. 2012. The presentation of dermatoglyphic abnormalities in schizophrenia: A meta-analytic review. Schizophr Res. 142(1–3):1–11. https://doi.org/10.1016/j.schres.2012.10.002

Green R, Young R. 2000. Fingerprint asymmetry in male and female transsexuals. Personal Individ Differ. 29(5): 933–42. https://doi.org/10.1016/S0191-8869(99)00244-5

Guo J, Wu C, Zhang J, Li W, Lv S, Lu D, Qi X, Feng C, Liang W, Chang X, Zhang Y, Xu H, Cao Y, Wang G, Zhou Z. 2021. Prenatal exposure to multiple phenolic compounds, fetal reproductive hormones, and the second to fourth digit ratio of children aged 10 years in a prospective birth cohort. Chemosphere 263:127877. https://doi.org/10.1016/j.chemosphere.2020.127877

Hall JAY, Kimura D. 1994. Dermatoglyphic Asymmetry and Sexual Orientation in Men. Behav Neurosci. 108(6):1203–6. http://dx.doi.org/10.1037/0735-7044.108.6.1203

Hall LS. 2000. Dermatoglyphic Analysis of Total Finger Ridge Count in Female Monozygotic Twins Discordant for Sexual Orientation. J Sex Res. 37(4):315–20. https://doi.org/10.1080/00224490009552053

Hettmansperger TP, McKean JW. 2011. Robust Nonparametric Statistical Methods. 2nd edition. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Ho YYW, Evans DM, Montgomery GW, Henders AK, Kemp JP, Timpson NJ, St Pourcain B, Heath AC, Madden PAF, Loesch DZ, McNevin D, Daniel R, Davey-Smith G, Martin NG, Medland SE. 2016. Genetic variant influence on whorls in fingerprint patterns. J Invest Dermatol. 136(4):859–62. https://doi.org/10.1016/j.jid.2015.10.062

Hocking RR. 2003. Methods and Applications of Linear Models. 2nd edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

Holt SB. 1951. The Correlation Betwen Ridge-counts on Different Fingers. Ann Eugen. 16(1):287–97. https://doi.org/10.1111/j.1469-1809.1951.tb02481.x

Holt SB. 1961. Quantitative genetics of finger-print patterns. Br Med Bull. 17(3):247–50.

Holt SB. 1979. Epidermal Ridge-counts. Coll Antropol. 3(1):97–106.

Ingrová P, Králík M, Bártová V, Jandová M, Daňko M, Skalická E. 2018. Sociosexualita mladých dospělých: Změny v 21. Století, vliv pohlaví a sexuální orientace. Čes Antropol. 68(1–2):18–34.

Jantz RL. 2022. Finger ridge-counts correlate with the second to fourth digit ratio (2d:4d). Am J Hum Biol. 34(2): e23625. https://doi.org/10.1002/ajhb.23625

Jantz RL, Hunt DR. 1986. The influence of sex chromosomes on finger dermatoglyphic patterns. Ann Hum Biol. 13(3):287–95. https://doi.org/10.1080/03014468600008461

Kahn HS, Graff M, Stein AD, Lumey LH. 2009. A fingerprint marker from early gestation associated with diabetes in middle age: The Dutch Hunger Winter Families Study. Int J Epidemiol. 38(1):101–09. https://doi.org/10.1093/ije/dyn158

Kahn HS, Graff M, Stein AD, Zybert PA, McKeague IW, Lumey LH. 2008. A fingerprint characteristic associated with the early prenatal environment. Am J Hum Biol. 20(1):59–65. https://doi.org/10.1002/ajhb.20672

Kahn HS, Ravindranath R, Valdez R, Narayan KMV. 2001. Fingerprint Ridge-Count Difference between Adjacent Fingertips (dR45) Predicts Upper-Body Tissue Distribution: Evidence for Early Gestational Programming. Am J Epidemiol. 153(4):338–44. https://doi.org/10.1093/aje/153.4.338

Kasielska-Trojan A, Manning JT, Kałuża M, Głowacka E, Antoszewski B. 2024. First trimester maternal sex steroids and the digit ratios of mothers and children. Early Hum Dev. 195:106067. https://doi.org/10.1016/j.earlhumdev.2024.106067

Kimura D, Carson MW. 1995. Dermatoglyphic asymmetry: Relation to sex, handedness and cognitive pattern. Personal Individ Differ. 19(4):471–78. https://doi.org/10.1016/0191-8869(95)00076-I

Kimura D, Clarke PG. 2001. Cognitive pattern and dermatoglyphic asymmetry. Personal Individ Differ. 30(4):579–86. https://doi.org/10.1016/S0191-8869(00)00056-8

Kinsley CH, Bridges RS. 1988. Prenatal stress and maternal behavior in intact virgin rats: Response latencies are decreased in males and increased in females. Horm Behav. 22(1):76–89. https://doi.org/10.1016/0018-506X(88)90032-3

Kloke JD, McKean JW. 2012. Rfit: Rank-based estimation for linear models. R J. 4(2):57–64. https://doi.org/10.32614/RJ-2012-014

Králík M, Hupková A, Zeman T, Hložek M, Hlaváček L, Slováčková M, Čuta M, Urbanová P. 2019a. Family effects on the digit ratio (2D:4D): The role of the interbirth interval. Am J Hum Biol. 31(4): e23260. https://doi.org/10.1002/ajhb.23260

Králík M, Katina S, Urbanová P. 2014. Distal Part of the Human Hand: Study of Form Variability and Sexual Dimorphism Using Geometric Morphometrics. Anthropol Integra 5(2):7–25. https://doi.org/10.5817/AI2014-2-7

Králík M, Klíma O, Polcerová L. 2017. Dermatoglyphix 1.0. Software. [English; Windows]. Masaryk University, Faculty of Science, Department of Anthropology. LaMorFA. http://www.sci.muni.cz/lamorfa/veda-a--vyzkum#projekty

Králík M, Polcerová L, Čuta M. 2019b. Sex Differences in Frequencies of Dermatoglyphic Patterns by Individual Fingers. Ann Hum Biol. 46(3):231–45. https://doi.org/10.1080/03014460.2019.1622778

Kunter M, Rühl M. 1995. Seiten- und Geschlechtsunterschiede quantitativer Hautleistenbefunde der Fingerbeeren bei einer mitteleuropäischen Stichprobe (Grießen, Hessen). Anthropol Anz. 53(1):79–90.

Kücken M. 2007. Models for fingerprint pattern formation. Forensic Sci Int. 171(2–3):85–96. https://doi.org/10.1016/j.forsciint.2007.02.025

Lippa RA. 2007. The relation between sex drive and sexual attraction to men and women: A cross-national study of heterosexual, bisexual, and homosexual men and women. Arch Sex Behav. 36(2):209–22. https://doi.org/10.1007/s10508-006-9146-z

Lippa RA. 2009. Sex Differences in Sex Drive, Sociosexuality, and Height across 53 Nations: Testing Evolutionary and Social Structural Theories. Arch Sex Behav. 38(5):631–51. https://doi.org/10.1007/s10508-007-9242-8

Liu C, Xu X, Zhang Y, Li W, Huo X. 2016. Associations between maternal phenolic exposure and cord sex hormones in male newborns. Hum Reprod. 31(3):648–56. https://doi.org/10.1093/humrep/dev327

Loesch DZ. 1983. Quantitative dermatoglyphics – classification, genetics, and pathology. Oxford: Oxford University Press.

Lyons MJ, Koenen KC, Buchting F, Meyer JM, Eaves L, Toomey R, Eisen SA, Goldberg J, Faraone SV, Ban RJ, Jerskey BA, Tsuang MT. 2004. A Twin Study of Sexual Behavior in Men. Arch Sex Behav. 33(2):129–36. https://doi.org/10.1023/B:ASEB.0000014327.11433.66

Mangiafico SS. 2015. An R Companion for the Handbook of Biological Statistics. Version 1.3.8, revised 2023. http://rcompanion.org/rcompanion/index.html

Manning JT. 2002. Digit Ratio: A Pointer to Fertility, Behavior, and Health. New Jersey: Rutgers University Press.

Manning JT, Scutt D, Wilson J, Lewis-Jones DI. 1998. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. Hum Reprod. 13(11):3000–04.

Millard SP. 2013. EnvStats: An R Package for Environmental Statistics. Springer.

Mitsui T, Araki A, Miyashita C, Ito S, Ikeno T, Sasaki S, Kitta T, Moriya K, Cho K, Morioka K, Kishi R, Shinohara N, Takeda M, Nonomura K. 2016. The Relationship between the Second-to-Fourth Digit Ratio and Behavioral Sexual Dimorphism in School-Aged Children. *PLOS ONE* 11(1):e0146849. https://doi.org/10.1371/journal.pone.0146849

Mitsui T, Araki A, Miyashita C, Ito S, Ikeno T, Sasaki S, Kitta T, Moriya K, Cho K, Morioka K, Kishi R, Shinohara N, Takeda M, Nonomura K. 2019. Effects of prenatal sex hormones on behavioral sexual dimorphism. Pediatr Int. 61(2):140–46. https://doi.org/10.1111/ped.13756

Mulvihill JJ, Smith DW. 1969. The genesis of dermatoglyphics. J Pediatr. 75(4):579–89. https://doi.org/10.1016/S0022-3476(69)80453-1

Mustanski BS, Bailey M, Kaspar S. 2002. Dermatoglyphics, Handedness, Sex, and Sexual Orientation. Arch Sex Behav. 31(1):113–22. https://doi.org/10.1023/a:1014039403752

Penke L, Asendorpf J. 2008. Beyond Global Sociosexual Orientations: A More Differentiated Look at Sociosexuality and Its Effects on Courtship and Romantic Relationships.

J Pers Soc Psychol. 95(5):1113–35. https://doi.org/10.1037/0022-3514.95.5.1113

Penrose LS. 1963. Finger-Prints, Palms and Chromosomes. Nature 197(4871):933–38. https://doi.org/10.1038/197933a0

Penrose LS. 1967. Finger-print pattern and the sex chromosomes. The Lancet 289(7485): 298–300. https://doi.org/10.1016/S0140-6736(67)91237-8

Polani PE, Polani N. 1979. Dermatoglyphics in the testicular feminization syndrome. Ann Hum Biol. 6:417–30. https://doi.org/10.1080/03014467900003811

Polcerová L, Chovancová M, Králík M, Beňuš R, Klíma O, Meinerová T, Čuta M, Petrová ME. 2022a. Radioulnar contrasts in fingerprint ridge counts: Searching for dermatoglyphic markers of early sex development. Am J Hum Biol. 34(5):e23695. https://doi.org/10.1002/ajhb.23695

Polcerová L, Jantz RL, Králík M, Chovancová M, Čuta M. 2023. Sex differences in radioulnar contrasts of the finger ridge counts across 21 human population samples. Ann Hum Biol. 50(1):370–89. https://doi.org/10.1080/03014460.2023.2247970

Polcerová L, Králík M, Meinerová T, Chovancová M, Čuta M. 2022b. Meta-analysis of radioulnar contrasts in dermatoglyphic ridge-counts between individual fingers. Anthropol Integra 13(1):39–52. https://doi.org/10.5817/AI2022-1-39

Puts DA, Pope LE, Hill AK, Cárdenas RA, Welling LLM, Wheatley JR, Breedlove SM. 2015. Fulfilling desire: Evidence for negative feedback between men's testosterone, sociosexual psychology, and sexual partner number. Horm Behav. 70:14–21. https://doi.org/10.1016/j.yhbeh.2015.01.006

Qazi QH, Thompson MW. 1971. Dermatoglyphics in Congenital Virilizing Adrenal Hyperplasia. Am J Dis Child. 122(1):28–30. https://doi.org/10.1001/archpedi.1971.02110010064009

R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. https://www.R-project.org/

Sanders G, Sjodin M, de Chastelaine M. 2002. On the elusive nature of sex differences in cognition: Hormonal influences contributing, to within-sex variation. Arch Sex Behav. 31(1):145–52. https://doi.org/10.1023/A:1014095521499

Schaumann B, Alter M. 1976. Dermatoglyphics in Medical Disorders. New York-Heidelberg-Berlin: Springer-Verlag.

Schmitt DP. 2005. Sociosexuality from Argentina to Zimbabwe: A 48-nation study of sex, culture, and strategies of human mating. Behav Brain Sci. 28(2):247–75. https://doi.org/10.1017/S0140525X05000051

Schwidetzky I, Jantz RL. 1977. Rassenunterschiede der Geschlechtsdifferenzierung von Hautleistenmerkmalen. Mitteilungen Anthropol Ges Wien 107:182–87.

Schwidetzky I, Jantz RL. 1979. Race differences in the sex dimorphism of dermatoglyphic traits. J Hum Evol. 8(8):773–76. https://doi.org/10.1016/0047-2484(79)90006-X

Simpson J, Gangestad S. 1991. Individual differences in sociosexuality: Evidence for convergent and discriminant validity. J Pers Soc Psychol. 60(6):870–83. https://doi.org/10.1037/0022-3514.60.6.870

Slabbekoorn D, van Goozen SHM, Sanders G, Gooren LJG, Cohen-Kettenis PT. 2000. The dermatoglyphic characteristics of transsexuals: Is there evidence for an organizing effect of sex hormones. Psychoneuroendocrinology 25(4):365–75. https://doi.org/10.1016/S0306-4530(99)00063-3

van Anders SM, Hamilton LD, Watson NV. 2007. Multiple partners are associated with higher testosterone in North American men and women. Horm Behav. 51(3):454–59. https://doi.org/10.1016/j.yhbeh.2007.01.002

Velazquez-Moctezuma J, Salazar ED, Cruz Rueda ML. 1993. The effect of prenatal stress on adult sexual behavior in rats depends on the nature of the stressor. Physiol Behav. 53(3):443–48. https://doi.org/10.1016/0031-9384(93)90137-5

Vonk R, van der Schot AC, van Baal GCM, van Oel CJ, Nolen WA, Kahn RS. 2014. Dermatoglyphics in relation to brain volumes in twins concordant and discordant for bipolar disorder. Eur Neuropsychopharmacol. 24(12):1885–95. https://doi.org/10.1016/j.euroneuro.2014.09.010

Wong WI, Hines M. 2016. Interpreting digit ratio (2D:4D)–behavior correlations: 2D:4D sex difference, stability, and behavioral correlates and their replicability in young children. Horm Behav. 78:86–94. https://doi.org/10.1016/j.yhbeh.2015.10.022

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The Association of Body Temperature with Longevity: Insights from Historical Cohorts

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Abstract: Effective thermoregulation is crucial for maintaining homeostasis. Previous research has suggested a link between lower steady-state body temperature and longevity, particularly in physically healthy, non-obese older adults. However, the exact mechanisms behind this relationship remain unclear. Despite the physiological insights gained from studies on body temperature, limited attention has been given to its potential role as a biomarker of longevity in physically healthy older populations. This study aimed to evaluate the relationship between body temperature and longevity using historical data from two cohorts. The longitudinal cohort consisted of 142 individuals, followed for 25 years beginning at age 45, while the cross-sectional cohort included 204 individuals stratified into four lifespan categories. To examine age-related trends in body temperature, Page's test was employed, and ordinal regression was used. The analysis revealed a significant decrease in body temperature in women with age, while men showed no significant change. The cross-sectional analysis indicated a trend toward lower body temperatures in individuals with longer lifespans. Lower body temperature may reflect a reduced metabolic rate, thereby mitigating oxidative stress and molecular damage, both of which are known to drive aging and limit lifespan. Furthermore, lower body temperatures may signal a favorable inflammatory profile, which could translate into slower aging and increased survival. However, the observed sex-specific differences in thermoregulatory patterns raise important questions about the role of hormonal influences, such as estrogen levels. Overall, these findings suggest that lower lifetime steady-state body temperature may be a biomarker of healthy aging and longevity, warranting further exploration of its mechanistic underpinnings.

Key words: age, aging, biomarker, body temperature, lifespan, longevity, survival

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Introduction

Identifying reliable biomarkers of healthy aging and longevity is one of the central challenges in biogerontology and medical research (Martin-Ruiz et al. 2011; Dodds et al. 2014; Arai et al. 2015; Sayer and Kirkwood 2015; Chen et al. 2016; Davis et al. 2016; Ferrucci et al. 2018; Levine et al. 2018; Smith et al. 2019; Guerville et al. 2020; He et al. 2024). Among the various candidates, core body temperature stands out as an intriguing and potentially informative biomarker (Conti 2008; Lehmann et al. 2013; Keil et al. 2015), as studies have associated lower temperatures with longer lifespan and higher temperatures with shorter lifespan in diverse species, including animal models of aging (e.g., *Caenorhabditis elegans*, *Drosophila melanogaster*, and mice) as well as humans (Rikke and Johnson 2004; Waalen and Buxbaum 2011; Palani et al. 2023 Chmielewski et al. 2025). Reflecting the delicate equilibrium between heat production and dissipation, body temperature not only underpins homeostatic control but also encapsulates the cumulative effects of metabolic, immunological, and environmental influences on aging organisms (Roth et al. 2002; Ruggiero et al. 2008; Åström et al. 2011; Soare et al. 2011; Keil et al. 2015; Geneva et al. 2019; Lee et al. 2023; Kowald et al. 2024; Li et al. 2024).

In healthy individuals, body temperature follows a circadian rhythm, typically reaching its lowest point in the early morning and peaking in the late afternoon. Such diurnal fluctuations underscore the importance of considering the timing of temperature measurements, as sporadic readings may fail to capture the basal set point that is critical for assessing long-term health and survival (Simonsick et al. 2016). The distinction between adaptive and maladaptive alterations in body temperature is further highlighted by the differential responses seen in hyperthermia versus fever. Hyperthermia is characterized by an excessive accumulation of heat that overwhelms the body's dissipative mechanisms, which is harmful to health. In contrast, fever is a regulated increase in the body's temperature set point, which is orchestrated by endogenous pyrogens such as interleukins (e.g., IL-1, IL-6, and IL-8), interferons (e.g., interferon-γ), tumor necrosis factor-β etc., in response to infectious or inflammatory stimuli. The fever response represents an adaptive strategy that evolved to combat pathogens and increase survival.

Previous studies have suggested that lower basal body temperature may be a biomarker of healthy aging and greater longevity, particularly in physically healthy, non-obese older adults (Waalen and Buxbaum 2011; Simonsick et al. 2016; Chmielewski et al. 2025). However, this association remains understudied in the Polish population, and it is unclear whether reduced core temperature directly influences longevity or simply serves as a surrogate marker for other health-promoting processes. Enhanced immune responses, decreased chronic low-grade systemic inflammation (CLSI), and the absence of disease or infirmity may all contribute to a reduced temperature profile, which could also correlate with longevity benefits in the elderly population (Franceschi and Campisi 2014; Nilsson et al. 2014; Proctor et al. 2015; Chmielewski et al. 2016; Chmielewski and Strzelec 2018; Ferrucci and Fabbri 2018).

One should consider whether there are factors and mechanisms that underlie the association between lower lifetime steady-state body temperature and extended longevity, and, if so, identify what they are. For instance, the phenomenon of lower body temperature has been closely linked with caloric restriction (CR), which is a well-established intervention that promotes longevity across a range of species (Colman et al. 2009; Fontana et al. 2010; Anderson and Weindruch 2010; Chmielewski 2017; 2020; Picca et al. 2017; Campisi et al. 2019; Dorling et al. 2020; Speakman 2020; Giacomello and Toniolo 2021; Hoong and Chua 2021; Sultanova et al. 2021; Waziry et al. 2023; Di Francesco et al. 2024; Greenhill 2024). CR is known to induce a metabolic shift characterized by reduced energy expenditure and improved physiological efficiency, which is often accompanied by a modest decline in core temperature (Carrillo and Flouris 2011).

Furthermore, subclinical conditions such as endocrine disorders, latent infections (e.g., tuberculosis, hepatitis B and C, and HIV), autoimmune disorders (e.g., lupus), as well as insulin resistance, metabolic dysregulation, and type 2 diabetes mellitus, have been linked to elevated body temperature and reduced survival. Moreover, unhealthy lifestyle factors, including chronic psychological stress, long-term alcohol consumption, and inadequate sleep, can lead to changes in inflammatory cytokines and white blood cell counts (Mullington et al. 2010; Knutson 2012; Chen et al. 2024). Conversely, progressive sarcopenia and atherosclerosis—conditions commonly observed in older adults—can lead to a decline in body temperature, but they are also associated with increased cardiovascular risk and premature mortality (Barquera et al. 2015; Herrington et al. 2016; Agnelli et al. 2020; Bayraktar et al. 2020; He et al. 2021).

Despite the physiological insights gained from studies on body temperature (Lu et al. 2010; Obermeyer et al. 2017; Diamond et al. 2021), little attention has been devoted to its potential role as an independent biomarker of longevity in physically healthy older populations. Most clinical measurements of body temperature are conducted during acute illness or hospitalization, which restricts our understanding of its normative patterns in the context of longevity among community-dwelling older adults. This gap is especially pronounced in historical cohorts, where comprehensive longitudinal data are extraordinarily scarce. Consequently, key questions regarding the typical profiles of core body temperature and their association with reliable markers of survival (e.g., inflammatory biomarkers and epigenetic 'clocks') in long-lived versus short-lived individuals remain largely unexplored.

This study aims to address this gap by analyzing both longitudinal and cross-sectional data to investigate whether lower body temperature is associated with greater longevity in physically healthy older adults within the Polish population.

Materials and methods

Study Population

The study adhered to the principles of the Declaration of Helsinki. Archival clinical data from physical examinations at the Mental Health Center in the vicinity of Zielona Góra, Lubuskie Province, Poland, were used for this research. Ethical approval for the study was granted by the institutional review board in 2007 as part of a doctoral research project. All medical records were anonymized to protect patient confidentiality and subsequently used to construct a comprehensive database incorporating both longitudinal and cross-sectional data.

The longitudinal cohort comprised 142 residents (68 men and 74 women), who were monitored continuously from ages 45 to 70 years. These individuals reached the age of 70 years, after which their outcomes were not further tracked. The cross-sectional cohort consisted of 204 individuals, including 98 men and 106 women, who were assessed during periodic clinical examinations at multiple intervals. These participants were stratified into four lifespan categories based on death certificates: (1) short lifespan: 15 men (aged 50–58 years, mean age 53 years) and 12 women (aged 50–58 years, mean age 53 years), (2) medium lifespan: 26 men (aged 58–65 years, mean age 63 years) and 30 women (aged 58–65 years, mean age 63 years), (3) long lifespan: 42 men (aged 65–72 years, mean age 68 years) and 40 women (aged 65–72 years, mean age 68 years), and (4) very long lifespan: 15 men and 24 women (aged 76+). The short lifespan category included only individuals who lived significantly below their life expectancy at birth ($< e_0$), while the medium and long lifespan categories contained individuals with life expectancies close to e_0. The very long lifespan category exclusively included individuals who surpassed 76 years, thus exceeding the e_0 threshold.

Physiological Measurements

Sublingual body temperature (°C) was measured monthly under clinical conditions using a standard thermometer with 0.1°C accuracy. All measurements were taken systematically by trained medical personnel in standardized conditions at the same medical institution, typically in the morning. This study used only averaged data derived from 60 measurements per 5-year period for each individual in the longitudinal cohort, resulting in 300 measurements per person over the entire study period.

In the cross-sectional cohort, each individual contributed at least several dozens of measurements. These rigorous data collection practices ensured statistical robustness. Comprehensive details regarding the study cohorts, including the daily routines of patients and medical staff, as well as the data collection procedures, have been documented in previous publications (Borysławski et al. 2015; Chmielewski et al. 2015; 2016; 2017; 2025).

Statistical Analysis

To calculate reliable estimates of central tendency and variability, we aggregated frequently repeated measurements for each participant, including arithmetic means, medians, percentiles, and standard deviations (SDs). This approach minimized variability and enhanced the reliability of the findings. The normality of data distribution was tested with the Shapiro-Wilk test (Shapiro and Wilk 1965). The significance level was set at 0.05.

To examine whether a trend exists in body temperature with age, Page's test (Page 1963) was employed. This test serves as an alternative to Friedman's test and has greater statistical power. The null hypothesis in Page's test, similar to Friedman's test, assumes equality among the measures of central tendency across all analyzed groups. However, the alternative hypothesis in Page's test differs from that in Friedman's test. It posits that for the measures of central tendency in n studied groups—$\theta_1, \theta_2, \theta_3, \ldots, \theta_n$—the following sequence of inequalities holds: $\theta_1 \leq \theta_2 \leq \theta_3 \leq \ldots \leq \theta_n$, with at least one strict inequality. This implies the presence of an increasing trend in the measures of central tendency. In the present analysis, this would correspond to an increase in the median values of the studied variables across successive age groups: 45, 50, 55, 60, 65, and 70 years.

Ordinal regression was conducted using the Cumulative Link Model (CLM), which accounts for covariates and provides a robust framework for modeling ordinal outcomes. All statistical analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Longitudinal Cohort

The normality of data distribution was confirmed by the Shapiro-Wilk test ($p > 0.05$). In men, no significant change in body temperature was observed over the study period (Table 1, Fig. 1), as Page's test did not reveal any significant increasing or decreasing trend in body temperature for men (test statistic = 4965.5; $p = 0.692$). In contrast, for women, Page's test identified as significant decreasing trend (test statistic = 5876; $p < 0.05$), indicating a significant decline in body temperature associated with aging (Table 2, Fig. 1).

Table 1. Basic descriptive statistics of age-related changes in body temperature in the longitudinal data for men who were examined for 25 years, starting from age 45 onwards

Age	Men					
	Min	Q_1	Median	Q_3	Max	Mean ± SD
45	36.0	36.4	36.6	36.7	37.2	36.6 ± 0.2
50	36.2	36.5	36.6	36.6	37.0	36.6 ± 0.2
55	36.0	36.5	36.6	36.7	37.0	36.6 ± 0.2
60	36.3	36.5	36.6	36.7	37.0	36.6 ± 0.2
65	36.2	36.5	36.6	36.7	36.9	36.6 ± 0.2
70	36.0	36.4	36.6	36.7	37.2	36.6 ± 0.1

Table 2. Basic descriptive statistics of age-related changes in body temperature in the longitudinal data for women who were examined for 25 years, starting from age 45 onwards

Age	Women					
	Min	Q_1	Median	Q_3	Max	Mean ± SD
45	35.8	36.4	36.5	36.6	37.0	36.5 ± 0.3
50	36.0	36.4	36.5	36.6	36.9	36.5 ± 0.2
55	36.0	36.5	36.6	36.6	36.9	36.6 ± 0.2
60	36.2	36.5	36.6	36.6	36.9	36.6 ± 0.2
65	36.2	36.5	36.6	36.7	37.0	36.6 ± 0.2
70	36.2	36.5	36.6	36.8	37.1	36.6 ± 0.2

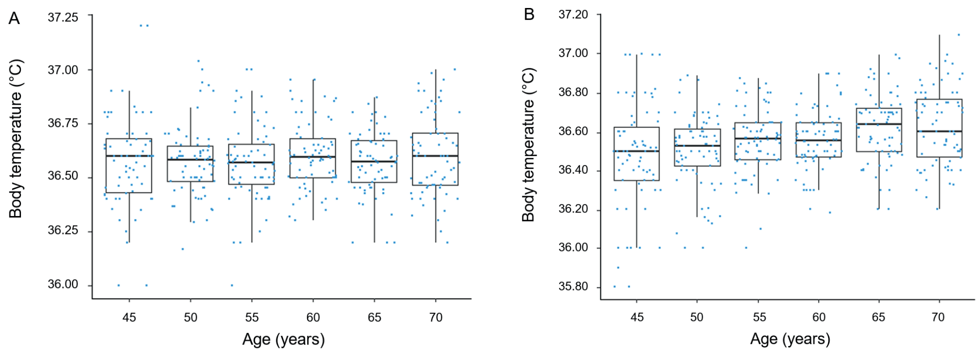

Fig. 1. Age-related trends in body temperature for men (panel A) and women (panel B) based on longitudinal data, stratified into six consecutive age categories. In the box-and-whisker plots, the bold line within each box represents the median, while the lower and upper edges denote the first and third quartiles, respectively. Whiskers extend to the most extreme values within 1.5 times the interquartile range from the quartiles, and values beyond this range are plotted as outlier points

Cross-Sectional Cohort

The basic descriptive statistics for men and women in the cross-sectional cohort are summarized in Tables 3 and 4, respectively. Age-related changes in measures of central tendency, along with standard deviations across consecutive lifespan categories, are presented in Fig. 2. The cross-sectional analysis revealed a trend toward lower body temperatures in long-live men and women, but it was statistically non-significant ($p > 0.05$). The results of the CLM analysis for men and women are provided in Table 5.

Table 3. Basic descriptive statistics of survival-related changes in body temperature in the cross-sectional data for men who were examined for several years until their death

Lifespan category	Men					
	Min	Q_1	Median	Q_3	Max	Mean ± SD
Short	36.3	36.4	36.7	36.8	36.9	36.6 ± 0.2
Medium	36.0	36.5	36.6	36.6	36.8	36.5 ± 0.2
Long	36.2	36.5	36.5	36.6	37.0	36.5 ± 0.2
Very long	36.0	36.4	36.6	36.6	36.7	36.5 ± 0.2

Table 4. Basic descriptive statistics of survival-related changes in body temperature in the cross-sectional data for women who were examined for several years until their death

Lifespan category	Women					
	Min	Q_1	Median	Q_3	Max	Mean ± SD
Short	36.0	36.5	36.6	36.8	36.9	36.6 ± 0.2
Medium	36.3	36.5	36.6	36.7	37.0	36.6 ± 0.2
Long	36.0	36.5	36.5	36.6	37.0	36.5 ± 0.2
Very long	36.0	36.5	36.6	36.7	36.8	36.5 ± 0.2

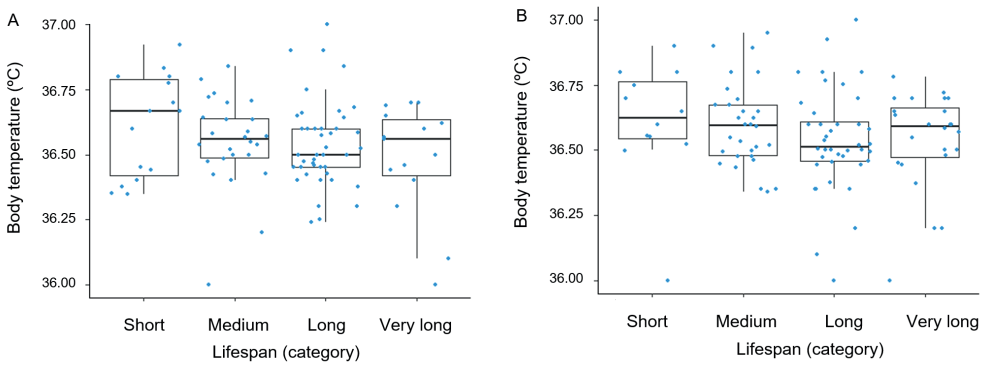

Fig. 2. Survival-related trends in body temperature for men (panel A) and women (panel B) based on cross-sectional data, stratified into four lifespan categories. In the box-and-whisker plots, the bold line within each box represents the median, while the lower and upper edges denote the first and third quartiles, respectively. Whiskers extend to the most extreme values within 1.5 times the interquartile range from the quartiles, and values beyond this range are plotted as outlier points

Table 5. Cumulative Link Model (CLM) outcomes in both sexes

Sex	Estimate	Standard Error	z-value	Pr (>|z|)	Odds Ratio	2.5%	97.5%
Men	−1.892	1.086	−1.742	0.0815	0.1508	0.0172	1.236
Women	−1.486	0.948	−1.568	0.1169	0.2262	0.0344	1.442

Discussion

This study builds on previous research investigating the relationship between resting body temperature and longevity (Chmielewski et al. 2015; 2025) by analyzing historical data from long-term residents of the same mental health center. The findings offer novel insights into the association between body temperature and long-term survival. Specifically, the analysis revealed sex-specific differences in long-term trends, warranting further investigation into the link between lower body temperature and increased longevity.

The longitudinal analysis showed that body temperature declined with advancing age in women, while no significant age-related trend was observed in men. Similarly, the cross-sectional data, which categorized individuals by lifespan, revealed a downward trend, with older individuals tending to have lower body temperatures compared to those with shorter lifespans. Although this difference did not reach statistical significance, it suggests a potential trend worthy of further exploration. For instance, it was claimed that because women generally have a higher body temperature than men—and yet consistently outlive them—it is unlikely that core body temperature affects longevity (see Introduction). However, studies have shown that women have only a slightly higher body temperature than men (approximately 0.5 °C, largely attributable to temperature fluctuations during the menstrual cycle, which diminish after menopause), and our analysis clearly demonstrated that during the study period—between the ages of 45 and 70—a statistically significant reduction in body temperature occurred in women but not in men. Thus, since only women experienced a significant reduction in body temperature while living longer, the notion that core body temperature does not affect human longevity becomes less tenable.

This serves as an example of the challenges in redefining classical models and views on aging in light of emerging experimental evidence (Chmielewski 2017; 2020). One classical theory on the evolution of aging is the Disposable Soma Theory of Aging (DSTA), formulated by Thomas Kirkwood (1977), which posits that aging evolved as a byproduct of natural selection due to an evolutionary trade-off between resources allocated to somatic maintenance and sexual reproduction—that is, the more an organism invests in sexual reproduction, the less is available for somatic maintenance, and *vice versa* (Kirkwood and Holliday 1979; Kirkwood and Rose 1991; Drenos and Kirkwood 2005). This influential, mathematically rigorous, and elegant theory holds that our bodies can be considered as disposable 'containers' for our genes and that, beyond an 'essential lifespan' (roughly between 35 and 45 years), they begin to deteriorate because evolution did not expect them to function indefinitely or much longer than this critical period, e.g., due to the selection shadow (Chmielewski 2017; 2019).

Although alternative models have been proposed (Maklakov and Chapman 2019; Speakman 2020; Carlsson et al. 2021; Gems 2022; Lemaître et al. 2024; Mitchell et al. 2024), including markedly different perspectives (Longo et al. 2005; Longo and Anderson 2022), the DSTA remains one of the more robust and influential frameworks in current biogerontology (Jasienska 2009; Hammers et al. 2013; Ziomkiewicz et al. 2016; Jasienska et al. 2017; Collins et al. 2023). Indeed, the DSTA can help elucidate our findings: despite investing more in sexual reproduction, women still live longer than men. Furthermore, the higher core body temperature that women experience during their fertile period (e.g., due to hormonal changes during the menstrual cycle) may represent one example of the biological costs of reproduction that women incur. Taken together, these findings suggest that lower lifetime steady-state body temperature may be associated with increased longevity. This finding is in agreement with previous studies (Rikke and Johnson 2004; Waalen and Buxbaum 2011; Simonsick et al. 2016; Palani et al. 2023 Chmielewski et al. 2025).

We hypothesize that a lower body temperature may reflect a reduced basal metabolic rate (BMR), which is a condition that has been associated with decreased production of reactive oxygen species (ROS) and a consequent reduction in cumulative molecular and cellular damage. In animal models, lower metabolic rates have been correlated with extended lifespans, positing that slower metabolic rates may help to mitigate the deleterious effects of oxidative stress. Additionally, the possibility exists that lower body temperature is indicative not only of reduced metabolic activity but also of a more favorable inflammatory profile, as elevated body temperature may signal the presence of chronic systemic inflammation, subclinical diseases, latent infections, or autoimmune processes—conditions that are known to contribute to age-related morbidity and mortality (Chmielewski 2018; Chmielewski and Strzelec 2018). Our observation that short-lived individuals tend to have higher temperatures suggests that elevated body temperature could indicate an underlying, suboptimal inflammatory state. This may predispose aging individuals to earlier mortality. Conversely, a lower body temperature in long-lived individuals could denote a more robust immune system or an absence of deleterious inflammatory activity, thereby supporting longevity.

The sex-specific divergence observed in our study enriches the discussion. Women not only displayed a significant decline in body temperature with advancing age, but they also, as other studies have shown, tend to have slightly higher baseline temperatures than men, yet women consistently outlive men (McGann et al. 1993; Chmielewski 2015; 2016; 2022; 2024; Keil et al. 2015; Chmielewski and Borysławski 2016; Baum et al. 2021; Öngel et al. 2021; Chmielewski et al. 2023). The dichotomy between the temperature trends observed in men and women raises intriguing questions about the underlying physiological mechanisms at play. It is possible that hormonal differences, variations in body composition, or disparities in the prevalence of autoimmune conditions contribute to these sex-specific patterns. For instance, the higher propensity for autoimmune disorders among women might initially elevate body temperature (Dolgin 2024). However, as adaptive mechanisms evolve, a subsequent decline might reflect a rebalancing that ultimately favors longevity. In contrast, the absence of a similar trend in men could indicate that other compensatory mechanisms, such as differences in metabolic regulation or thermogenic responses, come into play.

The interplay between body mass index (BMI), systemic inflammation, and body temperature should not be overlooked. Prior research has documented a positive association between higher BMI and increased body temperature, as well as between elevated temperature and higher mortality rates (Waalen and Buxbaum 2011; Simonsick et al. 2016; Chmielewski et al. 2025). It is plausible that individuals with a lower BMI, who may also experience reduced systemic inflammation, are more likely to exhibit a lower steady-state temperature and, consequently, a longer lifespan. This hypothesis is further bolstered by the observation that higher white blood cell counts—often reflective of ongoing inflammatory processes—are associated with poorer health outcomes in older adults (Ruggiero et al. 2007; Nilsson et al. 2014; Chmielewski 2018; Chmielewski et al. 2016; Chmielewski and Strzelec 2018). The converging lines of evidence thus suggest that a low basal temperature might be more than a passive marker of metabolic rate; it could also be a surrogate for an overall anti-inflammatory state that is conducive to healthy aging.

Notwithstanding the implications of these findings, several limitations must be acknowledged. First, the reliance on historical data from a specific institutionalized population raises questions about the generalizability of the results to the broader aging population, as clinical data may be affected by confounding variables (Chmielewski et al. 2015; 2016; 2025). Second, the cross-sectional component, while suggestive of a relationship between temperature and longevity, is inherently limited by its observational nature and the potential for confounding variables—such as undiagnosed subclinical conditions or lifestyle factors—that may not have been fully accounted for.

Despite these constraints, our study contributes to a growing body of literature that challenges traditional interpretations of age-related thermoregulatory decline. Rather than viewing lower body temperature simply as a result of diminished thermoregulatory function in the elderly, our findings raise the possibility that a lower steady-state temperature may be an adaptive trait reflecting a finely tuned balance between metabolic efficiency, immune function, and systemic inflammation. This interpretation suggests that effective interventions targeting the underlying mechanisms of aging could one day offer novel strategies for promoting longevity (Chmielewski et al. 2024; Li et al. 2024; Mahoney et al. 2024).

Future investigations should aim to clarify these relationships by employing prospective, population-based designs with rigorous standardization of temperature measurements. Such studies would benefit from the inclusion of a comprehensive set of biomarkers, including detailed assessments of metabolic rate, inflammatory mediators, and immune function, in order to disentangle the complex interdependencies underlying the observed associations. Furthermore, exploring the molecular and genetic determinants of thermoregulation across different populations could provide insight into why some individuals exhibit lower baseline temperatures and enjoy a survival advantage.

In conclusion, this study offers preliminary evidence suggesting that lower lifetime steady-state body temperature could be a biomarker of longevity. The observed trends, suggesting that long-lived individuals tend to have lower body temperature, support the hypothesis that a lower metabolic rate and reduced systemic inflammation are beneficial for survival. However, the sex-specific differences and the lack of statistically significant differences between lifespan categories caution against oversimplification and highlight the complexity of the relationship between body temperature and longevity. Our findings also emphasize the need for further research to clarify the causal pathways and potential clinical implications of these associations.

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Contributions from individual authors

PPC developed and designed the study, collected the data, performed the statistical analyses, conducted the literature search and collected all pertinent references, interpreted the results, drafted the initial version of the manuscript and all subsequent versions, as well as produced all figures and tables for this manuscript. KC planned and managed the research project, collected the data, and contributed to the critical review of the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Conflict of interest

The authors have no conflicts of interest to declare.

We certify that this manuscript represents entirely original work that has not been published previously or concurrently submitted elsewhere.

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References

Agnelli G, Belch JJF, Baumgartner I, Giovas P, Hoffmann U. 2020. Morbidity and mortality associated with atherosclerotic peripheral artery disease: A systematic review. Atherosclerosis 293:94–100. https://doi.org/10.1016/j.atherosclerosis.2019.09.012

Anderson RM, Weindruch R. 2010. Metabolic reprogramming, caloric restriction and aging. Trends Endocrinol Metab 21:134–41. https://doi.org/10.1016/j.tem.2009.11.005

Arai Y, Martin-Ruiz CM, Takayama M, Abe Y, Takebayashi T, Koyasu S, Suematsu M, Hirose N, von Zglinicki T. 2015. Inflammation, but not telomere length, predicts successful ageing at extreme old age: A longitudinal study of semi-supercentenarians. EBioMedicine 2:1549–58. https://doi.org/10.1016/j.ebiom.2015.07.029

Åström DO, Forsberg B, Rocklöv J. 2011. Heat wave impact on morbidity and mortality in the elderly population: A review of recent studies. Maturitas 69:99–105. https://doi.org/10.1016/j.maturitas.2011.03.008

Barquera S, Pedroza-Tobías A, Medina C, Hernández-Barrera L, Bibbins-Domingo K, Lozano R, Moran AE. 2015. Global Overview of the Epidemiology of Atherosclerotic Cardiovascular Disease. Arch Med Res 46:328–38. https://doi.org/10.1016/j.arcmed.2015.06.006

Baum F, Musolino C, Gesesew HA, Popay J. 2021. New Perspective on Why Women Live Longer Than Men: An Exploration of Power, Gender, Social Determinants, and Capitals. Int J Environ Res Public Health 18:661. https://doi.org/10.3390/ijerph18020661

Bayraktar E, Tasar PT, Binici DN, Karasahin O, Timur O, Sahin S. 2020. Relationship between Sarcopenia and Mortality in Elderly Inpatients. Eurasian J Med 52:29–33. https://doi.org/10.5152/eurasianjmed.2020.19214

Borysławski K, Chmielowiec K, Chmielewski P, Chmielowiec J. 2015. Zmiany z wiekiem wybranych cech antropometrycznych, fizjologicznych i biochemicznych oraz ich związek z długością życia mężczyzn i kobiet. Monographs of Physical Anthropology 2:1–224. Available at: http://antropologia.upwr.edu.pl/wp-content/uploads/mpa_vol2_2015.pdf [Accessed 11 March 2025].

Campisi J, Kapahi P, Lithgow GJ, Melov S, Newman JC, Verdin E. 2019. From discoveries in ageing research to therapeutics for healthy ageing. Nature 571:183–92. https://doi.org/10.1038/s41586-019-1365-2

Carlsson H, Ivimey-Cook E, Duxbury EML, Edden N, Sales K, Maklakov AA. 2021. Ageing as "early-life inertia": Disentangling life-history trade-offs along a lifetime of an individual. Evol Lett 5:551–64. https://doi.org/10.1002/evl3.254

Carrillo AE, Flouris AD. 2011. Caloric restriction and longevity: effects of reduced body temperature. Ageing Res Rev 10:153–62. https://doi.org/10.1016/j.arr.2010.10.001

Chen BH, Marioni RE, Colicino E, Peters MJ, Ward-Caviness CK, Tsai PC, Roetker NS, Just AC, Demerath EW, Guan W, Bressler J, Fornage M, Studenski S, Vandiver AR, Moore AZ, Tanaka T, Kiel DP, Liang L, Vokonas P, Schwartz J, Lunetta KL, Murabito JM, Bandinelli S, Hernandez DG, Melzer D, Nalls M, Pilling LC, Price TR, Singleton AB, Gieger C, Holle R, Kretschmer A, Kronenberg F, Kunze S, Linseisen J, Meisinger C, Rathmann W, Waldenberger M, Visscher PM, Shah S, Wray NR, McRae AF, Franco OH, Hofman A, Uitterlinden AG, Absher D, Assimes T, Levine ME, Lu AT, Tsao PS, Hou L, Manson JE, Carty CL, LaCroix AZ, Reiner AP, Spector TD, Feinberg AP, Levy D, Baccarelli A, van Meurs J, Bell JT, Peters A, Deary IJ, Pankow JS, Ferrucci L, Horvath S. 2016. DNA methylation-based measures of biological age: meta-analysis predicting time to death. Aging 8:1844–65. https://doi.org/10.18632/aging.101020

Chen Z, Ding C, Chen K, Lu C, Li Q. 2024. Exploring the impact of inflammatory cytokines on alcoholic liver disease: a Mendelian randomization study with bioinformatics insights into potential biological mechanisms. Am J Drug Alcohol Abuse 50:643–58. https://doi.org/10.1080/00952990.2024.2402569

Chmielewski P. 2015. Wysokość ciała i miesiąc urodzenia a długość życia osób zmarłych w Polsce w latach 2004–2008. [pdf] Doctoral dissertation. Available at: https://ruj.uj.edu.pl/server/api/core/bitstreams/1ecd8760-57c6-4e5c-8f48-7f5a7498b52c/content [Accessed 11 March 2025].

Chmielewski P. 2016. The relationship between adult stature and longevity: tall men are unlikely to outlive their short peers – evidence from a study of all adult deaths in Poland in the years 2004–2008. Anthropol Rev 79:439–60. https://doi.org/10.1515/anre-2016-0032

Chmielewski P. 2017. Rethinking modern theories of ageing and their classification: the proximate mechanisms and the ultimate explanations. Anthropol Rev 80:259–72. https://doi.org/10.1515/anre-2017-0021

Chmielewski P. 2018. Leukocyte count, systemic inflammation, and health status in older adults: a narrative review. Anthropol Rev 81:81–101. https://doi.org/10.2478/anre-2018-0007

Chmielewski PP. 2019. Human ageing, longevity and evolution: can ageing be programmed? Anthropol Rev 82:417–33. https://doi.org/10.2478/anre-2019-0032

Chmielewski PP. 2020. Human ageing as a dynamic, emergent and malleable process: from disease-oriented to health-oriented approaches. Biogerontology 21:125–30. https://doi.org/10.1007/s10522-019-09839-w

Chmielewski PP. 2022. Do taller people live longer? Evaluating the relationship between adult stature and longevity. Med J Cell Biol 10:176–83. https://doi.org/10.2478/acb-2022-0025

Chmielewski PP. 2024. The association between body height and longevity: evidence from a national population sample. Folia Morphol 83:139–45. https://doi.org/10.5603/FM.a2023.0005

Chmielewski P, Borysławski K, Chmielowiec K, Chmielowiec J. 2015. Longitudinal and cross-sectional changes with age in selected anthropometric and physiological traits in hospitalized adults: and insight from the Polish Longitudinal Study of Aging (PLSA). Anthropol Rev 78:317–36. https://doi.org/10.1515/anre-2015-0025

Chmielewski P, Borysławski K. 2016. Understanding the links between month of birth, body height, and longevity: why some studies reveal that shorter people live longer – further evidence of seasonal programming from the Polish population. Anthropol Rev 79:375–95. https://doi.org/10.1515/anre-2016-0028

Chmielewski PP, Borysławski K, Chmielowiec K, Chmielowiec J, Strzelec B. 2016. The association between total leukocyte count and longevity: Evidence from longitudinal and cross-sectional data. Ann Anat 204:1–10. https://doi.org/10.1016/j.aanat.2015.09.002

Chmielewski P, Strzelec B, Chmielowiec J, Chmielowiec K, Borysławski K. 2017. Association of serum bilirubin with longevity: Evidence from a retrospective longitudinal study and cross-sectional data. Anthropol Rev 80:335–48. https://doi.org/10.1515/anre-2017-0024

Chmielewski PP, Strzelec B. 2018. Elevated leukocyte count as a harbinger of systemic inflammation, disease progression, and poor prognosis: a review. Folia Morphol 77:171–8. https://doi.org/10.5603/FM.a2017.0101

Chmielewski PP, Kozieł S, Borysławski K. 2023. Do the short die young? Evidence from a large sample of deceased Polish adults. Anthropol Rev 86:77–90. https://doi.org/10.18778/1898-6773.86.1.07

Chmielewski PP, Data K, Strzelec B, Farzaneh M, Anbiyaiee A, Zaheer U, Uddin S, Sheykhi-Sabzehpoush M, Mozdziak P, Zabel M, Dzięgiel P, Kempisty B. 2024. Human Aging and Age-Related Diseases: From Underlying Mechanisms to Pro-Longevity Interventions. Aging Dis 16:1–25. https://doi.org/10.14336/AD.2024.0280

Chmielewski PP, Strzelec B, Data K, Chmielowiec K, Mozdziak P, Kempisty B. 2025. Resting Body Temperature and Long-Term Survival in Older Adults at a Mental Health Center: Cross-Sectional and Longitudinal Data. J Clin Med. 14:713. https://doi.org/10.3390/jcm14030713

Collins DH, Prince DC, Donelan JL, Chapman T, Bourke AFG. 2023. Costs of reproduction are present but latent in eusocial bumblebee queens. BMC Biol 21:153. https://doi.org/10.1186/s12915-023-01648-5

Colman RJ, Anderson RM, Johnson SC, Kastman EK, Kosmatka KJ, Beasley TM, Allison DB, Cruzen C, Simmons HA, Kemnitz JW, Weindruch R. 2009. Calorie restriction delays disease onset and mortality in rhesus monkeys. Science 325:201–04. https://doi.org/10.1126/science.1173635

Conti B. 2008. Considerations on temperature, longevity and aging. Cell Mol Life Sci 65:1626–30. https://doi.org/10.1007/s00018-008-7536-1

Davis JL, Moutinho V Jr, Panageas KS, Coit DG. 2016. A peripheral blood biomarker estimates probability of survival: the neutrophil–lymphocyte ratio in noncancer patients. Biomarkers in Medicine 10:953–57. https://doi.org/10.2217/bmm-2016-0103

Di Francesco A, Deighan AG, Litichevskiy L, Chen Z, Luciano A, Robinson L, Garland G, Donato H, Vincent M, Schott W, Wright KM, Raj A, Prateek GV, Mullis M, Hill WG, Zeidel ML, Peters LL, Harding F, Botstein D, Korstanje R, Thaiss CA, Freund A, Churchill GA. 2024. Dietary restriction impacts health and lifespan of genetically diverse mice. Nature 634:684–92. https://doi.org/10.1038/s41586-024-08026-3

Diamond A, Lye CT, Prasad D, Abbott D. 2021. One size does not fit all: Assuming the same normal body temperature for everyone is not justified. PLoS One 16:e0245257. https://doi.org/10.1371/journal.pone.0245257

Dodds RM, Syddall HE, Cooper R, Benzeval M, Deary IJ, Dennison EM, Der G, Gale CR, Inskip HM, Jagger C, Kirkwood TB, Lawlor DA, Robinson SM, Starr JM, Steptoe A, Tilling K, Kuh D, Cooper C, Sayer AA. 2014. Grip strength across the life course: normative data from twelve British studies. PLoS One 9:e113637. https://doi.org/10.1371/journal.pone.0113637

Dolgin E. 2024. Why autoimmune disease is more common in women: X chromosome holds clues. Nature 626:466. https://doi.org/10.1038/d41586-024-00267-6

Dorling JL, Martin CK, Redman LM. 2020. Calorie restriction for enhanced longevity: The role of novel dietary strategies in the present obesogenic environment. Ageing Res Rev 64:101038. https://doi.org/10.1016/j.arr.2020.101038

Drenos F, Kirkwood TB. 2005. Modelling the disposable soma theory of ageing. Mech Ageing Dev 126:99–103. https://doi.org/10.1016/j.mad.2004.09.026

Ferrucci L, Fabbri E. 2018. Inflammageing: chronic inflammation in ageing, cardiovascular disease, and frailty. Nat Rev Cardiol 15:505–22. https://doi.org/10.1038/s41569-018-0064-2

Ferrucci L, Levine ME, Kuo PL, Simonsick EM. 2018. Time and the Metrics of Aging. Circ Res 123:740–4. https://doi.org/10.1161/CIRCRESAHA.118.312816

Fontana L, Partridge L, Longo VD. 2010. Extending healthy life span-from yeast to humans. Science 328:321–6. https://doi.org/10.1126/science.1172539

Franceschi C, Campisi J. 2014. Chronic inflammation (inflammaging) and its potential contribution to age-associated diseases. J Gerontol A Biol Sci Med Sci 69:S4–9. https://doi.org/10.1093/gerona/glu057

Gems D. 2022. The hyperfunction theory: An emerging paradigm for the biology of aging. Ageing Res Rev 74:101557. https://doi.org/10.1016/j.arr.2021.101557

Geneva II, Cuzzo B, Fazili T, Javaid W. 2019. Normal Body Temperature: A Systematic Review. Open Forum Infect Dis 6:ofz032. https://doi.org/10.1093/ofid/ofz032

Giacomello E, Toniolo L. 2021. The Potential of Calorie Restriction and Calorie Restriction Mimetics in Delaying Aging: Focus on Experimental Models. Nutrients 13:2346.

Greenhill C. 2024. The complex effects of dietary restriction on longevity and health. Nat Rev Endocrinol 20:697. https://doi.org/10.3390/nu13072346

Guerville F, De Souto Barreto P, Ader I, Andrieu S, Casteilla L, Dray C, Fazilleau N, Guyonnet S, Langin D, Liblau R, Parini A, Valet P, Vergnolle N, Rolland Y, Vellas B. 2020. Revisiting the Hallmarks of Aging to Identify Markers of Biological Age. J Prev Alzheimers Dis 7:56–64. https://doi.org/10.14283/jpad.2019.50

Hammers M, Richardson DS, Burke T, Komdeur J. 2013. The impact of reproductive investment and early-life environmental conditions on senescence: support for the disposable soma hypothesis. J Evol Biol 26:1999–2007. https://doi.org/10.1111/jeb.12204

He N, Zhang Y, Zhang L, Zhang S, Ye H. 2021. Relationship Between Sarcopenia and Cardiovascular Diseases in the Elderly: An Overview. Front Cardiovasc Med 8:743710. https://doi.org/10.3389/fcvm.2021.743710

He Y, Li Z, Niu Y, Duan Y, Wang Q, Liu X, Dong Z, Zheng Y, Chen Y, Wang Y, Zhao D, Sun X, Cai G, Feng Z, Zhang W, Chen X. 2024. Progress in the study of aging marker criteria in human populations. Front Public Health 12:1305303. https://doi.org/10.3389/fpubh.2024.1305303

Herrington W, Lacey B, Sherliker P, Armitage J, Lewington S. 2016. Epidemiology of Atherosclerosis and the Potential to Reduce the Global Burden of Atherothrombotic Disease. Circ Res 118:535–46. https://doi.org/10.1161/CIRCRESAHA.115.307611

Hoong CWS, Chua MWJ. 2021. SGLT2 Inhibitors as Calorie Restriction Mimetics: Insights on Longevity Pathways and Age-Related Diseases. Endocrinology 162:bqab079. https://doi.org/10.1210/endocr/bqab079

Jasienska G. 2009. Reproduction and lifespan: Trade-offs, overall energy budgets, intergenerational costs, and costs neglected by research. Am J Hum Biol 21:524–32. https://doi.org/10.1002/ajhb.20931

Jasienska G, Bribiescas RG, Furberg AS, Helle S, Núñez-de la Mora A. 2017. Human reproduction and health: an evolutionary perspective. Lancet 390:510–20. https://doi.org/10.1016/S0140-6736(17)30573-1

Keil G, Cummings E, de Magalhães, JP. 2015. Being cool: how body temperature influences ageing and longevity. Biogerontology 16:383–97. https://doi.org/10.1007/s10522-015-9571-2

Kirkwood TB. 1977. Evolution of ageing. Nature 270:301–4. https://doi.org/10.1038/270301a0

Kirkwood TB, Holliday R. 1979. The evolution of aging and longevity. Proc R Soc Lond B Biol Sci 205:531–46. https://doi.org/10.1098/rspb.1979.0083

Kirkwood TB, Rose MR. 1991. Evolution of senescence: late survival sacrificed for reproduction. Philos Trans R Soc Lond B Biol Sci 332:15–24. https://doi.org/10.1098/rstb.1991.0028

Knutson KL. 2012. Does inadequate sleep play a role in vulnerability to obesity? Am J Hum Biol 24:361–71. https://doi.org/10.1002/ajhb.22219

Kowald A, Palmer D, Secci R, Fuellen G. 2024. Healthy aging in times of extreme temperatures: Biomedical approaches. Aging Dis15:601–11. https://doi.org/10.14336/AD.2023.0619

Lee HJ, Alirzayeva H, Koyuncu S, Rueber A, Noormohammadi A, Vilchez D. 2023. Cold temperature extends longevity and prevents disease-related protein aggregation through PA28γ-induced proteasomes. Nat Aging 3:546–66. https://doi.org/10.1038/s43587-023-00383-4

Lehmann G, Muradian KK, Fraifeld VE. 2013. Telomere length and body temperature-independent determinants of mammalian longevity? Front Genet 4:111. https://doi.org/10.3389/fgene.2013.00111

Lemaître JF, Moorad J, Gaillard JM, Maklakov AA, Nussey DH. 2024. A unified framework for evolutionary genetic and physiological theories of aging. PLoS Biol 22:e3002513. https://doi.org/10.1371/journal.pbio.3002513

Levine ME, Lu AT, Quach A, Chen BH, Assimes TL, Bandinelli S, Hou L, Baccarelli AA, Stewart JD, Li Y, Whitsel EA, Wilson JG, Reiner AP, Aviv A, Lohman K, Liu Y, Ferrucci L, Horvath S. 2018. An epigenetic biomarker of aging for lifespan and healthspan. Aging 10:573–91. https://doi.org/10.18632/aging.101414

Li FX, Xu F, Li CC, Lei LM, Shan SK, Zheng MH, Lin X, Guo B, Tang KX, Duan JY, Wu YY, Cao YC, Liu JJ, Yuan LQ. 2024. Cold Exposure Alleviates T2DM Through Plasma-Derived Extracellular Vesicles. Int J Nanomedicine 19:10077–95. https://doi.org/10.2147/IJN.S441847

Li Y, Tian X, Luo J, Bao T, Wang S, Wu X. 2024. Molecular mechanisms of aging and anti-aging strategies. Cell Commun Signal 22:285. https://doi.org/10.1186/s12964-024-01663-1

Longo VD, Mitteldorf J, Skulachev VP. 2005. Programmed and altruistic ageing. Nat Rev Genet 6:866–72. https://doi.org/10.1038/nrg1706

Longo VD, Anderson RM. 2022. Nutrition, longevity and disease: From molecular mechanisms to interventions. Cell 185:1455–70. https://doi.org/10.1016/j.cell.2022.04.002

Lu SH, Leasure AR, Dai YT. 2010. A systematic review of body temperature variations in older people. J Clin Nurs 19:4–16. https://doi.org/10.1111/j.1365-2702.2009.02945.x

Mahoney SA, Venkatasubramanian R, Darrah MA, Ludwig KR, VanDongen NS, Greenberg NT, Longtine AG, Hutton DA, Brunt VE, Campisi J, Melov S, Seals DR, Rossman MJ, Clayton ZS. 2024. Intermittent supplementation with fisetin improves arterial function in old mice by decreasing cellular senescence. AgingCell23:e14060. https://doi.org/10.1111/acel.14060

Maklakov AA, Chapman T. 2019. Evolution of ageing as a tangle of trade-offs: energy versus function. Proc Biol Sci 286:20191604. https://doi.org/10.1098/rspb.2019.1604

Martin-Ruiz C, Jagger C, Kingston A, Collerton J, Catt M, Davies K, Dunn M, Hilkens C, Keavney B, Pearce SH, den

Elzen WP, Talbot D, Wiley L, Bond J, Mathers JC, Eccles MP, Robinson L, James O, Kirkwood TB, von Zglinicki T. 2011. Assessment of a large panel of candidate biomarkers of ageing in the Newcastle 85+ study. Mech Ageing Dev 132:496–502. https://doi.org/10.1016/j.mad.2011.08.001

McGann KP, Marion GS, Camp L, Spangler JG. 1993. The influence of gender and race on mean body temperature in a population of healthy older adults. Arch Fam Med 2:1265–7. https://doi.org/10.1001/archfami.2.12.1265

Mitchell SE, Simpson M, Coulet L, Gouedard S, Hambly C, Morimoto J, Allison DB, Speakman JR. 2024. Reproduction has immediate effects on female mortality, but no discernible lasting physiological impacts: A test of the disposable soma theory. Proc Natl Acad Sci 121:e2408682121. https://doi.org/10.1073/pnas.2408682121

Mullington JM, Simpson NS, Meier-Ewert HK, Haack M. 2010. Sleep loss and inflammation. Best Pract Res Clin Endocrinol Metab 24:775–84. https://doi.org/10.1016/j.beem.2010.08.014

Nilsson G, Hedberg P, Öhrvik J. 2014. White blood cell count in elderly is clinically useful in predicting long-term survival. J Aging Res 2014:475093. https://doi.org/10.1155/2014/475093

Obermeyer Z, Samra JK, Mullainathan S. 2017. Individual differences in normal body temperature: longitudinal big data analysis of patient records. BMJ 359:j5468. https://doi.org/10.1136/bmj.j5468

Öngel ME, Yıldız C, Akpınaroğlu C, Yilmaz B, Özilgen M. 2021. Why women may live longer than men do? A telomere-length regulated and diet-based entropic assessment. Clin Nutr 40;1186–91. https://doi.org/10.1016/j.clnu.2020.07.030

Page EB. 1963. Ordered Hypotheses for Multiple Treatments: A Significance Test for Linear Ranks. Journal of the American Statistical Association 58:216–30. https://doi.org/10.2307/2282965

Palani SN, Sellegounder D, Wibisono P, Liu Y. 2023. The longevity response to warm temperature is neurally controlled via the regulation of collagen genes. Aging Cell 22:e13815. https://doi.org/10.1111/acel.13815

Picca A, Pesce V, Lezza AMS. 2017. Does eating less make you live longer and better? An update on calorie restriction. Clin Interv Aging 12:1887–902. https://doi.org/10.2147/CIA.S126458

Proctor MJ, McMillan DC, Horgan PG, Fletcher CD, Talwar D, Morrison DS. 2015. Systemic inflammation predicts all-cause mortality: a Glasgow inflammation outcome study. PLoS One 10:e0116206. https://doi.org/10.1371/journal.pone.0116206

Rikke BA, Johnson TE. 2004. Lower body temperature as a potential mechanism of life extension in homeotherms. Exp Gerontol 39:927–30. https://doi.org/10.1016/j.exger.2004.03.020

Roth GS, Lane MA, Ingram DK, Mattison JA, Elahi D, Tobin JD, Muller D, Metter EJ. 2002. Biomarkers of caloric restriction may predict longevity in humans. Science 297:811. https://doi.org/10.1126/science.1071851

Ruggiero C, Metter EJ, Cherubini A, Maggio M, Sen R, Najjar SS, Windham GB, Ble A, Senin U, Ferrucci L. 2007. White blood cell count and mortality in the Baltimore Longitudinal Study of Aging. J Am Coll Cardiol 49:1841–50. https://doi.org/10.1016/j.jacc.2007.01.076

Ruggiero C, Metter EJ, Melenovsky V, Cherubini A, Najjar SS, Ble A, Senin U, Longo DL, Ferrucci L. 2008. High basal metabolic rate is a risk factor for mortality: the Baltimore Longitudinal Study of Aging. J Gerontol A Biol Sci Med Sci 63:698–706. https://doi.org/10.1093/gerona/63.7.698

Sayer AA, Kirkwood TB. 2015. Grip strength and mortality: a biomarker of ageing? Lancet 386:226–7. https://doi.org/10.1016/S0140-6736(14)62349-7

Shapiro SS, Wilk MB. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591–611. https://doi.org/10.2307/2333709_

Simonsick EM, Meier HCS, Shaffer NC, Studenski SA, Ferrucci L. 2016. Basal body temperature as a biomarker of healthy aging. AGE 38:445–54. https://doi.org/10.1007/s11357-016-9952-8

Smith L, Yang L, Hamer M. 2019. Handgrip strength, inflammatory markers, and mortality. Scand J Med Sci Sports 29:1190–6. https://doi.org/10.1111/sms.13433

Soare A, Cangemi R, Omodei D, Holloszy JO, Fontana L. 2011. Long-term calorie restriction, but not endurance exercise, lowers core body temperature in humans. Aging 3:374–9. https://doi.org/10.18632/aging.100280

Speakman JR. 2020. Why does caloric restriction increase life and healthspan? The 'clean cupboards' hypothesis. Natl Sci Rev 7:1153–6. https://doi.org/10.1093/nsr/nwaa078

Sultanova Z, Ivimey-Cook ER, Chapman T, Maklakov AA. 2021. Fitness benefits of dietary restriction. Proc Biol Sci 288:20211787. https://doi.org/10.1098/rspb.2021.1787

Waalen J, Buxbaum JN. 2011. Is older colder or colder older? The association of age with body temperature in 18,630 individuals. J Gerontol A Biol Sci Med Sci 66:487–92. https://doi.org/10.1093/gerona/glr001

Waziry R, Ryan CP, Corcoran DL, Huffman KM, Kobor MS, Kothari M, Graf GH, Kraus VB, Kraus WE, Lin DTS, Pieper CF, Ramaker ME, Bhapkar M, Das SK, Ferrucci L, Hastings WJ, Kebbe M, Parker DC, Racette SB, Shalev I, Schilling B, Belsky DW. 2023. Effect of long-term caloric restriction on DNA methylation measures of biological aging in healthy adults from the CALERIE trial. Nat Aging 3:248–57. https://doi.org/10.1038/s43587-022-00357-y

Ziomkiewicz A, Sancilio A, Galbarczyk A, Klimek M, Jasienska G, Bribiescas RG. 2016. Evidence for the Cost of Reproduction in Humans: High Lifetime Reproductive Effort Is Associated with Greater Oxidative Stress in Post-Menopausal Women. PLoS One 11:e0145753. https://doi.org/10.1371/journal.pone.0145753

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Sexual Dimorphism in Estimated Stature from Long Bones in Gilimanuk, Semawang, Plawangan, and Recent Sample in Indonesia

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Abstract: The study of sexual dimorphism among ancient skeletons can provide information on community health in the past. Meanwhile, the younger geological age of skeletal remains from Gilimanuk, Semawang, and Plawangan have received little attention. This study aimed to evaluate the sexual dimorphism in estimated stature of Gilimanuk, Semawang, Plawangan, in addition to a recent sample, of long bones. Observations were conducted on 44 (16 males, 28 females) skeletal remains of Gilimanuk, nine of Semawang (five males, four females) and 11 of Plawangan, (four males, seven females), and nine of recent (four males, five females) human skeletons stored at Universitas Gadjah Mada, Yogyakarta, Indonesia. Stature was estimated from the length of long bones. The highest average stature in the ancient sample was for Gilimanuk females (168.74 ± 9.18 cm) and males (174.10 ± 9.42 cm) in the age 16–<20 years. However, the averages of estimated stature in all ages were similar in both sexes. The average estimated stature of Semawang and Plawangan remains was slightly lower than those of Gilimanuk remains, i.e., 162.60 ± 3.97 and 159.08 ± 1.59 cm, respectively. In comparison, the recent human skeletons indicated that the average estimated stature was 168.32 ± 4.70 for males and 160.45 ± 6.89 cm for females. Our findings indicate that long bone measurements are comparable among remains from each sample. However, sexual dimorphism in estimated stature was clearly greater in recent human remains in comparison to Gilimanuk, Semawang, and Plawangan skeletal remains. Our findings suggest temporal changes in stature in this part of Indonesia.

Key words: sexual dimorphism, stature, Gilimanuk, Plawangan, Semawang

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Introduction

Sexual dimorphism characterizes variability in the morphology of different sexes (male and female) in a population. Sexual dimorphism, which exists in human skeletons, can be more prominent in certain parts, and less prominent in other parts, of bones. For example, one study in a Thai sample indicated that the length of the upper limb bone in males was significantly longer in all dimensions compared to females (Duangto and Mahakkanukrauh 2019). Studies on sexual dimorphism of human skeletal remains can also provide information on the variability in biological traits and behaviors, and aid in identifying secular and evolutionary trends of past populations (Kay 1982; Dong 1997). For example, a study of the Pre-Hispanic Maya Coastal Population in Mexico conducted by Wanner et al. (2006), reported sex differences in occupations can be observed from sexual dimorphism in bone structures. Wanner et al. (2006) found a difference in the robustness in the upper limbs caused by the division of daily occupations, such as the use of different tools and methods of carrying heavier burdens by mostly the males. Generally, males look more robust with broader shoulders when compared to females (Wanner et al. 2006). It was also suggested that males tend to be more easily affected by poor nutritional conditions compared to females. When males receive poor nutritional quality, they tend to have a decrease in the length of their long bones, which may affect their stature. Meanwhile, fluctuations in nutritional quality do not necessarily have similar effects in females (Gray and Wolfe 1980).

In archaeology and forensic anthropology, an individual's stature can be estimated using a regression formula applied to their skeletal remains. Such formulae are typically based on maximum lengths of given long bones, since there is a good correlation between long bone lengths, such as the femur, and living height. Stature estimation regression formulae should be ancestry specific. Estimating stature for remains with Asian ancestry is often done using the Trotter and Glesser (1958) method. There are several other formulae, such as Sangvichien et al. (1985), and Mahakkanukrauh et al. (2011), but these may need further investigation for their application due to some limitations. For example, Sangvichien et al. (1985) used 200 long bones (femur, tibia and fibula) from a Thai and Chinese sample. Only the leg bones, not arm bones (humerus, radius, and ulna), were considered. While the Mahakkanukrauh et al. (2011) study developed a formula for all long bones, it has a high standard error obtained from female skeletal remains. While the regression formula by Trotter and Gleser (1958) is currently considered a better choice in determining individual's stature in Asia, it must be noted that several caveats have also been noted regarding its suitability in studies on sexual dimorphism (see Jeong and Jantz 2016).

The Gilimanuk (Indonesia) skeletons have received little attention in the bioarcheological literature. Koesbardiati et al. (2013) used Gilimanuk remains to examine past genetic variation in this population. Other studies used these skeletal remains to explain health conditions in the past (Prayudi and Suriyanto 2017; 2018). Indriati (2002) also studied human bones from the Gilimanuk prehistoric population and compared them to the measured stature of students in Yogyakarta and several other populations worldwide. The study found that there was no substantial variation in human stature in Indonesia within two millennia. The stature of Indonesians was intermediate relative to stature of other populations globally; in a similar range with several other Asian groups, including those from Hongkong, Taiwan, Thailand, and India, but lower than Europeans and Americans.

The Semawang site is located in Sanur Beach, Bali, Indonesia. Herbiamami (2014) discovered several ancient people buried at the Semawang site with modified teeth. Aside from that, the Semawang population have a poor life expectancy, with mortality occurring at the age of 40 years or younger. Whereas, the Plawangan site on the northern shore of Java, Indonesia, has received increased attention for Paleometallic artefacts. According to Boedhisampurno (1990), most of the individuals discovered during excavations at the Plawangan site were young adults with an average stature of 160.4 cm. The differences in the skull, bones, and teeth, as well as the altered form of the teeth, bring them closer to the Mongoloid characteristics, yet the Australomelanesoid traits are retained. Damai (2023) concluded that, based on the skeleton, the Plawangan population was an agricultural community, but also relied on the sea for sustenance. Meanwhile, Yuniawan (2002) found that there was no association between health and economic conditions in Plawangan population.

The present study builds on this earlier research to better understand the health and adaptive success of individuals in Indonesia by identifying intrapopulation and evolutionary trends (Khudaverdyan and Hobossyan 2017). While the use of human skeletons from the past as material for medical research has been widely done to determine the history of health and diseases in some countries, in Indonesia this approach is very limited. This study aimed to examine the sexual dimorphism in estimated stature of Gilimanuk, Semawang, and Plawangan and a more recent sample of long bones from Indonesia to discuss whether there has been a temporal trend in health change.

Materials and Methods

Sample

This research was conducted at the Laboratory of Bioanthropology and Paleoanthropology, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia where these skeletal remains were stored after exhumation. Data collection was done in 2023. The materials used were human skeletal remains including 44 individual skeletal remains from the Gilimanuk site (16 males, 28 females), nine from the Semawang site (five males, four females), 11 from the Plawangan site (four males, seven females), and nine from recent age (four males, five females). The recent age skeleton samples were anatomical samples stored at the Lab. of Bioanthropology & Paleoanthropology, Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada, Indonesia during the Middle of 20th Century. It was ensured that the skeletons had long bones with no or little damage, and that adult age-at-death and sex was estimated, so that stature estimation formulae could be applied. Figure 1 depicts the sites of Gilimanuk, Semawang, and Plawangan on a map of Indonesia.

The Gilimanuk ancient burial site had been used since 750 BCE up to 900 CE based on radiocarbon dating on charcoal and bone fragments of four individuals from the site (Aziz and Faisal 1997). The discovery of the Gilimanuk site was reported by Public Works Office workers while employed at the construction of the Gilimanuk – Singaraja road where they found a large number of pottery shards, with several archaeological objects such as a square pickaxe, animal and human bones in the Cekik Village, Gilimanuk, Bali Province, Indonesia. The first research on this site was conducted in 1962–1963 by Soejono from the Bedulu National Archaeological and Heritage Branch Office in Gianyar. Subsequent studies have continued and uncovered 160 individuals (Soejono 1977).

The other archaeological sites in the present study are the Semawang and Plawangan. Semawang is located about 10 m next to Sanur Beach in Semawang Village, Sanur District, Badung Regency, Bali Province, Indonesia (Harkatiningsih 1990). The Semawang site was first discovered by local people when they dug a septic tank in 1986, followed by a study that resulted in the discovery of the grave. Significant archaeological finds from the site included various kinds of ceramics that vary in age from the 10th to 17th centuries (Harkatiningsih 1990). Whereas, Plawangan is an archaeological site from prehistoric times located in Plawangan and Balongmulyo villages, Kragan, Rembang District, Central Java province, Indonesia covering an area of approximately 90 hectares, and about 500 m from the coastline 4 m above sea level. This site is not only a burial site but also a residential site with relics such as pottery, pendulum nets, hooks and coins. Food remains obtained from the site were shellfish, snails and marine fish which indicated that the people who lived in Plawangan were fishermen (Boedhisampurno 1990; Prasetyo 1995). The Plawangan site was discovered in 1977 by the local community while building the groundwork for the village hall. Subsequently, archaeological survey research was conducted and unearthed many prehistoric graves (Prasetyo 1995).

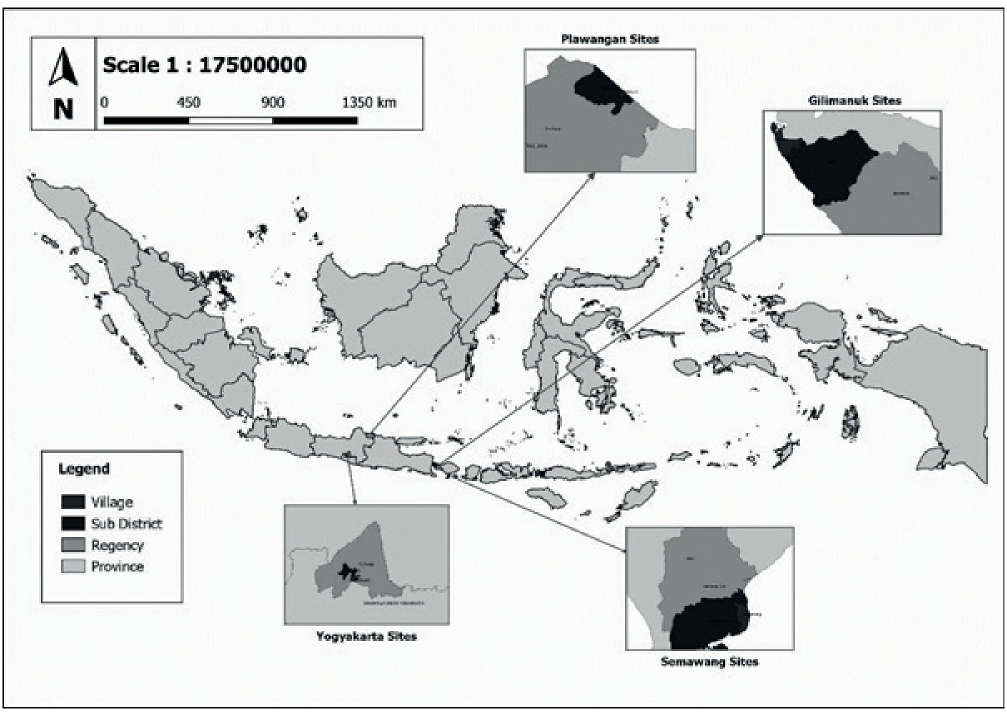

Fig.1. Gilimanuk, Semawang, Plawangan, and recent sites in Indonesian Map

Procedure

First, we observed the condition of the human skeletons to identify those that are in good condition, then we estimated sex by assessing bones that have sexually dimorphic traits on the pelvis or skull based on Walker in Buikstra and Ubelaker (1994). We used parts of the skull such as the nuchal crest, mastoid process, supraorbital margin, glabella, and mental eminence. Meanwhile, sex estimation using the pelvis was done by examining the greater sciatic notch, ventral arc, subpubic concavity, and ischiopubic ramus.

Second, we estimated the age-at-death by assessing the auricular surface, pubic symphysis, or the condition of the sutures in the skull. Estimation of age-at-death was carried out by examining several criteria, including the degree of closure of the cranial sutures based on Walker in Buikstra and Ubelaker (1994), the degree of fusion of the epiphyses of the bone based on McKern and Stewart (1957), the pattern of changes in the surface of the pubic symphysis based on Todd (1920), and changes in auricular surface based on Lovejoy et al. (1985).

Third, we measured the long bones including: humerus, radius, ulna, femur, tibia, and fibula. To provide validation, measurements were made by two research assistants who had skills and knowledge of measuring human skeletons using calibrated and standardized calipers (GPM, Swiss).

Stature estimation was done by entering the bone length measurements into the regression formula of Trotter and Gleser (1958) as showed in Table 1.

Individual ages were grouped based on a 10-year time span, to see significant growth in stature. These groups were:

1. < 16 years
2. 16 – <20 years
3. 20 – <30 years
4. 30 – <40 years
5. ≥ 40 years

Several bone structures were also observed and measured in addition to the maximum length of the bones (see Table 2). Measurements were done following the procedures of Olivier (1969).

Table 1. Regression formula for stature estimation based on Trotter and Gleser (1958)

No.	Bones	Formula
		Single bone
1.	Humerus	2.68 Humerus + 83.19 ± 4.25
2.	Radius	3.54 Radius + 82.00 ± 4.60
3.	Ulna	3.48 Ulna + 77.45 ± 4.66
4.	Fibula	2.40 Fibula + 80.56 ± 3.24
5.	Tibia	2.39 Tibia + 81.45 ± 3.27
6.	Femur	2.15 Femur + 72.57 ± 3.80
		Combined bones
7.	Humerus and Ulna	1.68 (Humerus + Ulna) + 71.18 ± 4.14
8.	Humerus and Radius	1.67 (Humerus + Radius) + 74.83 ± 4.16
9.	Femur and Humerus	1.22 (Femur + Fibula) + 70.24 ± 3.18
10.	Femur and Tibia	1.22 (Femur + Tibia) + 70.37 ± 3.24

Table 2. The long bone measurements

Bones	Measurements
Humerus	Transverse diameter of diaphysis
	Maximal length
Radius	Maximal diameters of medial diaphysis
	Antero-posterior diameters of medial diaphysis
	Minimal circumference of diaphysis
	Maximal length
Ulna	Minimal circumference of diaphysis
	Maximal anteroposterior diameters of diaphysis
	Maximal transverse diameters of diaphysis
	Maximal length
Femur	Trochanter lengths
	Maximal lengths
	Circumference of medial diaphysis
	Transverse diameter of medial diaphysis
	Transverse sub-trochanteric diameter
	Antero-posterior sub-trochanteric diameter
	Transverse diameters of head
	Sagittal diameters of head
	Collo-diaphyseal angle
	Divergent angle
Tiba	Maximal length without tibial spine
	Width of superior epiphysis
	Transverse diameter of diaphysis
	Maximal length

Data analyses were performed using descriptive analysis (average, standard deviation (SD), minimum-maximum). Comparative analysis is used to compare the estimated stature based on age and sex of the Gilimanuk, Semawang and Plawangan remains with recent Javanese skeletal remains.

Results

The estimation of stature from the maximum length of long bones of the prehistoric Gilimanuk sample is shown in Table 3, which is separated by sex and categorized into several age-at-death groups. The highest estimated stature is found in male individuals aged 16 – <20 years and in females aged ≥ 40 years. The highest average for males and females was found in the age range of 16 – <20 years (168.74 ± 9.18 cm), with the average estimated stature of males in that age range being the highest average stature in the entire Gilimanuk sample (174.10 ± 9.42 cm). The average estimated stature of males and females is almost similar i.e., approximately 164 cm.

Table 4 shows estimated stature of males and females from Semawang and Plawangan skeletal remains. It can be seen that in contrast to Gilimanuk, the highest estimated stature for males of Semawang and Plawangan remains is in the age range of ≥40 which also has the highest average estimated stature (166.31 ± 1.52 cm). Meanwhile, females, the highest average estimated stature was found in the age range of 20 – <30 years (160.51 cm). Males are about 3 cm taller than females (Table 4).

Table 3. Stature estimation of Gilimanuk skeletal remains

Age at death	N	Average Estimated Stature	SD	Minimum	Maximum
		Male			
16 – <20	2	174.10	9.42	167.44	180.77
20 – <30	10	164.40	6.77	151.23	174.75
30 – <40	3	160.84	5.41	157.36	167.07
≥ 40	1	163.41	–	163.41	163.41
Total	16	164.88	7.23	151.23	180.77
		Female			
16 – <20	2	168.74	9.18	162.25	175.24
20 – <30	12	163.12	5.99	152.10	171.21
30 – <40	8	165.11	3.45	159.17	170.56
≥ 40	6	162.78	8.11	155.28	178.37
Total	28	164.01	5.98	152.09	178.37

Age at death in year; N: number of specimens; SD: standard deviation; estimated stature in cm

Table 4. Stature estimation of Semawang and Plawangan skeletal remains

Age at death	N	Average Estimated Stature	SD	Minimum	Maximum
		Male			
20 – <30	2	160.40	3.80	157.71	163.09
30 – <40	1	159.57	–	159.57	159.57
≥40	2	166.31	1.52	165.24	167.39
Total	5	162.60	3.97	157.71	167.39
		Female			
16 – <20	2	159.58	2.64	157.40	158.88
20 – <30	1	160.51	–	160.51	160.51
30 – <40	3	158.27	0.77	157.71	161.45
Total	6	159.08	1.59	157.40	161.45

Age at death in year; N: number of specimens SD: standard deviation; estimated stature in cm

In our sample of recent population, the age-at-death range cannot be determined because there was no available data from the collections and only a little information about age can be identified. Males are on average 8 cm taller than females (Table 5).

Tables 6–7 present the sexual dimorphism characteristics of upper and lower limb bone remains from Gilimanuk, Semawang, Plawangan, and recent humans. Several bone structures in humerus, radius, ulna, femur, and tibia were compared among males and females from Gilimanuk, Semawang, Plawangan, and recent human remains. The measures vary considerably among population remains; however, the values are comparable. Humerus, radius, ulna, and tibia of males had greater maximum length of long bones than females in all population remains. The differences were not seen in femur measurements which had almost comparable length between males and females in all sample populations. More detailed structures in each of the long bones also were highly varied between males and females in the population remains. For examples, transversal diameter of diaphysis of humerus were greater in females than males in all populations except in the Semawang remains. The minimal circumference of diaphysis of radius, however, was greater in males than females in all populations, except in the Plawangan remains.

Table 5. Stature estimation of male and female recent skeletal remains

	N	Average Stature	SD	Minimum	Maximum
Males	5	168.32	4.70	161.65	174.89
Females	4	160.45	6.89	150.76	166.73

N: number of specimens; SD: standard deviation; estimated stature in cm

Table 6. Sexual dimorphism characteristics of upper limb bone remains from Gilimanuk, Semawang, Plawangan, and recent human

Bone and structures	Gilimanuk		Semawang		Plawangan		Recent	
	Male	Female	Male	Female	Male	Female	Male	Female
	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)
Humerus								
Transverse diameter of diaphysis	21.7 (3.8)	22.9 (14.1)	18.9 (3.1)	16.0 (1.9)	17.2 (3.9)	19.0 (1.5)	16.7 (2.9)	18.4 (2.3)
Maximal length	308.0 (16.1)	294.3 (19.9)	290.0	168.0	280.5	–	319.2 (11.3)	280.8 (17.7)
Radius								
Maximal diameter of medial diaphysis	15.9 (3.5)	15.8 (6.3)	16.2 (2.4)	12.0	14.0 (1.4)	16.4 (1.7)	13.1 (0.7)	9.5
Antero-posterior diameter of medial diaphysis	15.6 (7.4)	12.1 (2.2)	11.4 (1.3)	9.5	10.0 (1.0)	10.8 (0.9)	10.3 (0.8)	7.5
Minimal circumference of diaphysis	47.0 (11.6)	42.8 (6.4)	46.3 (1.9)	40	39.8 (4.5)	45.0 (3.5)	41.6 (3.1)	36.0
Maximal length	251.8 (23.3)	214.1 (56.6)	235.0	–	222.5	240.0	245.4 (10.5)	196.0

Bone and structures	Gilimanuk		Semawang		Plawangan		Recent	
	Male	Female	Male	Female	Male	Female	Male	Female
	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)
				Ulna				
Minimal circumference of diaphysis	40.2 (8.2)	39.1 (6.6)	37.3 (1.1)	33.0	26.3 (12.9)	37.0 (1.7)	35.5 (1.5)	29.6 (3.6)
Maximal antero-posterior diameter of diaphysis	24.7 (8.8)	31.2 (9.9)	32.0	1.00	31.4 (3.7)	29.6 (2.6)	33.5 (2.1)	29.8 (1.1)
Maximal transverse diameter of diaphysis	21.1 (6.8)	26.4 (9.3)	22.0	15.0	26.5 (0.6)	20.4 (3.6)	24.1 (1.0)	21.8 (0.8)
Maximal length	239.8 (18.8)	254.3 (23.0)	250.0	–	240.5	235.7 (8.3)	264.6 (10.4)	241.8 (7.4)

Avg: average; SD: standard deviation; measurement unit is in mm

Table 7. Sexual dimorphism characteristics of lower limb bone remains from Gilimanuk, Semawang, Plawangan, and recent human

Bone and structures	Gilimanuk		Semawang		Plawangan		Recent	
	Male	Female	Male	Female	Male	Female	Male	Female
	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)
				Femur				
Trochanter length	403.0	406.3 (18.8)	353.0 (7.3)	–	336.5	33.7.4	345.3 (27.2)	341.3 (34.9)
Circumference of medial diaphysis	90.2 (6.5)	83.3 (7.3)	85.8 (6.6)	77.0 (5.2)	76.0 (1.7)	84.3 (5.0)	74.6 (7.0)	76.0 (9.2)
Transverse diameter of medial diaphysis	25.8 (2.1)	27.9 (13.9)	25.9 (3.1)	23.7 (1.8)	24.5 (1.5)	24.9 (2.0)	22.3 (2.8)	23.8 (1.6)
Transverse sub-trochanteric diameter	33.1 (3.1)	34.9 (17.1)	32.2 (1.6)	27.0	26.3 (1.5)	28.9 (3.6)	25.4 (0.5)	26.8 (2.7)
Antero-posterior sub-trochanteric diameter	30.3 (4.9)	28.5 (4.0)	28.4 (4.7)	22.0	22.0 (1.9)	2.53 (2.4)	22.6 (1.6)	20.7 (4.0)
Transverse diameter of head	43.8 (3.8)	42.5 (3.0)	45.5 (2.1)	–	39.5	41.8 (2.3)	40.5 (5.4)	3.93 (0.49)
Sagittal diameter of head	44.0 (3.6)	42.6 (2.9)	44.5	–	39.5	41.3 (2.2)	40.5 (4.6)	3.88 (0.50)
Collo–diaphyseal angle	134.00º (8.31 º)	128.15º (6.79 º)	–	–	–	140º	135º	129º
Divergent angle	7.25 (1.50 º)	11.50º (2.65 º)	–	–	–	10º	12º	9º
Maximal length	420	430	382.7 (74.0)	328.3 (55.3)	400.0	416.3 (14.4)	407.1 (32.1)	400.2 (43.2)

Table 7. (cont.)

Bone and structures	Gilimanuk		Semawang		Plawangan		Recent	
	Male	Female	Male	Female	Male	Female	Male	Female
	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)	Avg (SD)
Tibia								
Maximal length without tibial spine	338.3 (14.7)	344.3 (18.0)	–	–	–	336.0	365.0 (16.6)	323.3 (38.2)
Width of superior epiphysis	58.0 (18.3)	71.8 (7.6)	62.5	–	61.0	61.2 (6.8)	71.2 (1.6)	62.0 (6.1)
Transverse diameter of diaphysis	31.0 (4.7)	34.6 (8.5)	29.5	–	24.5	27.0	25.8 (1.6)	25.7 (3.8)
Maximal length	353.5	348.2 (18.2)	370	–	–	346.0	377.3 (20.4)	334.0 (33.5)

Avg: average; SD: standard deviation; measurement unit is in mm

Discussion

Sexual dimorphism refers to the systemic biological differences between males and females, which can be measured and seen in estimated stature and bone structures. One of the common types of archeological evidence to find is that males are almost always taller than females. This is often ascribed to what is known about living males, such as that they tend to have a stocky face, muscular body, and are generally physically stronger and faster than females (Frayer and Wolpoff 1985). In our study on human skeletal remains from Indonesia, sexual dimorphism in estimated stature of Gilimanuk, Semawang, and Plawangan was obscure compared with the recent sample, where sexual dimorphism was more obvious. Nonetheless, long bones showed more obvious sexual dimorphism in all population groups.

It is believed that stature is strongly influenced by genetics. However, one possible confounding cause has emerged that could affect stature, i.e., nutrition (Eveleth 1975; Gray and Wolfe 1980). Overall, genetics and nutrition play the most important role in human growth, but when considered in other cultural and regional contexts, it can be seen that there are several other factors such as climate, marriage, or even access to the basic requirements of nutrients.

The Gilimanuk, Semawang, and Plawangan populations have genetic and physical traits as Mongoloid. They lived at around the same period and belonged to the Paleometallic Age and Austronesian civilizations. They dwell by the coast (Soejono 1977; Boedhisampurno 1990; Harkatiningsih, 1990, Aziz and Faisal 1997; Koesbardiati et al. 2013; Prayudi and Suriyanto, 2017, 2018). It is possible that in the past in Gilimanuk there were conditions when the community was malnourished so that the stature of males at that time did not reach the maximum when compared to the stature in the recent period. In this study, it was seen that there was a change in the estimated stature of the past sample when compared to modern, while modern males get taller (by 5.44 cm), modern females get shorter (by 3.65 cm). In the Gilimanuk community, males have an average estimated stature of 164.88 cm, while they were 162.60 cm in Semawang. This trend may indicate that in the past in Gilimanuk and Semawang, there may have been conditions that made it difficult for them to access nutrition. Sexual dimorphism among ancient populations has been reported in ancient European populations by Frayer (1980). It was noted that European Upper Paleolithic groups exhibited stronger sexual dimorphism than their Mesolithic and Neolithic descendants, particularly in the cranial skeleton. This decrease in sexual dimorphism towards more recent populations was linked to changes in technical processes connected with hunting of prey animals. The same process was proposed to have occurred between Mesolithic and Neolithic European populations, as well as between Neolithic and current European populations, indicating a stronger correlation with changes in women (Frayer 1980).

Sexual dimorphism is diminished in hominin descendants, and is more visible or higher in more ancient populations, in terms of skeletal, cranial, and dental dimensions (Suriyanto 2006; 2009). The degree of sexual dimorphism in hominin body size has shifted over the last three million years, from 100% in baboons and gorillas to 20% – 40% in current human populations (Frayer and Wolpoff 1985). Our study found that sexual dimorphism in the Gilimanuk sample was not obvious. This was seen in the average estimated stature difference between males and females, which was only 0.87 cm when compared with 7.87 cm different in modern males and females. When we compare the average stature of males and females across Gilimanuk, Semawang, and Plawangan, there was not much of a difference either (Tables 3 and 5). Changes in nutrition can cause wider sexual dimorphism (Chen et al. 2022; Pontifex et al. 2024) as shown in our more recent population. Males have a tendency to get more nutrition, because, for example, females tend to get diseases related to lack of nutrition, especially when there is a disaster (Rivers 1982). The absence of sexual dimorphism in bones from the past may also occur because there are similarities in activities between males and females (Murdock and Provost 1973). This seen in the robustness of the lower body of the Modern Hunter Gatherer from Australia which indicates both males and females have a high level of mobility (Carlson et al. 2007; Herrerín and Carmenate 2022). However, there are differences in the upper body, which based on ethnographic data may be due to differences in occupation (Carlson et al. 2007). There might be various explanations for the lack of prominent sexual dimorphism in prehistoric populations, such as equality of work between males and females and equal access to nourishment. Whereas, several causes of sexual dimorphism in the modern society may include unequal work between males and females as well as a lack of access to nutrients (Frayer and Wolpoff 1985; Kirchengast 2014).

Overall, our observations on the long bone structures showed the existence of sexual dimorphism among the skeletal remains in Indonesia. The humerus transverse diameter of the female population of Gilimanuk, Plawangan, and recent skeletons are greater than the male humerus, while the humerus transverse diameter of the Semawang male population are greater than the female humerus. There is an increase in the maximum length of the humerus of Gilimanuk, Semawang, Plawangan, and recent Indonesian males. The osteometric measurements of the radius and ulna of males appeared to be greater for all populations, but the differences in the osteometric measurements of the radius and ulna of males and females in the populations were relatively inconspicuous. The maximal length of radius between male and female recent populations is relatively greater compared to the ancient populations of Indonesia. Whereas, lengths, diameters, and angle of the female femur were relatively greater in ancient populations, the lengths, diameters, and angle of the male femur were greater in the recent population. Femur circumference is relatively greater in males Gilimanuk and Semawang populations than of Semawang and recent populations. Herrerín and Carmenate (2022) found that the robustness in legs showed higher dimorphic trends than in the arms in Santa Clara Necropolis skeletal remains. It was thought that there might be a similar manipulation activity between males and females in that population.

The tibia remains of Semawang and Plawangan populations are difficult to measure all osteometric variables because most of them are fragmentary since at the archeological sites, hence, the measurements were done only on the ancient population of Gilimanuk. In general, recent Indonesian tibial osteometric measurements show relatively less pronounced sexual dimorphism than the ancient Gilimanuk population. It may be that daily activities related to the sexual division of labor in tibial function were more pronounced in ancient populations than in more modern populations (Ruff 1987).

Concerning the sexual dimorphism in long bone structures, sexual division of labor can also be seen from the measurements of the actual size of the bones. For example, sexual dimorphism was found in the Pre-Hispanic Maya Coastal Population of Mexico where there was a difference in robustness in the upper limbs caused by the division of labor such as the use of different tools and carrying a heavier burden by males. In addition, the lower limbs also showed differences in work groupings, so there are differences in the structures of the bones. Additionally, in morphology, males look more robust with broader shoulders when compared to females. This pronounced difference is probably caused by males frequently traveling and carrying heavy loads (Wanner et al. 2006).

The strength of this study was the antiquity of the materials of Gilimanuk human remains and the methods of sex and age estimation. Sex identification used the Walker method in Buikstra and Ubelaker (1994). This method uses skull and pelvis, both of which are the parts that show the most sex differences. Individual age at death was identified using various methods such as Todd (1920), McKern and Stewart (1957), Lovejoy et al. (1985), and Walker in Buikstra and Ubeler (1994). Age identification is done using various methods because not all bones in an individual can be found. More recent methods assessed the use of osteometric measurement and indices; however, the results were less reliable than morphological characteristic observation (Barroso Flamino et al. 2020). The use of these two parts of the skeletons is also to reduce identification errors. Nonetheless, several limitations were found in this study, including the limited individual number of specimens and the remains were not comparably distributed in the observed age ranges. The limited number of specimens may hinder the representation of the whole population. Future study should investigate additional characteristics such as socioeconomic, culture, activities, and environment of the specimens.

Conclusions

In conclusion, long bone structure measurements are comparable among remains from each sample. Long bone structures, however, revealed more obvious sexual dimorphism in all skeletal remains. This finding may be due to the difference in household tasks between males and females. Additionally, there is a trend that males tend to get more nutrition and get it earlier in their development than females. Sexual dimorphism in estimated stature was clearly greater in recent human remains in comparison to Gilimanuk, Semawang, and Plawangan skeletal remains. This showed that the possibility of accessing nutrients by each individual tends to be similar. In addition, the work done during that time tended to be alike between males and females, indicating an equal division of labor in both sexes. Nonetheless, the average estimated stature and age at death varied among the premodern remains.

Ethics statement

Ethics approval for this study was obtained from the Medical and Health Research Ethics Committee Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada, Indonesia (KE/FK/1913/EC/2023).

Publication statement

We confirm that the paper has not been previously published or concurrently submitted to an editorial office of another journal, and also that it is approved by all authors for publication.

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Conflict of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Authors' contribution

JH: research concept and design, data analysis and interpretation, article writing, critical revision of the article for important intellectual content, provision of study materials, statistical expertise, data collection and compilation, final approval of the article; **AP:** data collection and compilation, technical and logistic support, article writing, data analysis; **NTR**: critical revision of the article for important intellectual content, provision of study materials, data collection and compilation, approval of the article. **NHF:** data collection and compilation, administrative, data analysis; **RAS:** critical revision of the article for important intellectual content, data collection and compilation, technical, or logistic support.

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References

Aziz FA, Faisal W. 1997. Pertanggalan radiocarbon rangka manusia situs Gilimanuk, Bali. Naditira Widya 2:52–62.

Barroso Flamino C, Oliveira D, Ferreira L, Martins M, Santos R., Laureano R, Nunes T, Bento B, Santos R, Palmela Pereira C. 2020. Osteometric and osteomorphological sex estimation from the os coxa in an archaeological population related to the 1755 Earthquake of Lisbon. Bull Int Assoc Paleodont 14(1):32–39.

Boedhisampurno S.1990. Temuan sisa manusia dari situs kubur Paleometalik Plawangan, Rembang, Jawa Tengah, In RP Soejono, NA Subagus, Nurhadi, HM Ambary, S Satari, DD Bintarti, and ES Hardiati, editors. Proceedings Analisis Hasil Penelitian Arkeologi I. Jakarta: Pusat Penelitian Arkeologi Nasional, Departemen Pendidikan dan Kebudayaan. 125–164.

Buikstra JE, Ubelaker DH. 1994. Standards for data collection from human skeletal remains. Arkansas Archaeological Survey, Arkansas.

Carlson KJ, Grine FE, Pearson OM. 2007. Robusticity and sexual dimorphism in the postcranium of modern hunter-gatherers from Australia. Am J Phys Anthropol 134:9–23. https://doi.org/10.1002/ajpa.20617

Chen Y, Kim M, Paye S et al. 2022. Sex as a biological variable in nutrition research: from human studies to animal models. Annu Rev Nutr 42: 227–250. https://doi.org/10.1146/annurev-nutr-062220-105852

Damai AH. 2023. Deskripsi paleopatologi gigi manusia purba berdasarkan aktivitas di Situs Plawangan. Unpublished bachelor dissertation. Program Studi Arkeologi Universitas Udayana. Dong Z. 1997. Mixture analysis and its preliminary application in archaeology. J Archaeol Sci I:141–161. https://doi.org/10.1006/jasc.1996.0100

Duangto P, Mahakkanukrauh P. 2020. Sex estimation from upper limb bones in sex dimorphism in a Thai population. Anat Cell Biol. 53(1):36–43. https://doi.org/10.5115/abc.19.179

Eveleth PB. 1975. Differences between ethnic groups in sex dimorphism of adult height. Ann Hum Biol 2(1):35–9. https://doi.org/10.1080/03014467500000541

Frayer D.W. 1980. Sexual dimorphism and cultural development in the Late Pleistocene and Holocene of Europe. J Hum Develop 9(5): 399–415.

Frayer DW, Wolpoff MH. 1985. Sexual dimorphism. Annu Rev Anthropol 14:429–473. https://doi.org/10.1146/annurev.an.14.100185.002241

Gray JP, Wolfe LD. 1980. Height and sexual dimorphism of stature among human societies. Am J Phys Anthropol 53(3):441–56. https://doi.org/10.1002/ajpa.1330530314

Harkatiningsih MN. 1990. Jenis dan Peletakan Bekal Kubur di Situs Semawang dan Selayar: Pola Kubur dari Abad ke-14–19. Analisis Hasil Penelitian Arkeologi I. Departemen Pendidikan dan Kebudayan, Jakarta.

Herbiamami ML. 2014. Status Kesehatan manusia di Situs Semawang, Bali (Kajian paleopatologi rangka dan gigi). Unpublished bachelor dissertation. Program Studi Arkeologi Universitas Gadjah Mada.

Herrerín J, Carmenate M. 2022. Selular dimorphism of a Mudejar Necropolis of Santa Clara (Cuéllar, Segovia, S. XIV and S. XV). Anthropologie (Brno) 60(1):0–0. https://doi.org/10.26720/anthro.21.06.10.1

Indriati E. 2002. Stature in Yogyakarta's students and prehistoric Balinese circa 110 A.C. Berkala Ilmu Kedokteran 34(1):1–7.

Ipiña SL, Durand AI. 2010. Some considerations on the use of the quotient of sample means as a measure of sexual dimorphism. Anthropologie (Brno) 48(1):1–4.

Jeong Y, Jantz LM. 2016. Caveats in using Trotter and Gleser's (1958) Asian equations for stature estimation. Korean J Phys Anthropol 29(3): 81–91.

Kay RF. 1982. Sivapithecus simonsi a new species of Miocene hominoid, with comments on the phylogenetic status of Ramapithecinae. Int J Primatol 3:113–173. https://doi.org/10.1007/BF02693493

Khudaverdyan A, Hobossyan SG. 2017. Bioarchaeological evidence for the health status of a late Bronze Age and Early Iron Age Bakheri Chala population (Armenia). Anthropologie (Brno) 55(3): 319–336.

Kirchengast S. 2014. Human sexual dimorphism—a sex and gender perspective. Anthropol Anz 71(1–2):123–33. https://doi.org/10.1127/0003-5548/2014/0376

Koesbardiati T, Yudianto A, Murti DB, Suriyanto RA. 2013. Loci STR codis (THO1,TPOX) genetic variation on Gilimanuk Man (Bali Islands). Berkala Arkeologi 33(2). https://doi.org/10.30883/jba.v33i2.11

Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP. 1985. Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. Am J Phys Anthropol 1(68):15–28. DOI: https://doi.org/10.1002/ajpa.1330680103

Mahakkanukrauh P, Khanpetch P, Prasitwattanseree S, Vichairat K, Case DT. 2011. Stature estimation from long bone lengths in a Thai population. Forensic Sci Int 210(279):e1–7. https://doi.org/10.1016/j.forsciint.2011.04.025

Mckern TW, Stewart TD. 1957. Skeletal age changes in young American males. Natick, MA: Quartermaster Research and Development Command Technical Report EP-45.

Murdock GP, Provost C. 1973. Factors in the division of labor by sex: A cross-cultural analysis. Ethnology 12(2):203–225.

Pontifex MG, Vauzour D, Muller M. 2024. Sexual dimorphism in the context of nutrition and health. Proc Nutr Soc. 83(2):109–119. https://doi.org/10.1017/S0029665123003610

Prasetyo B. 1995. Laporan Penelitian Situs Plawangan, Rembang, Jawa Tengah (1980–1993). Proyek Penelitian Purbakala Nasional. Pusat Penelitian Arkeologi Nasional. Departemen Pendidikan dan Kebudayaan, Jakarta.

Prayudi A, Suriyanto RA. 2017. Osteobiografi individu nomor 38 dari situs Prasejarah Gilimanuk. Amerta 35(1):19–32. https://doi.org/10.24832/amt.v35i1.139

Prayudi A, Suriyanto RA. 2018. GLM LVI: Tinjauan Osteoarkeologis atas sebuah rangka dari Gilimanuk. Forum Arkeologi 31(2):105–116. https://doi.org/10.24832/fa.v31i2.526

Rivers J. 1982. Women and children last: An essay on sex discrimination in disasters. Disasters 6: 256–267. https://doi.org/10.1111/j.1467-7717.1982.tb00548.x

Ruff C. 1987. Sexual dimorphism in human lower limb bone structure: Relationship to subsistence strategy and sexual division of labor. J Hum Evol 16(5):391–416. https://doi.org/10.1016/0047-2484(87)90069-8

Sangvichien SJ, Srisurin V, Wattanakyinsakul V. 1985. Estimation of stature of Thai and Chinese from the length of femur, tibia and fibula. Siriraj Hosp Gaz 37:215–8.

Soejono RP. 1977. Sistim-sistim penguburan pada akhir masa prasejarah di Bali. Unpublished dissertation (PhD), Program Studi Arkeologi Universitas Indonesia.

Suriyanto RA. 2005. Kajian perbandingan karakteristik epigenetis populasi tengkorak manusia paleometalik Gilimanuk (Bali) dan Liang Bua, Lewoleba, Melolo dan Ntodo Lesah (Nusa Tenggara Timur). Unpublished thesis (Master), Program Pascasarjana Antropologi Universitas Gadjah Mada.

Suriyanto R.A. 2006 Dimorfisme seksual dalam karakteristik epigenetis upper viscerocranium dari sampel tengkorak manusia Gilimanuk (Bali). Berkala Arkeologi 26 (2): 85–113.

Suriyanto R.A. 2009 Human sexual dimorphism: From an evolutionary perspective to practical overview. Berkala Ilmu Kedokteran 41 (4): 194–201.

Todd TW. 1920. Age changes in the pubic bone. I. The male white pubis. Am J Phys Anthropol 1(3):285–334. https://doi.org/10.1002/ajpa.1330030301

Trotter M, Gleser GC. 1958. A reevaluation of estimation of stature based on measurements of stature taken during life and of long bones after death. Am J Phys Anthropol 1(16):79–123. https://doi.org/10.1002/ajpa.1330160160

Wanner IS, Sosa TS, Alt KW, Blos VT. 2006. Lifestyle, occupation, and whole bone morphology of the Pre-Hispanic Maya coastal population from Xcambo, Yucatan, Mexico. Int J Osteoarchaeol. https://doi.org/10.1002/oa.873

Yuniawan AA. 2022. Paleopatologi manusia Plawangan ekskavasi tahun 1978: kaitan antara bekal kubur dan penyakit. Unpublished bachelor dissertation. Program Studi Arkeologi Universitas Gadjah Mada.

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Prevalence of Undernutrition and its Socio-Demographic Determinants among Rural Bengalee Muslim Preschool Children of Bankura District, West Bengal, India

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ABSTRACT: Despite recent global economic growth, the high prevalence of child undernutrition is an urgent public health issue in low and middle-income countries, including India. Moreover, one-third of infant mortality is associated with undernutrition. The present cross-sectional study aims to report the burden of undernutrition and to explore its association with socio-demographic variables among the Bengalee Muslim preschool children of Bankura district, West Bengal, India. This present study was conducted among 800 preschool children (400 males and 400 females) aged 12 to 59 months. The children were selected using a systematic random sampling method, and the sample size was estimated using standard formula. Descriptive, parametric, non-parametric, and inferential statistical analyses were performed accordingly. Males were taller and heavier than females. Significant age variations in mean height and weight were found among the study participants. The overall prevalence of stunting, wasting, and underweight was 23.0%, 30.5%, and 36.0%, respectively. The results of the chi-square test showed that all the socio-demographic variables were significantly associated with the nutritional status of these children. A multivariate logistic regression revealed that non-exclusive breastfeeding, higher birth order, and the lower mothers' age at childbirth were the significant predictors of stunting. Low family income, large family size, and low maternal educational status were the significant predictors of wasting. Moreover, low family income, non-exclusive breastfeeding, and mothers' age at childbirth were significant predictors of underweight. The findings of the present study revealed that there were numerous determinants of undernutrition among the Bengalee Muslim preschool children. Therefore, the appropriate government and non-government agencies should adopt the policy for an income-generating scheme to enhance household income, awareness of exclusive breastfeeding, family planning, adult education programmes, and surveillance against child marriage.

KEY WORDS: Undernutrition, Socio-demographic factors, Muslim, Preschool, Children

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Introduction

Childhood undernutrition is a complex public health problem in low and middle-income countries despite recent global economic growth (Ali et al. 2017; Kang and Kim 2019; Chowdhury et al. 2018; Brown et al. 2020; Hossain et al. 2023). It is determined by several socio-economic and demographic factors including maternal age at marriage, maternal age at childbirth, child birthweight, breastfeeding practice, parental education and occupation, household income, drinking water, and latrine facility (Abuya et al. 2012; Asfaw et al. 2015; Kang and Kim 2019; Murarkar et al. 2020; Ghosh 2023; Hossain et al. 2023; Toma et al. 2023; Singh et al. 2024).

Poor health hampers several factors in a nation's progress such as social well-being, national saving, demographic change, and higher labor productivity, which are obstacles to the development of a country (Devine et al. 2014; Duminy et al. 2023). Good health enhances a nation's well-being, higher labour productivity, improved human capital, higher rates of national saving, and demographic change (WHO 2003). Child undernutrition is one of the major causes of childhood morbidity and mortality (Chowdhury et al. 2018; Hossain et al. 2023)and it contributes to over half of child deaths each year, predominantly in developing countries (Benson and Shekar 2006). Undernourished children often face chronic illness and physical disabilities, which contribute to less productivity outcomes compared to normal children (Groce et al. 2014; Asfaw et al. 2015). The United Nations fixed the Sustainable Development Goals (SDGs) to reduce all forms of malnutrition along with child mortality among children by addressing their proper nutritional needs. However, the Food and Agriculture Organization (2023) reported that 725.1 million people are undernourished whereas 195.1 million and 458.7 million people are in lower-income and lower-middle-income countries respectively (FAO 2023). Poverty reduction is one of the important factors in reducing or achieving the above SDGs, including those related to health and well-being.

Undernutrition is one of the forms of malnutrition and it encompasses three broadly recognized indicators such as stunting (low height for age), wasting (low weight for height), and underweight (low weight for age) (WHO 2022). In this context, undernutrition among children is a silent threat of developing countries including India. Several schemes, including the National Health Mission (NHM-2005) and Integrated Child Development Service Scheme (ICDS 2008–2009), have been launched to reduce child undernutrition. Still, it remains significantly high in India, including West Bengal. The National Family Health Survey-V (2019–20) reported that the prevalence of stunting, wasting, and underweight in India are 35.5%, 19.3%, and 32.1%, respectively (IIPS 2020). It is a highly alarming report that stunting, wasting, and underweight affect 61 million, 25 million, and 47 million under-five children in India, respectively (Singh et al. 2019), including West Bengal (IIPS 2020).

Noteworthy, the Sachar Committee (2006) and Ranganath Mishra Commission (2007) reported that Muslim communities in India are socially and educationally regressive, economically poor, politically powerless, and medically disadvantaged community. The poverty level (both rural and urban) among Muslims in West Bengal is higher than the national average of poverty. Most of the Muslim population (78%) resides in rural areas and their economy predominantly depends on agriculture. It has also been reported that Muslim children suffer from higher rates of undernutrition compared to other communities (Prime Minister High Level Committee 2006). The above reviews highlight that socio-economic and demographic factors play a significant influence on every aspect of a child's health and nutritional status, and it has also been revealed that there is a dearth of information on the interaction between socio-demographic factors and nutritional status among the rural Bengalee Muslim preschool children. By identifying highly significant socio-demographic predictors and advocating for multi-sectoral interventions, it provides new insights for targeted public health policies in low-resource settings.

Therefore, the present study aims to report the prevalence of the different forms of undernutrition as well as to explore the relationship between undernutrition status and socio-demographic factors among the Bengalee Muslim preschool children of Kotulpur block, Bankura district of West Bengal, India.

Materials and Methods

Study Setting

The study was conducted at the different villages of Kotulpur Community Development (CD) block of Bankura district, West Bengal, India. The block is the most Muslim populated CD block of Bankura district, consisting of 32,922 population, representing 17.44% of the total population in this CD block (Census of India 2011). It consists of eight (8) gram panchayats with a total population of 1,88,775, of which 1,80,292 reside in rural areas and 8,483 in urban areas. The block covers an area of 250.38 km^2 and 65 km away from the district head quarter of the Bankura district.

Sample and sample size calculation

The present cross-sectional study was conducted among 12 to 59 months old Muslim preschool children. The study was approved by the Institutional Ethical Committee of the Institution of the Sidho-Kanho-Birsha University (Ref. No. R/IEC/406/SKBU/2023 dated 24.03.2023, with effect from July 2022). The information provided by participants was kept confidential by excluding personal identifiers from the schedule. Parents of the children's convenience was a priority in this study during data collection, and we respected their rights as participants. We also confirm that all methods and procedures were carried out in accordance with the relevant guidelines and regulations (Helsinki Declaration). The study participants were an unknown population due to the unavailability of the religious specific data on preschool children. The Integrated Child Development Scheme (ICDS) authority focuses on gathering only the social categorical data (General, SC, and ST). Therefore, Cochran's (1977) unknown sample formula was adopted to calculate the minimum sample size as follows:

$$n_0 = \frac{Z^2pq}{e^2},\ n_0 = \frac{(2.58)^2 \times 0.5 \times 0.5}{0.05^2} =$$

$$= \frac{6.6564 \times 0.25}{0.0025} = 666 + 10\% = 733$$

Where n_0= sample size; Z= level of confidence; p=degree of variability; q=1-p; e= level of precision (Cochran 1963).

According to NFHS-V (2019–21), the maximum prevalence of the Composite Index of Anthropometric Failure is 48.78% in Bankura district (computed by the author). Therefore, the maximum variability assumed is equal to 50% (p=0.5) and takes a 99% confidence level with ±10 %. The above calculation shows that the minimum sample size is 733. Therefore, a total of 800 Muslim preschool children (400 males and 400 females) were investigated.

Sampling Technique

The study participants were selected from forty Integrated Child Development Service scheme centers from twenty-eight Muslim dominated villages of Kotulpur Block. The study participants were selected using a systematic random sampling method, whereas age and sex-specific serial numbers of the children in the ICDS register book were used to choose the participants (children). Every consecutive third age and sex-specific children were selected from each center proportionally, out of the total estimated age and sex-specific sample (100 children), which comprised (100×2×4) of total 800 preschool children.

Anthropometric Measurements

Anthropometric measurement is a crucial tool for evaluating nutritional assessment and associated health risks (WHO 1995). Anthropometry is a quick, easy, and inexpensive method. Therefore, it is one of the most commonly used and globally accepted methods (Bhattacharya et al. 2019; WHO 1995). Anthropometric measurements (height and weight) were taken by a trained investigator (first authors) using an internationally accepted standard protocol (Lohman et al. 1988). Crown-heel length and height was measured using an infantometer and standard stadiometer respectively and recorded to the nearest 0.1 cm. Weight was measured using a spring balance weighing machine (Krups) and recorded to the nearest 0.5 kg.

Assessment of Nutritional Status

Three commonly recognized nutritional indicators, namely stunting, wasting, and underweight were assessed based on age, height, and weight as recommended by WHO in 2006. The Anthro-plus software (Version 3.2) was used to calculate the Z-score values of height for age (HAZ), weight for height (WHZ), and weight for age (WAZ), following the guidelines of the World Health Organization (WHO, 2006). These Z-score values were used to assess stunting (HAZ), wasting (WHZ), and underweight (WAZ). The cut-off points for stunting, wasting, and underweight were defined as <-2SD z-scores (age and sex specific).

The formula is given below.

$$\text{Z score} = \frac{\text{X} - \text{Median values of WHO, 2006}}{\text{Standard deviation of WHO, 2006}}$$

Where, X=Particular score of height or weight of a child. (WHO, 2006)

The above calculation reveals three Z score values. The values are:

HAZ= Height for age Z-score. Stunting is defined as <-2SD Z-scores value.

WHZ= Weight for height Z-score. Wasting is defined as <-2SD Z-scores value.

WAZ= Weight for age Z-score. Underweight is defined as <-2SD Z-scores value.

Socio-demographic variables

Socio-demographic data were collected from the ICDS register and head of household or guardian or parents of the children. The date of birth, religion, mother's age at marriage, age of mother at childbirth, and birth weight are recorded from the ICDS register. Birth order, number of siblings, number of household members, duration of breastfeeding, household income, mother's education, father's education, father's occupation, availability of latrine facilities and separate kitchens, and type of cooking fuel were collected through a schedule survey.

Data management

Mother's age at marriage was recorded per the Indian Child Protection Act (2006) which sets the minimum legal age for marriage of women at 18 years. The National Report (NFHS) in India justified that women's average age at childbirth is slightly over 21 years. And the present data on it were categorized accordingly.

Birth order and the number of siblings were also recorded and categorized into quartiles for analytic purposes. Birth weight was obtained from the *'mother and child protection card'* and categorized as WHO standard, with weights below 2,500 grams or 2.5 KG categorized as 'low birth weight'. Breastfeeding data was documented as continuous data and categorized according to the WHO standard, with the first six months of exclusive breastfeeding defined as exclusively breastfeeding. The number of household members was also recorded. Household income was recorded in Indian currency and categorized using quartile. Father's occupation was categorized into three categories Casual (engaged in irregular workers), Self (those meaning their businesses or properties), and Regular workers (employed in stable or long-term properties). The highest levels of parental education were recorded based on the various educational institutions they were schooled. Latrine facilities, cooking fuel, and separate kitchens were also recorded as socio-economic indicators.

Table 1. List of dependent and independent variables examined in the present study

Variables	Description
Stunting	'0' Not Stunted & '1' Stunted
Wasting	'0' Not Wasting & '1' Wasting
Underweight	'0' Not Underweight & '1' Underweight
Mother's Age at Marriage	Child Marriage (below 18 years) and Adult Marriage (18 years and above).
Age of Mother at Childbirth	20 years & below, and 21 years & above
Birth Order	1^{st} birth order and 2^{nd} and subsequent birth order
Sibling	No sibling and having sibling
Birth Weight	Normal birth weight ($\geq$ 2.5 kg) and low birth weight ($<$ 2.5 kg)
Exclusive Breastfeeding	Yes (exclusive breastfeeding or first six months of breastfeeding) and No (below six months of breastfeeding)
Number of Household Members	4 & below and 5 & above
Monthly Household Income	Rs <6500, Rs 6501 to Rs 9000 and Rs >9001
Father's Occupation	Casual (refer to irregular workers), Self (refer to work in own properties), and Regular workers
Father's Education	Primary (class IV and below) and Upper primary & above
Mother's Education	Upper primary & lower (class VIII and below) and High School & above
Latrine Facility	Yes and No
Separate Kitchen	Yes (separate kitchen room for cooking) and No (no separate kitchen for cooking)
Cooking Fuel	Gas and Fairwood or leave

Statistical Analysis

All statistical analyses were carried out using IBM SPSS (Version 25). Basic descriptive statistics were compiled. Student's t-test was performed to assess sex differences (age-specific) in mean height and weight. One-way ANOVA (Scheffe's procedure) was performed to test for age variations in mean height and weight for each sex. The chi-square test was also performed to assess the variation in the prevalence of undernutrition in the different categories of each independent variable. Binary logistic regression analyses were performed to find out the individual predictor(s) of stunting, wasting, and underweight. Furthermore, multiple logistic regressions (Forward: Likelihood Ratio) analyses were performed to explore the most important determinants of undernutrition after removing or controlling the effect of the other independent variables. In this analysis, undernutrition was presented as the dependent (outcome) variable, categorized into "0" (normal) and "1" (stunted, wasted, and underweight), while socio-demographic variables were the independent variable. All the Statistical tests were set at $p<0.05$.

Simple logistic regression

$$\text{Logit (P)} = \text{In}\,(p/1-p)=\beta_0+\beta_1X_1$$

Multivariate binary logistic regression

$$\text{logit(P)}= = \text{In}(p/1-p)=\beta_0+\beta_1X_1+\beta_2X_2+\ldots\ldots\beta_nX_n$$

Where,

P= the probability of the event occurring,

1-p=the probability of the event not occurring.

β_o=Intercept

β_1, β_2……βn = the coefficients for the independent variables X_1, X_2…..X_n.

Results

Socio-demographic characteristics

The results of socio-demographic characteristics revealed that more than half of mothers married before reaching adulthood (54.88%). Furthermore, it was observed that more than half of the present mothers gave birth at the age of below 21 years of age. About 45.15% of children were born in the first birth order and 40.75% of children did not have siblings. About one-fourth of the studied children (24.38%) were born with low birth weight. A total of 15% of children did not get exclusive breastfeeding during their first six months of life. More than half of the families are small in nature (4 and below family members). One-fourth of the household's monthly income was less than Rs 6500. About half of fathers were engaged in casual work and only 16.88% were involved in regular work. 43.00% of fathers completed at least the primary level. More than half of mothers completed at least the upper primary level. 20.50% of households did not have latrine facilities and 91.38% had separate kitchens. Only 24.75% of households were using LPG for cooking.

Anthropometric characteristics

Anthropometric characteristics among the studied Muslim preschool children are depicted in Table 3. There were increasing trends in height and weight with increasing age. Apparently, males were taller and heavier than females. Age-specific significant sex differences in mean height ($t=3.09$; $p=<0.01$) and weight ($t=3.16$; $p=<0.01$) were noticed at the age of 24–35 months. Overall, the males were significantly heavier ($t=2.26$, $p=<0.05$) than femlaes. Significant age variations in mean height (Males-F=134.32,

$p<0.001$; Females-F=148.03, $p<0.001$) and weight (Males-F=440.89, $p<0.001$; Females-F=552.26, $p<0.001$) were also found among the study participants.

Table 2. Socio-demographic characteristics of the study population

Background Characteristics		Frequency	Percent (%)
Mother's Age at Marriage	Child Marriage	439	54.88
	Adult Marriage	361	45.13
Mother's age at Childbirth	20 years and below	486	60.75
	21 years and above	314	39.25
Birth Order	1st	361	45.13
	2nd and Subsequent	439	54.88
Sibling	No Sibling	326	40.75
	Having Sibling	474	59.25
Birth Weight	2.5 kg and above	605	75.63
	Less than 2.5 kg	195	24.38
Exclusive Breastfeeding	Yes	680	85.00
	No	120	15.00
Number of Family Members	4 & below	415	51.88
	5 & above	385	48.13
Monthly Household Income	Rs below 6500	204	25.50
	Rs 6501 to 9000	290	36.25
	Rs more than 9001	306	38.25
Father's Occupation	Casual	399	49.88
	Self	266	33.25
	Regular	135	16.88
Father's Education	Primary	344	43.00
	Upper primary & above	456	57.00
Mother's Education	Upper primary & lower	410	51.25
	High school & above	390	48.75
Latrine facility	Yes	636	79.50
	No	164	20.50
Separate Kitchen	Yes	731	91.38
	No	69	8.63
Cooking Fuel	Gas	198	24.75
	Fairwood or leaves	602	75.25

Table 3. Anthropometric characteristics of the study participants

Age (Months)	Sex	No	Weight Mean (SD)	t-test	Height Mean (SD)	t-test
12–23	Males	100	9.29(1.54)	1.54	77.53(5.30)	1.7
	Females	100	8.96(1.42)		76.33(4.73)	
24–35	Males	100	11.16(1.71)	3.09**	87.84(5.02)	3.16**
	Females	100	10.43(1.62)		85.75(4.31)	
36–47	Males	100	12.58(1.82)	1.04	95.20(4.36)	1.43
	Females	100	12.33(1.66)		94.28(4.72)	
48–59	Males	100	13.99(1.85)	0.99	100.91(4.47)	-1.5
	Females	100	13.71(2.09)		101.91(4.98)	

Age (Months)	Sex	No	Weight Mean (SD)	t-test	Height Mean (SD)	t-test
Age Combined	Males	400	11.75(2.45)	2.26*	90.37(9.98)	1.1
	Females	400	11.36(2.49)		89.57(10.64)	
	Males		F=134.32***		F=440.89***	
	Females		F=148.03***		F=552.26***	

Level of significance: *p<0.05, **p<0.001, ***p<0.00

Prevalence of undernutrition

The overall prevalence of stunting among the studied preschool children was 23.0% and there was no sex difference in the prevalence of stunting (Table 4). According to WHO (1995), the severity of stunting among the studied preschool children was medium. The overall prevalence of wasting was 30.5% and males (32.8%) were more wasted compared to females (28.8%) (table 4). The prevalence shows that the rate of wasting is a critical situation (29) and males and females show similar rates of wasting. The overall prevalence of underweight was 36.0% and the sex-specific prevalence of underweight was high among males (37.3%) compared to females (34.8%). The prevalence of underweight also indicates that the severity of undernutrition was very high (WHO 1995) among the studied Muslim preschool children.

Table 4. Prevalence of undernutrition (stunting, Wasting and underweight) among the Bengalee Muslim preschool children

Category of undernutrition	Sex	Prevalence	χ^2
Stunting	Males	23.00% (92)	0.001
	Females	23.00% (92)	
	Overall	23.00% (184)	
Wasting	Males	32.75% (131)	1.91
	Females	28.75% (113)	
	Overall	30.50% (244)	
Underweight	Males	37.25% (149)	0.54
	Females	34.75% (139)	
	Overall	36.00% (288)	

Association between undernutrition and socio-demographic factors

The results of chi-square test are represented in Table 5. There were fourteen socio-demographic variables under consideration. The results revealed that mother's age at marriage (χ^2=5.61; p<0.01), mother's age at childbirth (χ^2=9.83; p<0.001), birth order (χ^2=5.61; p<0.01), siblings (χ^2=4.93; p<0.05), birth weight (χ^2=4.76; p<0.05), breastfeeding (χ^2=73.35; p<0.001), monthly household income (χ^2=6.44; p<0.01), father's occupation (χ^2=8.19; p<0.01), father's education (χ^2=4.78; p<0.05) and cooking fuel (χ^2=4.21; p<0.05) were significantly associated with stunting status of the studied preschool children. Furthermore, wasting is also significantly associated with twelve socio-demographic variables. Mother's age at marriage (χ^2=8.69; p<0.01), mother's age at childbirth (χ^2=9.67; p<0.001), birth order (χ^2=6.18; p<0.05), siblings (χ^2=7.42; p<0.01), birth weight (χ^2=10.98; p<0.001), breastfeeding (χ^2=12.44; p<0.001), number of household members (χ^2=40.89; p<0.001) monthly household income (χ^2=57.93; p<0.001), father's education (χ^2=4.77; p<0.05), mother's education (χ^2=37.67; p<0.001), separate kitchens (χ^2=6.00; p<0.05) and cooking fuel (χ^2=4.86; p<0.05) were significantly associated with wasting status of the children. Moreover, underweight was also significantly associated with the mother's age at marriage (χ^2=9.63; p<0.01), mother's age at childbirth (χ^2=14.27; p<0.001), birth order

(χ^2=15.93; p<0.001), siblings (χ^2=14.45; p<0.001), birth weight (χ^2=6.45; p<0.05), breastfeeding (χ^2=24.10; p<0.001), number of household members (χ^2=40.89; p<0.001), monthly household income (χ^2=34.12; p<0.001), father's occupation (χ^2=6.55; p<0.05), father's education (χ^2=3.83; p<0.05), mother's education (χ^2=22.80; p<0.001), latrine facilities (χ^2=5.91; p<0.05), separate kitchens (χ^2=7.11; p<0.05) and cooking fuel (χ^2=11.98; p<0.01).

Table 5. Relationship between socio-demographic variables and undernutrition among the preschool children

`		Stunting	χ2	Wasting	χ2	Underweight	χ2
Mother's Age at Marriage	Child Marriage	26.20%	**5.61****	34.85%	**8.69****	40.77%	**9.63****
	Adult Marriage	19.11%		25.21%		30.19%	
Mother's age at Childbirth	20 years & below	26.75%	**9.83*****	34.57%	**9.67****	41.15%	**14.27*****
	21 years & above	17.20%		24.20%		28.03%	
Birth Order	1st	19.11%	**5.61****	26.04%	**6.18***	28.53%	**15.93*****
	2nd and more	26.20%		34.17%		42.14%	
Sibling	No Sibling	19.02%	**4.93***	25.15%	**7.42****	28.22%	**14.45*****
	Having Sibling	25.74%		34.18%		41.35%	
Birth Weight	2.5 kg and above	21.16%	**4.76***	27.44%	**10.98*****	33.55%	**6.45***
	Less than 2.5 kg	28.72%		40.00%		43.59%	
Breastfeeding	Yes	17.65%	**73.35*****	28.09%	**12.44*****	32.50%	**24.10*****
	No	53.33%		44.17%		55.83%	
Number of Household Members	4 & below	22.89%	0.06	20.48%	**40.89*****	33.25%	2.82
	5 & above	23.12%		41.30%		38.96%	
Monthly Household Income	Rs below 6500	28.92%	**6.44****	50.98%	**57.93*****	51.47%	**34.12*****
	Rs 6501 to 9000	22.76%		27.24%		35.52%	
	Rs more than 9001	19.93%		19.93%		26.14%	
Father's Occupation	Casual	26.07%	**8.19****	32.33%	1.41	39.85%	**6.55***
	Self	22.93%		29.32%		34.21%	
	Regular	14.07%		27.41%		28.15%	
Father's Education	Primary	26.74%	**4.78***	34.59%	**4.77***	39.83%	**3.83***
	Upper primary & above	20.18%		27.41%		33.11%	
Mother's Education	Upper primary & lower	23.66%	0.206	40.24%	**37.67*****	43.90%	**22.80*****
	High school & above	22.31%		20.26%		27.69%	
Latrine facility	Yes	21.70%	2.97	29.56%	1.29	33.96%	**5.91***
	No	28.05%		34.15%		43.90%	
Separate Kitchen	Yes	22.71%	0.41	29.27%	**6.00***	34.61%	**7.11****
	No	26.09%		43.48%		50.72%	
Cooking Fuel	Gas	17.68%	**4.21***	24.24%	**4.86***	25.76%	**11.98*****
	Fairwood or leaves	24.75%		32.56%		39.37%	

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

The relationship between undernutrition and socio-demographic factors

The results of the binary logistics regression analyses are depicted in Table 6. The findings show the individual risk factors as socio-demographic determinants of undernutrition status of preschool children. The mother's age at marriage less than 18 years were 1.50, 1.59, and 1.59 times higher risk of stunting (O.R=1.50; C.I=1.07–2.11; $p<0.05$), wasting (O.R=1.59; C.I=1.17–2.16; $p<0.01$) and underweight (O.R=1.59; C.I=1.19–2.14; $p<0.01$) compared to the children of the mothers who got marriage at adulthood age. The mother's age at childbirth less than 21 years were 1.76, 1.65 and 1.80 times more at risk of stunting (O.R=1.76; C.I=1.23–2.51; $p<0.01$), wasting (O.R=1.65; C.I=1.20–2.28; $p<0.01$) and underweight (O.R=1.80; C.I=1.32–2.44; $p<0.01$) compared to the mother's age at childbirth 21 years and above years. Second and subsequent children are 1.50, 1.47, and 1.82 times higher prevalence of stunting (O.R=1.50; C.I=1.07–2.11; $p<0.05$), wasting (O.R=1.47; C.I=1.08–2.00; $p<0.05$) and underweight (O.R=1.82; C.I=1.36–2.45; $p<0.001$) rather than the first child. Children with siblings are at 1.48, 1.55 and 1.79 times higher risk of stunting (O.R=1.48; C.I=1.05–2.08; $p<0.05$), wasting (O.R=1.55; C.I=1.13–2.12; $p<0.01$) and underweight (O.R=1.79; C.I=1.32–2.43; $p<0.001$) compared to children with no sibling. Low birthweight children (less than 2.5 kg) are 1.50, 1.76 and 1.53 times more stunting (O.R=1.50; C.I=1.04–2.17; $p<0.05$), wasting (O.R=1.76; C.I=1.26–2.47; $p<0.001$) and underweight (O.R=1.53; C.I=1.10–2.13; $p<0.01$) rather than optimum birthweight children. The children who did not get exclusive breastfeed were 5.33, 2.03, and 2.63 times higher risk of stunting (O.R=5.33; C.I=3.54–8.03; $p<0.001$), wasting (O.R=2.03; C.I=1.36–3.01; $p<0.001$) and underweight (O.R=2.63; C.I=1.77–3.90; $p<0.001$) compared to those children who got exclusive breastfeeding. Large family size was 2.73 times more risk of wasting (O.R=2.73; C.I=2.00–3.74; $p<0.001$) than those who had a small family. Children in lower-monthly household income were at 1.70, 4.18, and 3.00 times higher risk of stunting (O.R=1.70; C.I=1.12–2.58; $p<0.05$), wasting (O.R=4.18; C.I=2.82–6.18; $p<0.001$) and underweight (O.R=3.00; C.I=2.06–4.36; $p<0.001$) compared to children in higher- monthly household income. Children in middle-income group families also face a higher risk of wasting (O.R=1.50; C.I=1.03–2.20; $p<0.05$) and underweight (O.R=1.56; C.I=1.10–2.21; $p<0.05$) compared to children in the higher-income group. Children whose fathers engaged in casual work were 2.15 and 1.69 times more likely to be at risk of stunting (O.R=2.15; C.I=1.26–3.67; $p<0.001$) and underweight (O.R=1.69; C.I=1.11–2.59; $p<0.05$) compared to those whose fathers engaged in regular work. Children with a lower level of father's education were 1.44, 1.40, and 1.34 times higher risk of stunting (O.R=1.44; C.I=1.04–2.01; $p<0.05$), wasting (O.R=1.40; C.I=1.03–1.90; $p<0.05$) and underweight (O.R=1.34; C.I=1.00–1.79; $p<0.05$) compared to higher level-educated father. The lower level of mother education was also a higher risk of wasting (O.R=2.65; C.I=1.93–3.64; $p<0.001$) and underweight (O.R=2.04; C.I=1.52–2.75; $p<0.001$) for children. The prevalence of underweight was 1.52 times higher risk among children in households without latrine facilities compared to those in households with latrine facilities (O.R=1.52; C.I.=1.07–2.16; p=<0.05).

Children in households without separate kitchens were 1.86 and 1.94 times more likely to be at risk of wasting (O.R=1.86; C.I=1.12–3.07; p<0.05) and underweight (O.R=2.04; C.I.=1.18–3.19, p=<0.01) compared to those with separate kitchens. Use of firewood or leaves for cooking were 1.53, 1.51, and 1.87 times higher risk of stunting (O.R=1.53; C.I=1.02–2.31; p<0.05), wasting (O.R=1.51; C.I=1.05–2.18; p<0.05) and underweight (O.R=1.87; C.I=1.31–2.68; p<0.05) compared to those that cook with LPG.

Furthermore, multivariate logistic regression analyses were run to assess the simultaneous impact of different socio-demographic variables on undernutrition (Tables 7, 8 and 9). Regarding stunting, ten significant predictors of earlier statistics had lost their impact due to the influence of the remaining four dominant variables in the multivariate model. Among these four variables, non-exclusive breastfeeding was the most dominant predictor (wald-64.55; Exp (B)-5.69; p<0.001) followed by the second and higher birth order (wald-13.18; Exp (B)-2.01; p<0.001), mother's age at childbirth below 21 years (wald-11.39; Exp (B)-1.96; p<0.001) and low birth weight (wald-5.18; Exp (B)-5.69; p<0.05). The final model (4) also revealed that the percent variation in stunting explained by all these independent variables combined was 16.00 %, and the final model was entirely satisfactory.

Concerning wasting, among twelve significant variables, four socio-demographic variables lost significance due to the influence of the remaining seven variables in the multivariate model. Among these seven variables, lower-income households (Rs below 6500) (wald-46.98; Exp (B)-5.02; p<0.001) are the most dominant predictor followed by fewer household members (4 and below) (Wald-43.39; Exp (B)-3.28; p<0.001), lower level of mother education (below upper primary) (Wald-22.23; Exp (B)-2.33; p<0.001), no separate kitchens (Wald-8.90; Exp (B)-2.43; p<0.01), mother's age at childbirth below 21 years (wald-13.07; Exp (B)-1.97; p<0.001), non-exclusive breastfeeding (Wald-8.06; Exp (B)-1.93; p<0.01), and low birth weight (Wald-9.38; Exp (B)-1.82; p<0.01). The results of the final model show that the percent variation in wasting explained by all these independent variables combined was 22.20 %, and the variation explained in the final model was statistically significant.

Regarding underweight, among thirteen significant variables, five socio-demographic variables lost their significance due to the influence of the remaining eight variables in the multivariate model. Among these eight variables, lower-income households (Rs below 6500) (Wald -22.36; Exp (B)-2.61; p<0.001) was the most dominant predictor followed by non-exclusive breastfeeding (Wald -19.87; Exp (B)-2.63; p<0.001), mother's age at childbirth below 21 years (Wald -16.69; Exp (B)-2.04; p<0.001), second and higher birth order (Wald -16.27; Exp (B)-2.04; p<0.001), no separate kitchens (Wald -7.69; Exp (B)-2.13; p<0.01), lower level of mother education (below upper primary) (Wald -8.81; Exp (B)-1.64; p<0.01), and low birth weight (Wald -4.81; Exp (B)-1.49; p<0.05). Furthermore, the results of the final model also revealed that the percent variation in underweight explained by all these independent variables combined was 17.90%, and the variation explained in the final model was statistically significant.

Table 6. Risk of undernutrition among Muslim children in the study area

Background Characteristics		Stunting O.R (95% of C.I)	Wasting O.R (95% of C.I)	Underweight O.R (95% of C.I)
Mother's Age at Marriage	Child Marriage	1.50 (1.07–2.11)*	1.59 (1.17–2.16)**	1.59 (1.19–2.14)**
	Adult Marriage		Reference	
Mother's age at Childbirth	20 years & below	1.76 (1.23–2.51)**	1.65 (1.20–2.28)**	1.80(1.32–2.44)***
	21 years & above		Reference	
Birth Order	1st		Reference	
	2nd & more	1.50 (1.07–2.11)*	1.47 (1.08–2.00)*	1.82 (1.36–2.45)***
Sibling	No Sibling		Reference	
	Having Sibling	1.48 (1.05–2.08)*	1.55 (1.13–2.12)**	1.79 (1.32–2.43)***
Birth Weight	2.5 kg and above		Reference	
	Less than 2.5 kg	1.50 (1.04–2.17)*	1.76 (1.26–2.47)***	1.53 (1.10–2.13)**
Exclusive Breastfeeding	Yes		Reference	
	No	5.33 (3.54–8.03)***	2.03 (1.36–3.01)***	2.63 (1.77–3.90)***
Number of Family Members	4 & below		Reference	
	5 & above	1.01 (0.73–1.41)	2.73 (2.00–3.74)***	1.28 (0.96–1.71)
Household Income	Rs below 6500	1.70 (1.12–2.58)*	4.18 (2.82–6.18)***	3.00 (2.06–4.36)***
	Rs 6501 to 9000	1.23 (0.83–1.83)	1.50 (1.03–2.20)*	1.56 (1.10–2.21)*
	Rs more than 9001		Reference	
Father's Occupation	Casual	2.15 (1.26–3.67)**	1.27 (0.82–1.95)	1.69 (1.11–2.59)*
	Self	1.82 (1.03–3.19)*	1.10 (0.69–1.74)	1.33 (0.84–2.09)
	Regular		Reference	
Father's Education	Primary	1.44 (1.04–2.01)*	1.40 (1.03–1.90)*	1.34 (1.00–1.79)*
	Upper primary & above		Reference	
Mother's Education	Upper primary & lower	1.08 (0.78–1.50)	2.65 (1.93–3.64)***	2.04 (1.52–2.75)***
	High school & above		Reference	
Latrine facility	Yes		Reference	
	No	1.41 (0.95–2.08)	1.24 (0.86–1.78)	1.52 (1.07–2.16)*
Separate Kitchen	Yes		Reference	
	No	1.20 (0.68–2.11)	1.86 (1.12–3.07)*	1.94 (1.18–3.19)**
Cooking Fuel	Gas		Reference	
	Fairwood or leaves	1.53 (1.02–2.31)*	1.51 (1.05–2.18)*	1.87 (1.31–2.68)***

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Table 7. Multivariate logistic regression analyses between stunting (dependent outcome variables) and socio-demographic variables among the studied preschool children

Background Characteristics		Model-1		Model-2		Model-3		Model-4	
		Wald	Exp(B) (95% of C.I.)	Wald	Exp(B) (95% of C.I.)	Wald	Exp(B) (95% of C.I.)	Wald	Exp(B) (95% of C.I.)
Exclusive Breastfeeding	Yes				Reference				
	No	64.27	5.33 (3.54–8.03) ***	66.63	5.67 (3.74–8.59) ***	63.29	5.52 (3.62–8.40) ***	64.55	5.69 (3.72–8.69) ***
Birth Order	1				Reference				
	2 and above			8.43	1.70 (1.19–2.44) **	13.80	2.04 (1.40–2.97) ***	13.18	2.01 (1.38–2.93) ***
Age of Mother at Childbirth	21 years and above				Reference				
	20 years and below					12.03	1.99 (1.35–2.93)***	11.39	1.96 (1.33–2.90) ***
Birth Weight	2.5 kg and above				Reference				
	less than 2.5 kg							5.18	1.58 (1.07–2.33) *
R^2			0.115		0.130		0.152		0.160

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Table 8. Multivariate logistic regression analyses between wasting (dependent outcome variables) and socio-demographic variables among the studied preschool children

Background Characteristics		Model-1		Model-2		Model-3		Model-4	
		Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)
Household Income	More Rs than 9001				Reference				
	Rs below 6500	50.98	4.18 (2.82–6.18)***	53.35	4.55 (3.03–6.84)***	45.23	4.13 (2.73–6.24)***	44.38	4.14 (2.72–6.28)***
	Rs 6501 to 9000	4.39	1.50 (1.03–2.20)*	8.12	1.78 (1.20–2.64)**	6.29	1.67 (1.12–2.49)*	6.48	1.69 (1.13–2.54)*
Number of Family Members	4 & below				Reference				
	5 & above			40.58	2.91 (2.10–4.05)***	36.18	2.78 (1.99–3.89)***	42.39	3.14 (2.22–4.43)***
Mother's Education	High school & above				Reference				
	Upper primary& above					24.09	2.31 (1.65–3.22)***	24.16	2.34 (1.67–3.28)***
Age of Mother at Childbirth	21 years and above				Reference				
	20 years and below							15.09	2.02 (1.42–2.89)***
Separate Kitchen	Yes								
	No								
Birth Weight	2.5 kg and above								
	less than 2.5 kg								
Exclusive Breastfeeding	Yes								
	No								
Father's Occupation	Regular								
	Casual								
	Self								
R^2		0.095		0.164		0.202		0.225	

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Table 8. (cont.)

Background Characteristics		Model-5		Model-6		Model-7		Model-8	
		Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)
Household Income	More than Rs 9001				Reference				
	below Rs 6500	45.39	4.26 (2.79–6.49)***	46.10	4.36 (2.85–6.66)***	42.77	4.16 (2.72–6.38)***	46.98	5.02 (3.17–7.96)***
	Rs 6501 to 9000	7.05	1.74 (1.16–2.61)**	7.53	1.77 (1.18–2.67)**	6.92	1.74 (1.15–2.62)**	8.97	1.94 (1.26–3.01)**
Number of Family Members	4 & below				Reference				
	5 & above	43.02	3.19 (2.26–4.52)***	42.98	3.21 (2.27–4.55)***	41.93	3.18 (2.24–4.52)***	43.39	3.28 (2.30–4.67)***
Mother's Education	High school & above				Reference				
	Upper primary& above	25.24	2.40 (1.71–3.38)***	23.25	2.33 (1.65–3.28)***	24.34	2.39 (1.69–3.38)***	22.23	2.33 (1.64–3.31)***
Age of Mother at Childbirth	21 years and above				Reference				
	20 years and below	14.11	1.99 (1.39–2.84)***	13.48	1.96 (1.37–2.82)***	11.85	1.89 (1.32–2.72)***	13.07	1.97 (1.36–2.84)***
Separate Kitchen	Yes				Reference				
	No	8.18	2.28 (1.30–4.01)**	8.02	2.27 (1.29–4.02)**	7.69	2.25 (1.27–3.98)**	8.90	2.43 (1.36–4.36)**
Birth Weight	2.5 kg and above				Reference				
	less than 2.5 kg			7.96	1.72 (1.18–2.51)**	8.51	1.76 (1.20–2.57)**	9.38	1.82 (1.24–2.67)**
Exclusive Breastfeeding	Yes				Reference				
	No					7.47	1.87 (1.19–2.94)**	8.06	1.93 (1.23–3.03)**
Father's Occupation	Regular				Reference				
	Casual							3.88	0.59 (0.35–0.0998)*
	Self							6.04	0.50 (0.29–0.87)*
R^2			0.237		0.249		0.259		0.268

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Table 9. Multivariate logistic regression analyses between underweight (dependent outcome variables) and socio-demographic variables among the studied preschool children

Background Characteristics		Model-1		Model-2		Model-3		Model-4	
		Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)
Household Income	More than Rs 9001				Reference				
	Below Rs 6500	32.95	3.00 (2.06–4.36)***	28.81	2.83 (1.94–4.14)***	23.31	2.59 (1.76–3.80)***	22.94	2.58 (1.75–3.80)***
	Rs 6501 to 9000	6.11	1.56 (1.10–2.21)*	5.36	1.52 (1.07–2.17)*	4.41	1.47 (1.03–2.10)*	4.30	1.47 (1.02–2.10)*
Exclusive Breastfeeding	Yes				Reference				
	No			18.67	2.43 (1.62–3.64)***	20.57	2.58 (1.71–3.89)***	18.45	2.48 (1.64–3.75)***
Mother's Education	High school & above				Reference				
	Upper primary& above					18.86	1.98 (1.45–2.69)***	18.53	1.97 (1.45–2.69)***
Age of Mother at Childbirth	21 years and above				Reference				
	20 years and below							18.45	2.48 (1.64–3.75)***
Birth Order	1st								
	2nd and subsequent								
Separate Kitchen	Yes								
	No								
Birth Weight	2.5 kg and above								
	Less than 2.5 kg								
R^2		0.057		0.087		0.118		0.135	

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Table 9. (cont.)

Background Characteristics		Model-5		Model-6		Model-7	
		Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)	Wald	Exp(B) (95% of C.I)
Household Income	More than Rs 9001			Reference			
	Below Rs 6500	21.23	2.51 (1.70–3.72)***	22.02	2.58 (1.74–3.83)***	22.36	2.61 (1.75–3.88)***
	Rs 6501 to 9000	2.92	1.38 (0.95–1.99)	3.43	1.42 (0.98–2.05)	3.84	1.45 (1.00–2.10)*
Exclusive Breastfeeding	Yes			Reference			
	No	19.57	2.59 (1.70–3.94)***	19.24	2.58 (1.69–3.94)***	19.87	2.63 (1.72–4.03)***
Mother's Education	High school & above			Reference			
	Upper primary& above	9.12	1.64 (1.19–2.27)**	9.56	1.67 (1.21–2.31)**	8.81	1.64 (1.18–2.27)**
Age of Mother at Childbirth	21 years and above			Reference			
	20 years and below	18.33	2.10 (1.49–2.95)***	17.39	2.07 (1.47–2.91)***	16.69	2.04 (1.45–2.88)***
Birth Order	1^{st}			Reference			
	2^{nd} and above	16.42	2.03 (1.44–2.86)***	16.54	2.05 (1.45–2.89)***	16.27	2.04 (1.44–2.88)***
Separate Kitchen	Yes			Reference			
	No			7.85	2.15 (1.26–3.66)**	7.69	2.13 (1.25–3.65)**
Birth Weight	2.5 kg and above			Reference			
	less than 2.5kg					4.81	1.49 (1.04–2.12)*
R^2		0.160		0.172		0.179	

Level of significance- *=p<0.05, **=<0.01 and ***=<0.001

Discussion

Better health status brings good human resources which adhere to the nation's well-being, whereas under five children are the base of the developing nation's demography, and well-nourished preschool children are the mirror of the nation's development. Although, the major causes of under-five morbidity and mortality is undernutrition (Hossain et al. 2023) in developing countries, including India (Benson and Shekar 2006). They may have chronic illness and physical disabilities compared to normal children (Asfaw et al. 2015). This study aims to observe the impacts of socio-demographic variables on undernutrition based on stunting, wasting, and underweight among rural Muslim preschool children. The prevalence of undernutrition was high in the studied children. Wasting refers to a critical life-threatening indicator, and it significantly elevates the risk of mortality if not effectively managed with proper treatment (Black et al. 2013). Underweight seems to be a significant contributing factor in child mortality globally, with an exceptionally high impact in developing countries (Chowdhury et al. 2018; Hossain et al. 2023).

The major findings of the present study revealed that socio-demographic variables were significantly associated with the undernutrition status of and predicted the nutritional status of the children. After designing several models using multivariate analysis, the results indicate that breastfeeding, birth order, age of mother at childbirth, birth weight, household income, number of family members, mother's education, separate kitchen, and father's occupation were the strong predictors of undernutrition among rural Muslim preschool children in the study area. Early childbearing is a significant issue in developing countries. Globally, 11% of births are to adolescent mothers, and developing nations contribute 95% of these births (WHO 2011). Early motherhood also raises the risk of premature birth, low birth weight, undernutrition, frequent illness, infant mortality, and poor growth in children (Tarigan et al. 2023; Fall et al. 2015). The present study also shows the same result. Twenty years of age of the mother at childbirth is the third strongest predictor of stunting and underweight and the fourth strongest predictor for wasting among Muslim preschool children. Birth order plays a crucial role in child undernutrition. Several studies have thoroughly documented that children with higher birth order face a greater risk of undernutrition compared to those of lower birth order (Rahman 2016; Dharmaraj et al. 2021; Dhingra and Pingali 2021). Higher birth order was the second most significant predictor of stunting and fourth for underweight among children in the study area.

According to WHO guidelines (2023), children born weighing less than 2.5 kg are classified as having low birth weight (WHO 2023c). Low birth weight significantly increases health risks in children as well as it is associated with undernutrition, different diseases (cough, diarrhoea, pneumonia), delayed growth and development, and the risk of mortality (Ntenda 2019; Jana et al. 2023). It is a leading cause of half of all premature deaths (Jana, Dey, and Ghosh 2023). In the study area, 24.38% of Muslim children are born with low birth weight, and models indicate that low birth weight is one of the strong predictors of stunting, wasting, and underweight. Exclusive breastfeeding plays a critical role in infants' health and in sustaining optimum nutritional status in children (WHO 2023a). Children breastfed for less than 6 months are at risk of poor nutritional status along with higher rates of mortality and morbidity (Syeda et al. 2021; Scherbaum and Srour 2016). Several studies have found that it is one of the predictors of child undernutrition (Akter 2021; Khan and Islam 2017; Kumar and Singh 2015; Pereira et al. 2021). In the study, non-exclusive breastfeeding was the strongest predictor of stunting and the second strongest predictor of underweight. Income played a significant role in maintaining good health. Without economic self-sufficiency, a household cannot sustain the necessary quality and quantity of food required for balanced nutrition (Raghunathan et al. 2021). In developing countries, the majority of children face a high prevalence of undernutrition, which significantly delays their growth (McGovern et al. 2017; Rahma and Mutalazimah 2022). High household incomes contribute to better food quality, safe drinking water, improved sanitation, and the well-being of a family, which is related to child nutrition (Singh et al., 2019).

Multivariate regression suggests that household income is the strongest predictor of wasting and underweight. Large family members also influence the child's undernutrition, but this relationship is complex and influenced by socio-economic conditions and cultural practices (Faye, Fonn, and Kimani-Murage 2019). Several previous studies reported that children in large families are more likely to experience undernutrition compared to children in small families (Ahmed et al. 2016; Ghimire et al. 2020; Mandosir et al. 2023; Toma et al. 2023). The number of household members is the second strongest predictor of wasting among Muslim preschool children. Mother education plays a significant role in influencing undernutrition and is crucial for its reduction and prevention (Makoka and Masibo 2015; Prasetyo et al. 2023). An educated mother has been found to have an understanding of the importance of hygienic food, good feeding practices, recognition and causes of diseases, means of prevention and health management for their child, as well as other activities that promote the well-being of the child's health (Khattak et al. 2017; Kavosi et al. 2014). Mother education was the third strongest predictor of wasting and the fifth of being underweight. Occupation influences income, access to health care services, and quality and quantity of food available (Babar et al. 2010; Abraham et al. 2015; WHO 2017). Low-income households often struggle to provide nutritious food and cover medical expenses for their children, resulting in undernutrition (French et al. 2019). Therefore, child undernutrition is very high in developing countries, including India (Vyas et al. 2011).

This study also suggests that the father's occupation is one of the strongest predictors of wasting and the second strongest predictor of being underweight, and fathers seem to be the main earning member of the family. World Health Organization (2023) states that air pollution within the household was responsible for an estimated 3.2 million deaths of children under the age of 5 years (WHO 2023b), and cooking in living rooms may be the primary cause of household air pollution. Although the present study did not estimate household pollution, the relationship between smoking and undernutrition has not been examined. This study treats separate kitchens as socio-economic indicators. However, a study also reported that children from households without separate kitchens have frequently experienced undernutrition (Mondal and Paul 2020). The present study also found that a separate kitchen is one of the strongest predictors of wasting and being underweight. This determinant is considered a proxy indicator of socio-economic status. The present study revealed that there are several determinants of the different forms of undernutrition among the studied children. These determents comprise socio-economical, demographic as well as socio-behavioral. The optimal living standards are very scarce among the studied children. The economic upliftment may bring the optimal living standard which accompanies the good health and nutritional status of the younger children.

Conclusion

The present study finds that undernutrition seems to be a serious health among rural Muslim preschool children in the study area. Exclusive breastfeeding, household income, mother's age at childbirth, birth weight, maternal educational status, household income, separate kitchen, and birth order are significant predictors of childhood nutritional status. Therefore, the appropriate authorities should take effective policies of skill enhancement programs aimed at boosting household income, which can directly contribute to better nutritional outcomes. Additionally, the government should actively promote awareness programs that focus on educating communities about essential issues like the importance of exclusive breastfeeding, low birth weight, child health, eliminating child marriage, mother education, and family planning. Also, promoting the involvement of Non-government Organizations (NGOs) is a prerequisite for implementing different awareness programs and strategies to improve child health and nutritional status.

Institutional Ethical Approval

The present study was approved by the Institutional Ethical Committee of the Institution of the Sidho-Kanho-Birsha University (Ref. No. R/IEC/406/SKBU/2023 dated 24.03.2023, with effect from July 2022). The information provided by participants was kept confidential by excluding personal identifiers from the schedule. Parents of the children's convenience was a priority in this study during data collection, and we respected their rights as participants. We also confirm that all methods and procedures were carried out in accordance with the relevant guidelines and regulations (Helsinki Declaration).

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Authors' contributions

SAH: Originated study ideas, drafted and designed research, performed the statistical analysis and interpretation of results and primarily drafted a manuscript. MDA: Compiled and designed the study, providing direction and supervision. KB: Revised the manuscript. SB supervised the study and finalized the manuscript.

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References

Abraham EM, Martin AM, Cofie O, Raschid-Sally L. 2015. Urban households' access to water for livelihoods enhancement in Accra, Ghana. Waterlines 34(2):139–155. https://doi.org/10.3362/1756-3488.2015.014

Abuya BA, Ciera J, Kimani-Murage E. 2012. Effect of mother's education on child's nutritional status in the slums of Nairobi. BMC Paediatr 12(80):1–10. https://doi.org/10.1186/1471-2431-12-80

Ahmed MM, Hokororo A, Kidenya BR, Kabyemera R, Kamugisha E. 2016. Prevalence of undernutrition and risk factors of severe undernutrition among children admitted to Bugando Medical Centre in Mwanza, Tanzania. BMC Nutr 2(49):1–6. https://doi.org/10.1186/s40795-016-0090-6

Akter K. 2021. The association between exclusive breastfeeding and nutritional status among infants under six months of age in Bangladesh: A secondary analysis of Bangladesh Demographic and Health Survey.

Ali Z, Saaka M, Adams AG, Kamwininaang SK, Abizari AR. 2017. The effect of maternal and child factors on stunting, wasting and underweight among preschool children in Northern Ghana. BMC Nutr 3(1):1–13. https://doi.org/10.1186/s40795-017-0154-2

Asfaw M, Wondaferash M, Taha M, Dube L. 2015. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. BMC Public Health 15(41):1–9. https://doi.org/10.1186/s12889-015-1370-9

Babar NF, Muzaffar R, Khan MA, Imdad S. 2010. Impact of socioeconomic factors on nutritional status in primary school children. J Ayub Med Coll Abbottabad 22(4):15–8.

Benson T, Shekar M. 2006. Trends and Issues in Child Undernutrition. The World Bank 87–106.

Bhattacharya A, Pal B, Mukherjee S, Roy SK. 2019. Valoración del estado nutricional mediante variables antropométricas mediante análisis multivariado. BMC Public Health 19:1–9. https://doi.org/10.1186/s12889-019-7372-2

Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet 382:427–51. https://doi.org/10.1016/S0140-6736(13)60937-X

Brown ME, Backer D, Billing T, White P, Grace K, Doocy S, et al. 2020. Empirical studies of factors associated with child malnutrition: highlighting the evidence about climate and conflict shocks. Food Secur 12:1241–52. https://doi.org/10.1007/s12571-020-01041-y

Census of India. 2011. District Census Handbook: West Bengal. Directorate of Census Operations.

Chowdhury TR, Chakrabarty S, Rakib M, Saltmarsh S, Davis KA. 2018. Socio-economic risk factors for early childhood underweight in Bangladesh. Glob Health 14(54):1–12. https://doi.org/10.1186/s12992-018-0372-7

Cochran WG. 1963. Sampling Techniques. Wiley, New York.

Devine J, Wood G, Goto R, da Corta L. 2014. Health and Wellbeing in the Lives of the Extreme Poor. DFID, GoB. http://r4d.dfid.gov.uk/Output/199586/Default.aspx

Dharmaraj A, Ghimire A, Chinnaiyan S, Tiwari AK, Barik RK. 2021. Comparison of Growth in Children of 6 to 59 Months of Age According to Birth Order: Insights from the National Family Health Survey-4. J Clin Diagnos Res 15(8):25–32. https://doi.org/10.7860/JCDR/2021/49080.15301

Dhingra S, Pingali PL. 2021. Effects of short birth spacing on birth-order differences in child stunting: Evidence from India. Proc Natl Acad Sci 118(8):1–8. https://doi.org/10.1073/pnas.2017834118

Duminy J, Ezeh A, Galea S, Harpham T, Montgomery MR, Salas JMI, et al. 2023. Demographic change and urban health: Towards a novel agenda for delivering sustainable and healthy cities for all. F1000Research 12(1017). https://doi.org/10.12688/f1000research.139309.2

Fall CHD, Sachdev HS, Osmond C, Restrepo-Mendez MC, Victora C, Martorell R, et al. 2015. Association between maternal age at childbirth and child and adult outcomes in the offspring: A prospective study in five low-income and middle-income countries (COHORTS collaboration). Lancet Glob Health 3:e366–77. https://doi.org/10.1016/S2214-109X(15)00038-8

FAO. 2023. The State of Food Security and Nutrition in the World. Food and Agriculture Organization of the United Nations.

Faye CM, Fonn S, Kimani-Murage E. 2019. Family influences on child nutritional outcomes in Nairobi's informal settlements. Child Care Health Development 45:509–17. https://doi.org/10.1111/cch.12670

French SA, Tangney CC, Crane MM, Wang Y, Appelhans BM. 2019. Nutrition quality of food purchases varies by household income : the SHoPPER study. BMC Public Health 19(231):1–7. https://doi.org/10.1186/s12889-019-6546-2

Ghimire U, Aryal BK, Gupta AK, Sapkota S. 2020. Severe acute malnutrition and its associated factors among children under-five years: A facility-based cross-sectional study. BMC Pediatr 20(249):1–9. https://doi.org/10.1186/s12887-020-02154-1

Ghosh P. 2023. Undernutrition Among the Children from Different Social Groups in India: Prevalence, Determinants, and Transition Over Time (2005–2006 to 2019–2021). J Racial Ethn Heal Disparities. 11(6):3427–3444. https://doi.org/10.1007/s40615-023-01796-y

Groce N, Challenger E, Berman-Bieler R, Farkas A, Yilmaz N, Schultink W, et al. 2014. Malnutrition and disability: Unexplored opportunities for collaboration. Paediatr Int Child Health 34(4):308–14. https://doi.org/10.1179/2046905514Y.0000000156

Hossain MM, Abdulla F, Rahman A. 2023. Prevalence and risk factors of underweight among under-5 children in Bangladesh: Evidence from a countrywide cross-sectional study. PLoS One 18(4):1–15. https://doi.org/10.1371/journal.pone.0284797

IIPS. National Family Health Survey (NFHS-5), 2019–21. 2020. Demographic and health surveys.

Jana A, Dey D, Ghosh R. 2023. Contribution of low birth weight to childhood undernutrition in India: evidence from the national family health survey 2019–2021. BMC Public Health 23(1336):1–14. https://doi.org/10.1186/s12889-023-16160-2

Kang Y, Kim J. 2019. Risk factors for undernutrition among children 0–59 months of age in Myanmar. Matern Child Nutr e12821:1–13. https://doi.org/10.1111/mcn.12821

Kavosi E, Rostami ZH, Kavosi Z, Nasihatkon A, Moghadami M. 2014. Original Article Prevalence and determinants of under-nutrition among children under six: a cross-sectional survey in Fars province, Iran. Int J Heal Policy Manag 3(2):71–6. https://doi.org/10.15171/ijhpm.2014.63

Khan MN, Islam MM. 2017. Effect of exclusive breastfeeding on selected adverse health and nutritional outcomes: A nationally representative study. BMC Public Health 17(889):1–7. https://doi.org/10.1186/s12889-017-4913-4

Khattak UK, Iqbal SP, Ghazanfar H. 2017. The Role of Parents' Literacy in Malnutrition of Children Under the Age of Five Years in a Semi-Urban Community of Pakistan : A Case-Control Study. Cureus 9(6):1–10. https://doi.org/10.7759/cureus.1316

Kumar A, Singh VK. 2015. A Study of Exclusive Breastfeeding and its impact on Nutritional Status of Child in EAG States. J Stat Appl Probab 4(3):435–45. https://doi.org/10.12785/jsap/040311

Lohman TG, Roche AF, Martorell R. 1988. Anthropometric Standardization Reference Manual. Hum Kinet Books.

Makoka D, Masibo PK. 2015. Is there a threshold level of maternal education sufficient to reduce child undernutrition? Evidence from Malawi, Tanzania and Zimbabwe. BMC Pediatricts 15(96):1–10. https://doi.org/10.1186/s12887-015-0406-8

Mandosir YM, Irab SP, Mollet G, Irmanto M, Palela D, Renyaan D, et al. 2023. Factors Influencing the Occurrence of Malnutrition on Under-Fives Aged 12–59 Months in Jayapura, Papua. Univers J Public Health 11(5):647–54. https://doi.org/10.13189/ujph.2023.110513

McGovern ME, Krishna A, Aguayo VM, Subramanian S V. 2017. A review of the evidence linking child stunting to economic outcomes. Int J Epidemiol 0(0):1–21. https://doi.org/10.1093/ije/dyx017

Mondal D, Paul P. 2020. Effects of indoor pollution on acute respiratory infections among under-five children in India: Evidence from a nationally representative population-based study. PLoS One 15(8 August):1–13. https://doi.org/10.1371/journal.pone.0237611

Murarkar S, Gothankar J, Doke P, Pore P, Lalwani S, Dhumale G, et al. 2020. Prevalence and determinants of undernutrition among under-five children residing in urban slums and rural area, Maharashtra, India: a community-based cross-sectional study. BMC Public Health 20(1559):1–9. https://doi.org/10.1186/s12889-020-09642-0

Ntenda PAM. 2019. Association of low birth weight with undernutrition in preschool-aged children in Malawi. Nutr J 18(51):1–15. https://doi.org/10.1186/s12937-019-0477-8

Pereira ATDM, Freire KAG, Goncalves V. 2021. Exclusive Breastfeeding And Underweight In Children Under Six Months Old Monitored In Primary Health Care In Brazil, 2017. Rev Paul Pediatr 39:1–9. https://doi.org/10.1590/1984-0462/2021/39/201929

Prasetyo YB, Permatasari P, Susanti HD. 2023. The effect of mothers ' nutritional education and knowledge on children's nutritional status : a systematic review. Int J Child Care Educ Policy 17(11):1–16. https://doi.org/10.1186/s40723-023-00114-7

Prime Minister High Level Committee. 2006. Social, Economic and Education Status of the Muslim Community of India.

Raghunathan K, Headey D, Herforth A. 2021. Affordability of nutritious diets in rural India. Food Policy 99. https://doi.org/10.1016/j.foodpol.2020.101982

Rahma IM, Mutalazimah M. 2022. Correlation between Family Income and Stunting among Toddlers in Indonesia: A Critical Review. Adv Heal Sci Res 49:78–86. https://doi.org/10.2991/ahsr.k.220403.011

Rahman M. 2016. Associação entre ordem de nascimento e desnutrição crônica em crianças: Estudo de uma amostra nacional representativa em Bangladesh. Cad Saude Publica 32(2):1–12. https://doi.org/10.1590/0102-311X00011215

Scherbaum V, Srour ML. 2016. The role of breastfeeding in the prevention of childhood malnutrition. World Rev Nutr Diet 115:82–97. https://doi.org/10.1159/000442075

Singh S, Srivastava S, Upadhyay AK. 2019. Socio-economic inequality in malnutrition among children in India: An analysis of 640 districts from National Family Health Survey (2015–16). Int J Equity Health 18(203):1–9. https://doi.org/10.1186/s12939-019-1093-0

Singh SK, Chauhan A, Alderman H, Avula R, Dwivedi LK, Kapoor R, et al. 2024. Utilization of Integrated Child Development Services (ICDS) and its linkages with undernutrition in India. Matern Child Nutrition 20(e13644). https://doi.org/10.1186/s12939-019-1093-0

Syeda B, Agho K, Wilson L, Maheshwari GK, Raza MQ. 2021. Relationship between breastfeeding duration and undernutrition conditions among children aged 0–3 Years in Pakistan. Int J Paediatric Adolescent Medical 8:10–7. https://doi.org/10.1016/j.ijpam.2020.01.006

Tarigan N, Simanjuntak RR, Nainggolan O. 2023. Maternal Age at Birth and Low Birth Weight (Lbw) in Indonesia (Analysis of Riskesdas 2018). Gizi Indonesia 46(1):1–10. https://doi.org/10.36457/gizindo.v46i1.694

Toma TM, Andargie KT, Alula RA, Kebede BM, Gujo MM. 2023. Factors associated with wasting and stunting among children aged 06–59 months in South Ari District, Southern Ethiopia: a community-based cross-sectional study. BMC Nutr 9(34):1–16. https://doi.org/10.1186/s40795-023-00683-3

Vyas S, Kandpal SD, Semwal J. 2011. Article Role of Maternal Education & Occupation in the nutritional status of under three children. Indian J Community Health 22(2):2010–2.

WHO. 1995. Nutrition Landscape Information System (NLIS). www.who.int/nutrition

WHO. 2003. Poverty and health. OECD.

WHO. 2011. Preventing Early Pregnancy and Poor Reproductive Outcomes. 2011. http://whqlibdoc.who.int/publications/2011/9789241502214_eng.pdf?ua=1

WHO. 2017. Determinants of health. https://www.who.int/news-room/questions-and-answers/item/determinants-of-health

WHO. 2022. Malnutrition. https://www.who.int/health-topics/micronutrients#tab=tab_1

WHO. 2023. Breastfeeding. https://www.who.int/health-topics/breastfeeding#tab=tab_1

WHO. 2023. Household air pollution. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

WHO. 2023. Low Birth Weight. https://www.who.int/data/nutrition/nlis/info/low-birth-weight

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Supplementary materials

Relationships between Sociosexuality and Dermatoglyphic Traits

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nT	number of triradii (category)	1				2					
	raw number of triradii	0	1			2					?
	pattern type	plain arch	tended arch	ulnar loop	radial loop	concentric whorl	spiral whorl	central pocket	lateral pocket	twin loop	accidental pattern
	abbreviation	A	T	U	R	Wc	Ws	CP	LP	TL	Acc
	raw number of cores	0	1						2		?
nC	number of cores (category)	1							2		

Table S1. Correspondence of the variables used in the study – categories of number of triradii (nT) and categories of number of cores (nC) – to number of triradii and cores, and respective pattern types in traditional dermatoglyphic methodology

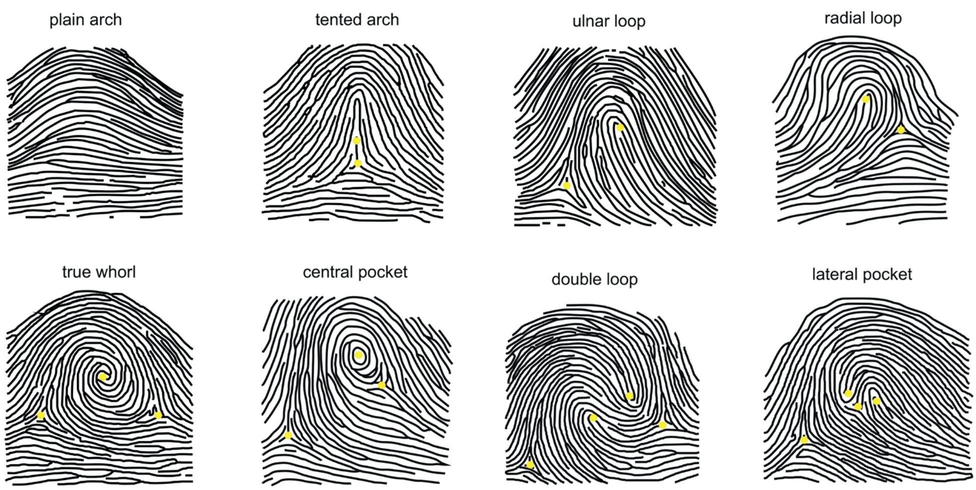

Fig. S1. Examples illustrating traditional dermatoglyphic patterns on black-ink fingerprints; for the right hand fingers the loops represents imprints of the annotated radial and ulnar loops; scheme of the true whorl represents a spiral whorl type

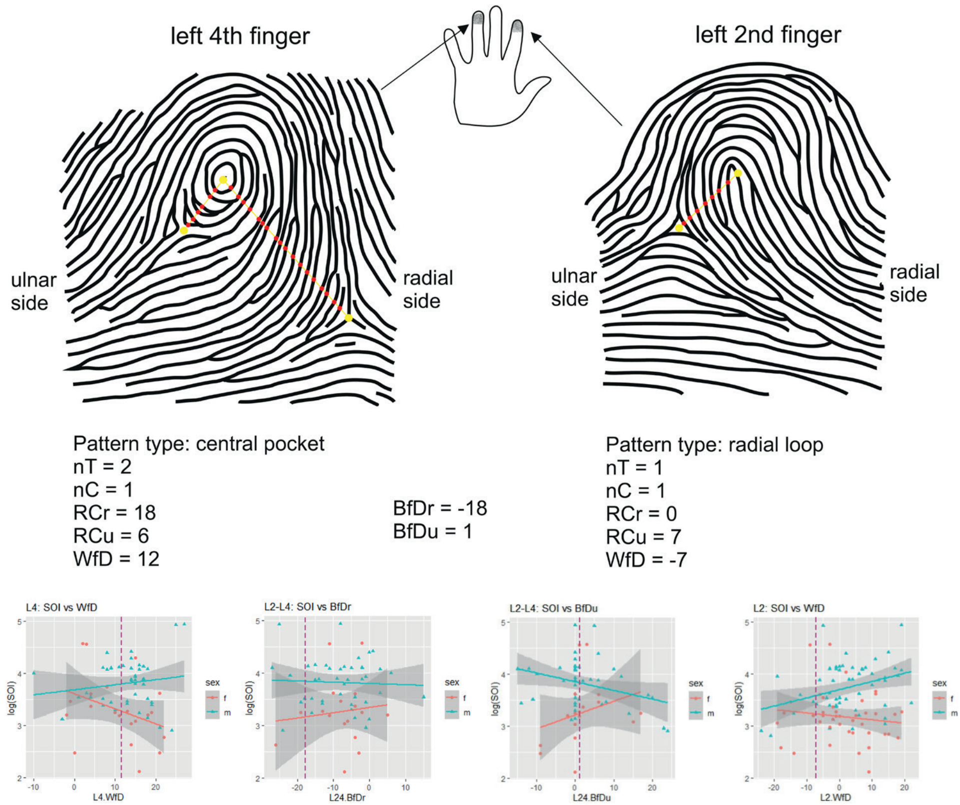

Fig. S2. An artificial example illustrating ridge count variables; two dermatoglyphic patterns are schematically depicted – radial loop on the 2nd finger and central pocket on the 4th finger – along with triradii and cores (yellow points), lines connecting them and red points on the crossing of the lines and epidermal ridges. Counts of the red points represent the ridge counts. Radial loop has one triradius on the ulnar side, no triradius on radial side and one core, hence formally RCr equals zero, while central pocket has two triradii and one core point, hence it has two non-zero ridge counts; respective within-finger differences (WfD) and between-finger differences (BfD) are also computed for this example. According to the basic categories these patterns are classified as a whorl and a loop. The lower row represents comparison of this artificial case (dashed verticals) with ridge-count variables variation in the recorded sample

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