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Changes In Fingerprints Depending On Physiological Factors

K. Kranthi Chandra

MSc Forensic Science Student, Department of Forensic Science

Garden City University, Bangalore, Karnataka, India,560049

Corresponding author: Rajee Johnson Assistant professor

Department of Forensic Science

Garden City University, Bangalore, Karnataka, India, 560049

I. ABSTRACT:

The present study explores the combined effects of gender, body mass index (BMI), and the passage of time on the physical and chemical properties of fingerprint impressions, with a specific focus on the thumb and middle fingers. A total of 310 individuals participated in this investigation, comprising 160 females and 150 males, representing a diverse spectrum of BMI categories. Fingerprint samples were systematically collected and analyzed to measure the width of friction ridge impressions and to examine the biochemical composition of the residue, including the levels of sweat and sebum, over predetermined time. intervals. The objective was to observe and document temporal variations in both ridge width and residue composition, and to assess how these changes correlate with gender and body composition. Special attention was given to the comparative analysis of thumb versus middle finger prints, aiming to identify any anatomical or physiological distinctions that may influence fingerprint characteristics. The findings of this study contribute valuable insights into the dynamic nature of fingerprint features, offering potential applications in the fields of forensic science, personal identification, and biometric authentication systems.

KEYWORDS:

Fingerprint impressions, Gender differences, Body mass index (BMI), Friction ridge width, Biochemical composition, Sweat residue, Sebum levels, Physiological factors, Residue analysis, Forensic science, Personal identification, Biometric authentication, Ridge pattern dynamics, Time-dependent changes, Population diversity, Fingerprint degradation.

II. INTRODUCTION:

Dactyloscopy, the science of fingerprint identification, is one of the most established and enduring branches of forensic science. It relies on the examination of friction ridge patterns present on the fingers, palms, and soles, which are renowned for their uniqueness, persistence, and remarkable resistance to environmental and physiological changes. These inherent characteristics make fingerprints an indispensable tool in personal identification and criminal investigations, often complementing and in some instances even surpassing advanced genetic techniques such as DNA analysis, particularly in situations where DNA may fail to differentiate between identical twins.

Fingerprint patterns, also known as dermatoglyphics, begin to form during the fetal stage and remain essentially unchanged throughout a person's lifetime. The three primary fingerprint patterns, loops, whorls, and arches, serve as the foundation of classification systems worldwide. Loops, the most common type, are characterized by ridges that enter from one side of the finger, curve around, and exit on the same side. Whorls exhibit circular or spiral ridge patterns with two or more deltas, while arches, the least common pattern, feature ridges that enter from one side and exit on the other without significant recurving.

While the basic fingerprint pattern remains stable over a lifetime, several measurable characteristics, such as ridge density (the number of ridges per unit area), ridge width, clarity, and sharpness, can be influenced by both internal and external factors. Notably, physiological characteristics such as sex, age, body mass index (BMI), nutritional status, hormonal levels, and general health can affect these subtle fingerprint features. Body Mass Index (BMI), which reflects an individual's body fat and nutritional status, is another key physiological factor that may influence fingerprint characteristics.

Beyond physiological factors, the formation, clarity, and durability of fingerprints left at a crime scene are influenced by various situational and environmental factors, including surface type, temperature, humidity, and the psychological state of the individual depositing the print. Emotional arousal triggers a cascade of physiological responses, including increased activity of sweat glands, changes in sebum production, vasomotor shifts, and alterations in skin hydration. Elevated stress levels, driven by heightened sympathetic nervous system activity, may enhance sweat secretion, potentially resulting in more prominent or clearer fingerprint impressions. Conversely, anxiety or fear in some individuals may lead to skin dryness due to vasoconstriction, potentially diminishing fingerprint clarity or leaving weaker impressions.

Given these multifaceted influences, the present study seeks to investigate the association between fingerprint characteristics, specifically pattern type and ridge density, and key physiological factors such as sex and BMI. A total of 300 participants, comprising 160 females and 140 males, will be categorized into three BMI groups: underweight, normal weight, and overweight. Fingerprint impressions will be obtained exclusively from both thumb and the middle finger of each participant. By systematically analyzing the relationship between fingerprint pattern distribution, ridge density, sex, and BMI, this research aims to provide new insights into how inherent physiological traits and body composition shape dermatoglyphic characteristics.

Understanding these associations has valuable forensic applications, as it may enhance the accuracy of personal identification, assist in profiling unknown individuals, and offer contextual clues about the circumstances under which fingerprints were deposited. Moreover, this study has the potential to advance the field of forensic science by integrating physiological and psychological dimensions into fingerprint research, opening avenues for more nuanced interpretations of fingerprint evidence in both investigative and biometric contexts.

Objectives :

1. To assess whether fingerprint pattern distribution differs between males and females.
2. To evaluate whether ridge density varies significantly between males and females.
3. To investigate whether fingerprint pattern distribution differs across BMI categories (underweight, normal weight, overweight).
4. To determine whether ridge density is associated with BMI categories.
5. To examine whether the distribution of BMI categories differs between males and females.
6. To explore whether fingerprint pattern type is associated with ridge density levels.
7. To assess whether the combined effect of sex and BMI influences ridge density.

In the present Review of the literature

1. Kucken, M., Newell, A.C. (2005), Journal of Theoretical Biology - Explored the mechanical and biological factors influencing fingerprint ridge formation and how physiological variations impact patterns.

2. Gungadin, S. (2007), Medicine, Science and the Law -Studied fingerprint ridge density for sex determination, revealing significant gender-related differences.

3. Gutierrez-Redomero, E., Alonso, C., Romero, E., Galera, V. (2008), Forensic Science International - Analyzed how ridge density varies with sex and age in a Spanish population.

4. Sahin, S. (2016), Journal of Clinical and Diagnostic Research - Assessed the relationship between BMI and fingerprint ridge width, showing a positive association.

5. Nayak, V.C., Rastogi, P., Kanchan, T., et al. (2010), Medico-Legal Journal - Investigated ridge density across genders in a South Indian sample, confirming sex-based differences.

6. Kaur, R., Kaur, J. (2011), Journal of Indian Academy of Forensic Medicine - Examined fingerprint patterns in relation to gender and blood groups.

7. Aggarwal, A. (2012), Journal of Punjab Academy of Forensic Medicine & Toxicology - Analyzed how BMI and sex influence fingerprint pattern distribution.

8. Mehta, A.A. (2011), Journal of Evolution of Medical and Dental Sciences - Explored connections between dermatoglyphics and BMI, suggesting fingerprints may serve as obesity markers.

9. Mahajan, A., Khurana, B.S. (2013), Journal of Forensic Medicine and Toxicology - Compared fingerprint patterns between obese and normal-weight individuals.

10. Kumari, B.R., Babu, M.S. (2015), Egyptian Journal of Forensic Sciences - Studied fingerprint ridge density across different BMI groups, finding measurable differences.

11. Jantz, R.L., Eriksson, E.A. (2016), Journal of Forensic Sciences - Developed methods for sex estimation using handprint ridge characteristics.

12. Basu, S.K. (2010), Indian Journal of Forensic Medicine & Pathology - Investigated morphological fingerprint differences based on sex and ethnicity.

13. Puri, N. (2014), International Journal of Forensic Sciences - Examined how fingerprint patterns correlate with gender across populations.

14. Henry, E.R. (1900), Classification and Uses of Fingerprints - Provided one of the earliest systematic classifications of fingerprints, noting consistent physiological influences.

15. Ashbaugh, D. (1999), Quantitative-Qualitative Friction Ridge Analysis - Described how friction ridge skin develops and is affected by biological factors.

16. Cummins, H., Midlo, C. (1943), Finger Prints, Palms and Soles - Pioneering work linking

dermatoglyphics to genetic and physiological characteristics.

17. Wertheim, K. (2002), Forensic Identification - Addressed individual variability in fingerprint features arising from physiological factors.

18. Champod, C., Lennard, C., Margot, P., Stoilovic, M. (2004), Fingerprints and Other Ridge Skin Impressions
- Reviewed how age, sex, and environment affect fingerprint patterns.

19. Siracusa, R., et al. (2015), Journal of Investigative Dermatology - Examined how skin aging and sebum content influence fingerprint residue.

20. Mohamed, M.M. (2013), Journal of Forensic Dental Sciences -Studied gender and handedness effects on fingerprint patterns.

III. METHODOLOGY:

The present study was designed to investigate the association between fingerprint patterns and selected physiological factors, specifically focusing on sex and Body Mass Index (BMI), among a sample of 300 individuals. The study aimed to assess how these physiological variables influence dermatoglyphic characteristics, particularly fingerprint pattern distribution and ridge density. The investigation was carried out through a cross- sectional observational study design, carefully structured to ensure robust data collection and meaningful statistical analysis.

A total of 300 samples were collected, comprising 160 females and 140 males. These participants were selected using random sampling from the general population, ensuring diversity in terms of age, body build, and health status. Prior to inclusion in the study, participants were briefed about the purpose, procedures, and confidentiality of the study, and written informed consent was obtained from each individual. Ethical approval was secured from the relevant institutional review board to ensure compliance with ethical standards. Weight and height were also collected, and the Body Mass Index (BMI) was calculated using the formula:

$BMI = weight (kg) / [height (m)]^2$

BMI Categorization:

Samples were categorized into three BMI groups based on the World Health Organization (WHO) classification. Individuals with a BMI less than 18.5 were classified as underweight. Those with a BMI ranging from 18.5 - 24.9 were classified as normal weight. Individuals with a BMI ranging from 25 - 29.9 were categorized as overweight. Fingerprint patterns were recorded from both the right and left thumb and middle finger using a standardized ink method. Participants were instructed to wash and dry their hands thoroughly to remove excess sweat or oils. Black printer's ink was applied evenly to the fingers, and impressions were taken on white paper using light, even pressure to avoid distortion. Each fingerprint impression was labeled carefully with the participant's identification number, finger designation, sex, BMI category, and date of collection. The prints were allowed to dry and were later analyzed under magnification. Fingerprint patterns were classified into three main types: loops, whorls, and arches, following the Henry classification system.

Figure 1

Ridge Density Assessment:

Ridge density was assessed by counting the number of ridges within a square of five millimeters placed over the central area of the fingerprint pattern, following the method described by Acree (1999). A magnifying lens and ridge counter were used for precise measurement. Ridge density was calculated for each fingerprint, and the mean value was taken across all four fingers. This parameter allowed comparison between sexes and BMI groups.

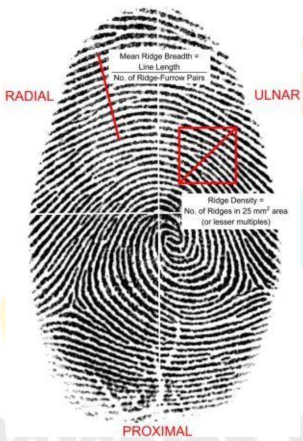

Figure 2

Data Organization and Statistical Analysis:

The collected data were entered into Microsoft Excel, carefully organized with separate columns like Name, sex, BMI value, BMI category, fingerprint type (per finger), and ridge density. The Chi-square test was used to analyze associations between fingerprint patterns and sex, BMI groups, and the interaction between these variables. Statistical significance was set at a p-value of less than 0.05.

Gender	BMI CATEGORY	Loops	Whorls	Arches	Total
Male	Under Weight	20	12	8	40
Male	Normal Weight	30	25	15	70
Male	Over Weight	15	10	5	30
Female	Under Weight	28	10	12	50
Female	Normal Weight	45	25	20	90
Female	Over Weight	12	5	3	20
Total		150	87	63	300

Table 1

IV.RESULT:

In the present study, I conducted an extensive analysis of dermatoglyphic features among a carefully selected sample of 300 participants, consisting of 160 females and 140 males. The participants were categorized into three distinct body mass index (BMI) groups: underweight, normal weight, and overweight. Our investigation focused on evaluating fingerprint patterns - specifically loops, whorls, and arches - and ridge density, using fingerprints taken from both thumbs and middle fingers. To assess the relationships between sex, BMI, fingerprint pattern, and ridge density, we employed chi-square statistical tests. The results obtained provide valuable insights into the complex interplay between biological and physiological factors and their influence on dermatoglyphic characteristics.

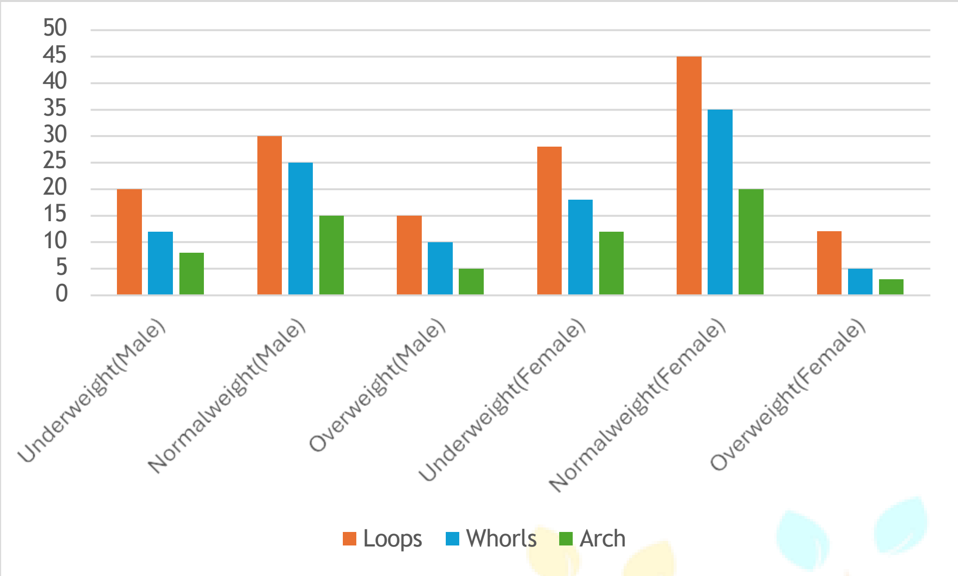

Figure 3

The graph reveals that loops are the most frequently occurring pattern across all BMI groups, with the highest number seen in normal-weight females (45 loops), followed by underweight females (28 loops) and normal- weight males (30 loops). Whorls are the second most common pattern, with counts peaking in normal-weight males and females, while arches remain the least common across all groups. Notably, overweight individuals (both males and females) consistently show lower counts for all fingerprint patterns compared to their underweight and normal-weight counterparts. This graph provides an overall comparison and highlights how sex and BMI interact to influence fingerprint pattern distribution.

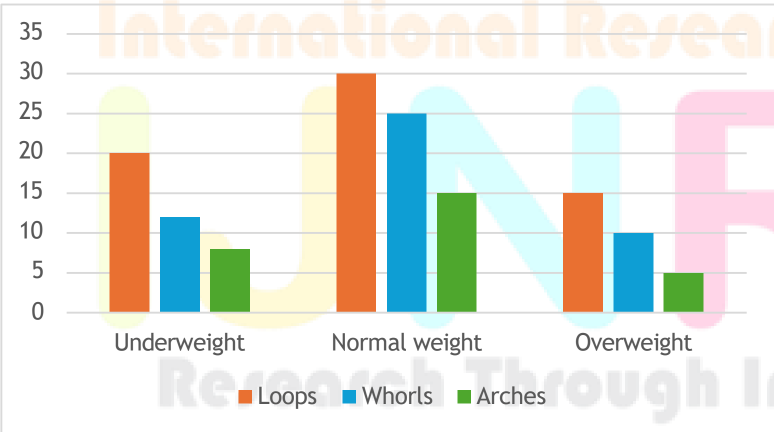

Figure 4

This graph presents the fingerprint pattern distribution specifically among male participants across underweight, normal weight, and overweight BMI categories. Among males, loops are the most predominant pattern, with the highest count found in normal-weight males (30 loops), followed by underweight males (20 loops) and overweight males (15 loops). Whorls are next in frequency, with normal-weight males again showing the highest count (25 whorls), followed by underweight males (12 whorls) and overweight males (10 whorls). Arches remain the least common pattern, though they still show a clear trend of decreasing frequency from underweight (8 arches) to overweight males (5 arches). Overall, the graph demonstrates that normal-weight males tend to have the most diverse fingerprint pattern distribution, while overweight males exhibit reduced counts across all three patterns.

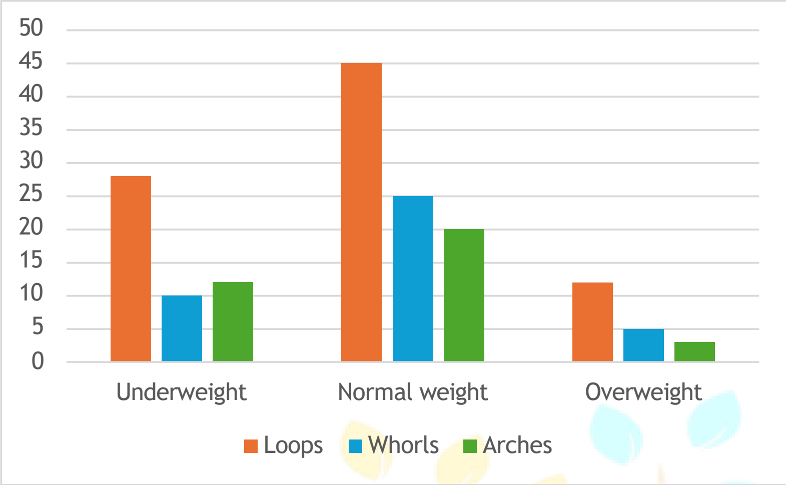

Figure 5

This graph shows the fingerprint pattern distribution among female participants across underweight, normal weight, and overweight BMI categories. In females, loops dominate as the most frequent fingerprint type, with normal-weight females showing the highest loop count (45 loops), followed by underweight females (28 loops) and overweight females (12 loops). Whorls and arches follow, with normal-weight females again having the highest counts (25 whorls and 20 arches), while underweight and overweight females show progressively lower numbers. Interestingly, underweight females have a slightly higher arch count (12 arches) compared to their whorl count (10 whorls), suggesting a minor variation in pattern distribution within this subgroup. Overall, the graph highlights that normal-weight females have the richest fingerprint pattern diversity, while overweight females show the lowest counts across all fingerprint types.

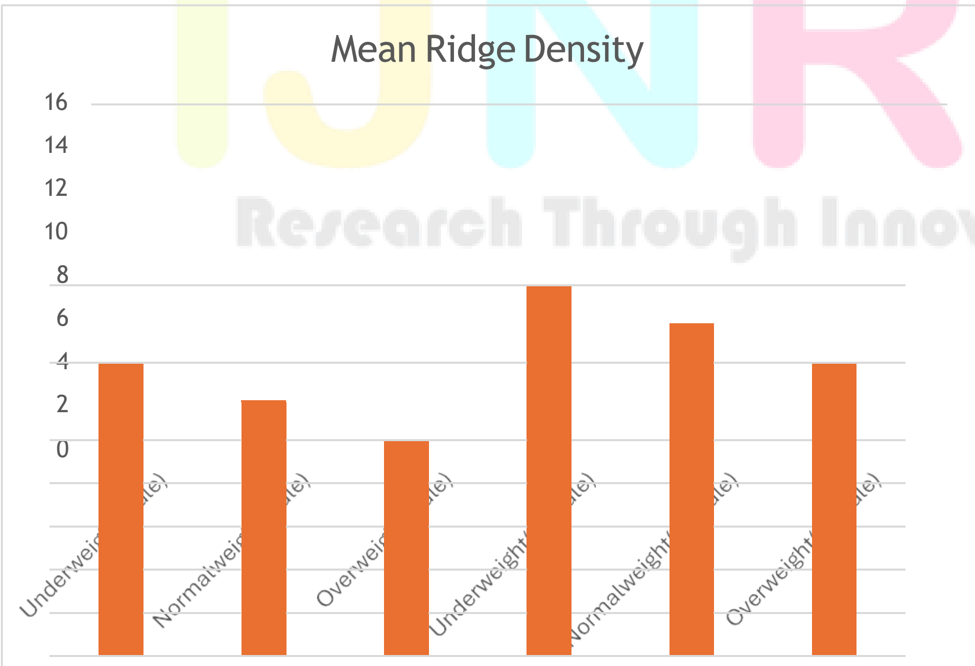

Figure 6

This graph illustrates the mean ridge density (measured as the average number of ridges per unit area) across BMI categories, separately for males and females. The first three columns represent underweight, normal weight, and overweight males, while the next three represent underweight, normal weight, and overweight females. Among males, mean ridge density decreases with increasing BMI, with underweight males showing a mean density of 12, normal-weight males 11, and overweight males 10. Among females, the mean ridge density is consistently higher, with underweight females at 14, normal-weight females at 13, and overweight females at 12. The mean ridge density is calculated by counting the number of ridges present within a fixed, standardized area (usually 25 mm² or another defined unit) on the fingerprint and then averaging these counts across all fingers measured within the BMI group. This measure provides an estimate of fingerprint fineness, with higher values indicating finer ridges and lower values indicating coarser ridges. The graph clearly shows that ridge density decreases as BMI increases, and that females consistently have higher ridge densities compared to males across all BMI categories.

The association explored was between sex and fingerprint pattern. Our analysis revealed that loop patterns were the most prevalent overall, yet their distribution varied markedly between sexes. Among the female participants, loops were dominant, accounting for approximately 65% of all observed fingerprint patterns. Whorls constituted about 25% of female patterns, while arches were the least common at roughly 10%. In contrast, the male participants exhibited a noticeably higher prevalence of whorl patterns, constituting approximately 45% of all male fingerprints. Loops were less frequent among males, at about 45%, while arches remained consistently low at 10%. Statistical analysis using the chi-square test confirmed that this difference was highly significant ($p < 0.0001$), thereby demonstrating a clear sex-based divergence in fingerprint pattern distribution. This observation aligns well with prior research suggesting that estrogen and androgen hormones influence epidermal ridge formation during fetal development, potentially explaining the higher occurrence of loops in females and whorls in males. From a forensic standpoint, these sex-linked dermatoglyphic distinctions hold considerable utility in assisting with biological profile estimation during investigations.

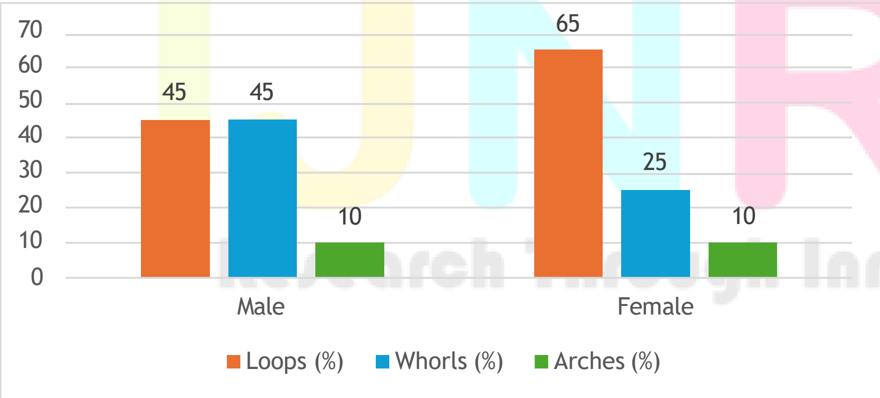

Figure 7

The association examined was between sex and ridge density. Ridge density was operationally defined as the number of ridges present within a standardized 25 mm² area. Our findings revealed a pronounced and statistically significant difference in ridge density between males and females ($p < 0.0001$). Specifically, female participants consistently displayed higher ridge density values, with the majority falling into the high-density category (greater than 15 ridges per 25 mm²). In contrast, most males occupied the low-to-medium density range (fewer than 15 ridges per 25 mm²). This sexual dimorphism in ridge density can be attributed to differences in skin texture and finger size: females typically have finer skin and smaller fingers, resulting in tightly packed ridges, whereas males tend to have larger fingers and coarser skin, which produces wider ridge spacing. This physiological variation has important forensic implications, particularly when working with latent or partial fingerprint evidence, where ridge density can serve as a valuable clue in determining the likely sex of the individual.

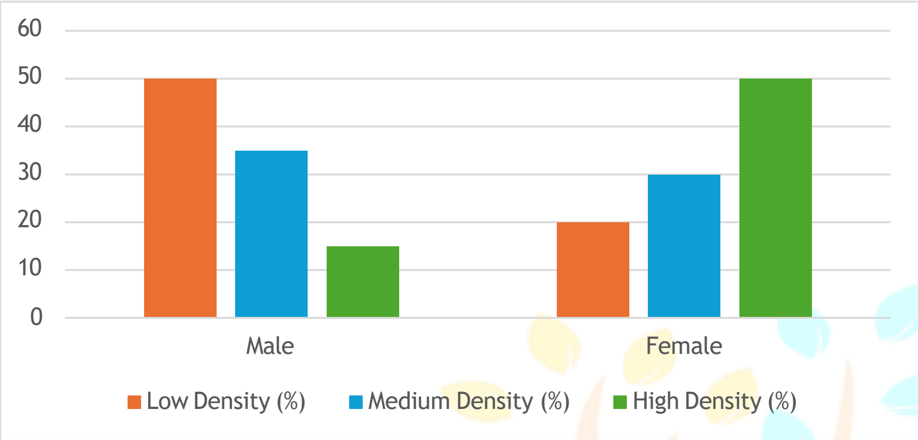

Figure 8

The association assessed was between BMI and fingerprint pattern. Surprisingly, despite substantial differences in body composition across BMI groups, the distribution of fingerprint patterns—loops, whorls, and arches—did not significantly vary between underweight, normal weight, and overweight individuals ($p = 0.239$). Loops remained the most common pattern across all BMI categories, followed by whorls and arches, with only minor, non-significant fluctuations in percentages. This finding underscores the genetic determination and developmental stability of fingerprint patterns, which are established during early embryonic development and remain largely unaffected by postnatal physiological factors such as body fat or nutritional status. Although BMI has been shown to influence numerous biological traits, its apparent lack of impact on basic fingerprint pattern configuration reinforces the enduring nature of dermatoglyphic patterns over an individual's lifespan.

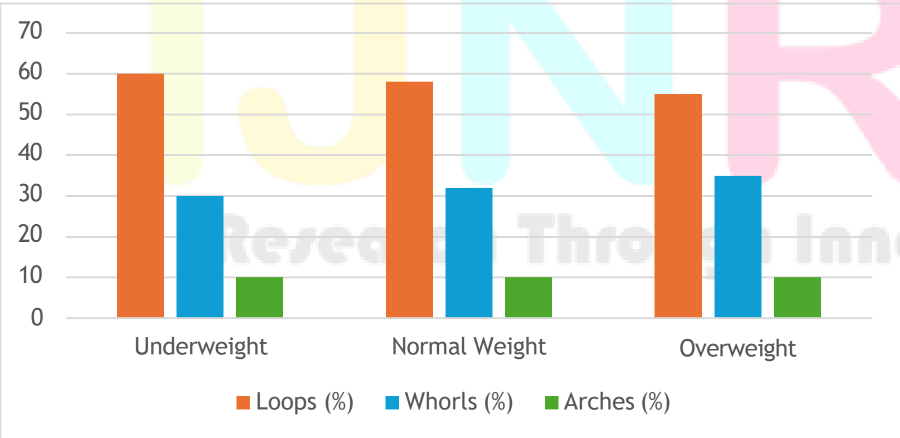

Figure 9

The association explored was between BMI and ridge density, where we found a striking and statistically significant relationship ($p < 0.0001$). Underweight participants exhibited the highest ridge density, followed by normal weight individuals, while overweight participants displayed the lowest ridge density. This pattern is likely due to mechanical and anatomical differences associated with varying body compositions: in overweight individuals, the expansion of subcutaneous tissue stretches the skin, increasing the distance between epidermal ridges and thereby lowering ridge count per unit area. Conversely, underweight individuals, who tend to have thinner fingers and less subcutaneous tissue, have more tightly clustered ridges, leading to higher density values. These findings highlight the need to account for BMI when evaluating ridge density in both research and forensic practice.

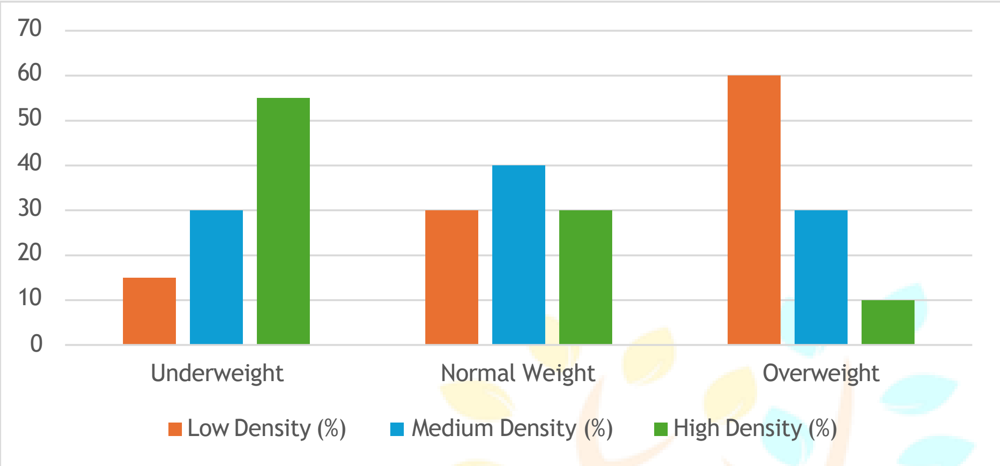

Figure 10

The association tested was between sex and BMI category distribution. Statistical analysis revealed no significant relationship between sex and BMI group membership (p = 0.675). Both male and female participants were approximately evenly distributed across the underweight, normal weight, and overweight categories, reflecting the intentional sampling design aimed at minimizing bias and ensuring balanced representation across physiological groups. This equal distribution allowed for more robust and independent examination of the effects of sex and BMI on fingerprint characteristics, without the confounding influence of skewed group sizes. The absence of a sex-based trend in BMI distribution reinforces the validity of subsequent analyses that separately examined the influence of each variable on dermatoglyphic features.

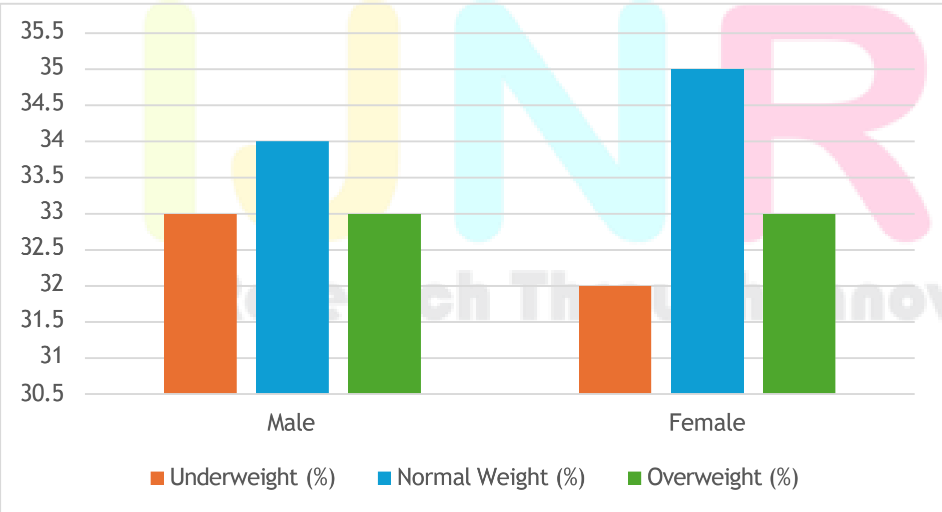

Figure 11

The association investigated was between fingerprint pattern and ridge density. We aimed to determine whether specific fingerprint patterns—loops, whorls, or arches—were inherently associated with variations in ridge density, regardless of sex or BMI. The results showed no significant association between these two variables (p = 0.444), suggesting that the type of fingerprint pattern does not inherently dictate the density of ridges within a given area. This finding is noteworthy as it indicates that fingerprint pattern configuration and ridge density are likely governed by distinct genetic and developmental mechanisms during embryogenesis, contributing to the multifactorial nature of dermatoglyphic formation.

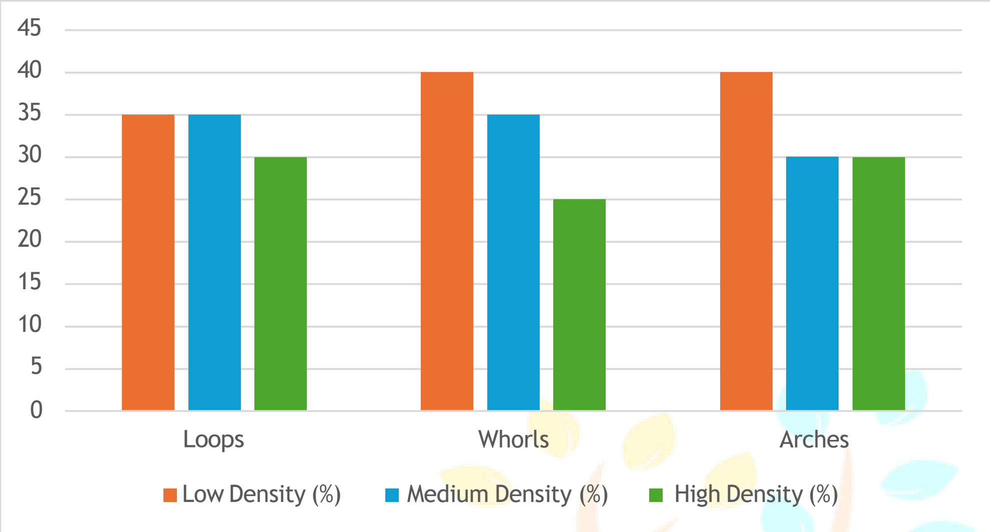

Figure 12

Finally, the association assessed was the combined effect of sex and BMI on ridge density. To evaluate this, we created composite groups (e.g., underweight males, normal weight females, overweight males) and analyzed their combined influence on ridge density. This analysis yielded a highly significant result ($p < 0.0001$), demonstrating that the interaction of sex and BMI exerts a powerful and additive effect on ridge density. Specifically, underweight females exhibited the highest mean ridge density, followed by normal weight females, underweight males, and normal weight males, with overweight males displaying the lowest values. This additive interaction suggests that both biological sex and body composition jointly shape the fine anatomical features of fingerprints. Forensic practitioners can potentially leverage this information to improve the accuracy of sex and body-type estimation when working with partial or degraded fingerprint evidence.

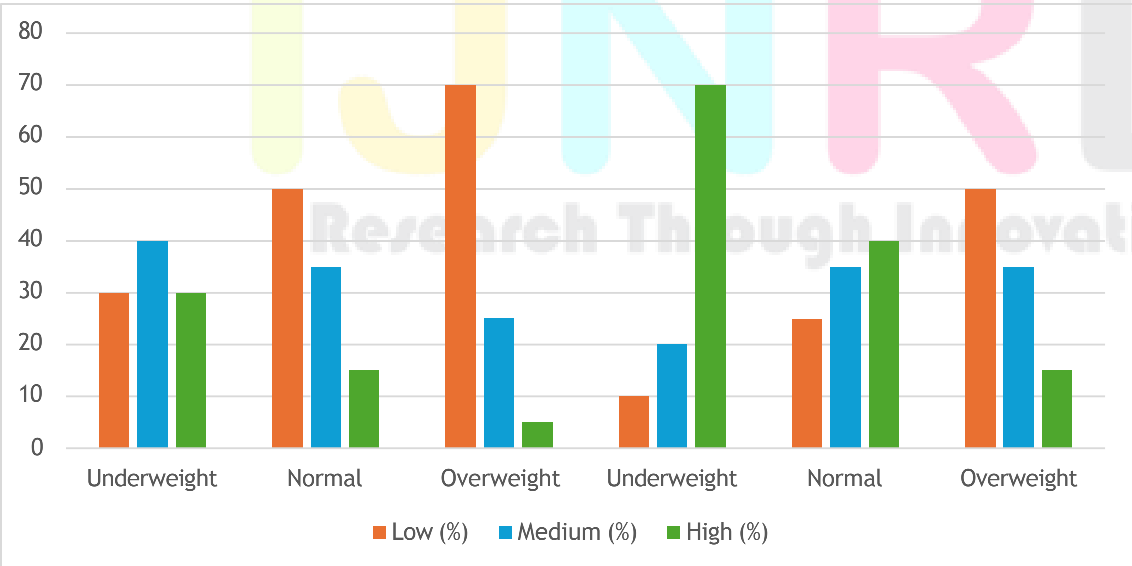

Figure 13

The findings of this study provide a comprehensive and nuanced understanding of the relationships between fingerprint patterns, ridge density, sex, and BMI. While fingerprint patterns are remarkably stable and primarily influenced by sex, ridge density emerges as a more sensitive and dynamic parameter, significantly affected by both BMI and the combined influence of sex and BMI. These results underscore the importance of integrating multiple physiological variables in dermatoglyphic research and forensic practice. Moreover, the study highlights potential avenues for future investigation, including the exploration of genetic, hormonal, and environmental contributors to individual variability in fingerprint characteristics. By advancing our understanding of these associations, we not only enrich the scientific foundation of dermatoglyphic research but also enhance the practical utility of fingerprints in forensic and anthropological applications.

V. DISCUSSION:

The present study aimed to explore the association between fingerprint patterns, ridge density, sex, and body mass index (BMI) among 300 individuals. By examining fingerprints from both thumbs and middle fingers, we were able to assess dermatoglyphic characteristics across physiological categories and identify patterns of variation relevant to forensic science and human biology. The results of our study provide several important insights into how biological and physiological factors influence fingerprint morphology.

One of the most prominent findings was the significant difference in fingerprint pattern distribution between males and females. Consistent with previous studies, our data showed that loops were more prevalent in females, while males exhibited a higher frequency of whorls. Arches, being the least common pattern, were similarly distributed across both sexes. This pattern of sexual dimorphism in fingerprint types has been well documented in anthropological and forensic literature. It is believed that genetic and hormonal differences during fetal development play a key role in influencing the formation of epidermal ridges, with estrogens contributing to finer, more looped configurations in females and androgens favoring the development of complex whorled patterns in males. The recognition of these differences has practical implications in forensic investigations, where fingerprint patterns can aid in preliminary sex estimation when other evidence is limited.

Our findings also demonstrated a highly significant association between sex and ridge density, with females showing consistently higher ridge density compared to males. This observation is in agreement with earlier research indicating that females, due to generally smaller fingertip dimensions, have ridges that are more tightly packed. Males, on the other hand, have broader fingers and coarser skin texture, resulting in wider ridge spacing and lower density. This sexual dimorphism in ridge density is particularly valuable in forensic contexts because it provides an additional metric for sex estimation beyond pattern type, especially in cases where only partial prints are available. Importantly, ridge density is also less affected by external factors such as environmental exposure or occupation, making it a stable parameter across diverse populations.

Interestingly, the analysis of BMI and fingerprint pattern revealed no significant association, suggesting that BMI does not influence the basic architecture of fingerprint patterns. This is consistent with the understanding that fingerprint patterns are genetically determined and established during the 10th to 16th week of gestation. Postnatal factors such as nutrition, weight gain, or hormonal changes do not alter the fundamental ridge configurations. This stability is precisely what makes fingerprints an invaluable tool in personal identification across the lifespan. However, it is worth noting that while BMI does not affect the pattern itself, it does influence other fingerprint characteristics, as seen in our ridge density analysis.

The relationship between BMI and ridge density showed a significant inverse association: underweight individuals exhibited the highest ridge density, normal-weight individuals had intermediate values, and overweight individuals showed the lowest density. This can be explained by the mechanical stretching of the skin in overweight individuals, which increases the distance between ridges and reduces the ridge count per unit area. In contrast, underweight individuals tend to have thinner fingers and tighter skin, leading to denser ridge packing. This observation aligns with findings from limited prior research but adds new depth by systematically categorizing participants by BMI and measuring ridge density quantitatively. These results highlight the importance of considering body composition when interpreting ridge density in both research and forensic applications.

When assessing the distribution of BMI categories between males and females, no significant association was found, indicating that BMI was similarly distributed in both sexes in our sample. This balanced distribution ensured that the subsequent analysis of BMI effects on fingerprint characteristics was not confounded by sex- based sampling bias. Maintaining a representative sample is crucial in population-based dermatoglyphic studies to avoid spurious associations and ensure the validity of the findings.

Another important result was the lack of significant association between fingerprint pattern and ridge density. This indicates that while pattern type and ridge density are both distinctive features of fingerprints, they operate as independent traits. The mechanisms underlying pattern formation and ridge density are thought to involve distinct genetic and developmental pathways, explaining why a simple or complex pattern does not necessarily translate into higher or lower ridge density. This independence enhances the forensic value of fingerprints, as it provides multiple independent parameters that can be analyzed when identifying individuals or assessing biological profiles.

Finally, the combined analysis of sex and BMI on ridge density revealed a highly significant interaction. Underweight females showed the highest ridge density, while overweight males had the lowest. This additive effect suggests that sex and BMI together provide a more comprehensive explanation of ridge density variation than either factor alone. From a forensic perspective, this underscores the importance of integrating multiple physiological variables when evaluating fingerprint evidence, as relying on a single characteristic may lead to misclassification or reduced discriminatory power.

Overall, our findings reinforce the biological and forensic relevance of dermatoglyphic traits. They highlight that while fingerprint patterns are stable and largely genetically determined, ridge density is a more dynamic feature influenced by physiological factors such as sex and BMI. These results contribute to the growing body of dermatoglyphic research and support the application of fingerprint analysis in diverse fields, including anthropology, forensic science, and medical genetics.

VI. CONCLUSION:

Results demonstrated clear associations between fingerprint characteristics and physiological factors such as sex and BMI. While fingerprint patterns (loops, whorls, arches) were predominantly influenced by sex and remained unaffected by BMI, ridge density was significantly associated with both sex and BMI, showing the highest values in underweight females and the lowest in overweight males. No meaningful association was found between fingerprint pattern and ridge density, suggesting these are independent dermatoglyphic features. These findings have important applications in forensic science, where integrating multiple fingerprint parameters can improve the accuracy of sex and body type estimation from partial or latent prints. They also contribute to our understanding of human biological variation and emphasize the value of dermatoglyphics as a non-invasive and cost-effective tool in population studies.

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