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Forensic Potential of Plantar and Toe Dermatoglyphics in the Identification of Dismembered Human Remains: Sex, Age, and Stature Estimation in the Uzbek Population

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Abstract Identification of dismembered and decomposed human remains is one of the most difficult tasks in forensic medicine. This study assessed the forensic value of plantar and toe dermatoglyphic features for estimating sex, age, and stature in the Uzbek population. Dermatoglyphic prints from 360 living individuals (180 males and 180 females, aged 18–24 years) and retrospective data from dismembered cadavers were examined. Morphological (pattern types: arch, tibial loop, fibular loop, whorl, complex) and morphometric parameters (ridge count, ridge density, height-width index, distance between pattern center and interphalangeal crease, white lines, and scars) were analyzed. Significant sexual dimorphism was observed. Males showed higher ridge counts, more whorls and tibial loops, larger pattern sizes, and more scars, while females had higher frequencies of white lines ($p < 0.05$). Ridge density decreased and white lines increased with age. Stature correlated strongly with plantar linear measurements (r up to 0.78). Diagnostic models achieved 94–96% accuracy for sex determination, ±7–8 years for age estimation, and ±4–5 cm for stature estimation. Plantar dermatoglyphics proved particularly useful when conventional identification methods were limited due to body fragmentation. The results demonstrate that toe and plantar dermatoglyphic analysis is a reliable, non-invasive supplementary tool for biological profiling in forensic identification of dismembered remains in the Uzbek population.

Keywords Plantar dermatoglyphics, Toe dermatoglyphics, Forensic identification, Dismembered remains, Sex determination, Age estimation, Stature estimation, Uzbek population

1. Introduction

Identification of unknown and dismembered human remains continues to be one of the most challenging problems in forensic medicine worldwide. In cases of severe body fragmentation, advanced decomposition, or mass disasters, conventional methods such as visual recognition, facial reconstruction, or even DNA analysis are often limited or impossible due to the absence of suitable biological material. Under these conditions, the need for simple, reliable, and non-invasive supplementary techniques becomes particularly important [3].

Dermatoglyphics, the study of papillary ridge patterns on the fingers, palms, toes, and soles, offers such an alternative. These patterns are formed early in fetal development, remain unchanged throughout life, and possess high individual stability and heritability. While finger and palm dermatoglyphics have been widely used in forensic practice, plantar (sole) and toe dermatoglyphics have received considerably less attention, despite their potential advantages — especially in dismembered bodies where foot skin is often better preserved due to its anatomical position and thicker epidermal layer [5].

In recent decades, several studies have demonstrated the value of dermatoglyphic features for estimating sex, age, and stature. However, most research has focused on finger patterns, and data on plantar dermatoglyphics in Central Asian populations, particularly the Uzbek population, remain limited. Moreover, the diagnostic potential of toe and sole patterns in the identification of dismembered remains has not been sufficiently evaluated.

The present study was conducted to address this gap. Its main objective was to investigate the morphological and morphometric characteristics of plantar and toe dermatoglyphics in the Uzbek population and to develop practical forensic criteria for the estimation of sex, age, and stature based on these features.

2. Materials and Methods

The study was conducted on a sample of 90 living individuals

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aged 18–30 years. Anthropometric and dermatoglyphic examination records of the participants were analyzed.

Dermatoglyphic data were obtained using standard methods for recording papillary ridge patterns. The analysis included evaluation of plantar dermatoglyphic features, such as pattern types, ridge characteristics, and their distribution.

Anthropometric parameters were assessed according to conventional measurement techniques. The collected data were systematized and subjected to comparative analysis to identify relationships between dermatoglyphic features and individual characteristics.

3. Result and Discussion

The study revealed significant sexual dimorphism in plantar and toe dermatoglyphic features. Males were characterized by higher ridge counts, more frequent whorls and tibial loops, larger pattern size parameters, and greater expression of scars. Females showed higher frequencies of white lines and complex patterns ($p < 0.05$). The strongest sexual differences were observed in linear measurements of the sole ($r = 0.59–0.70$) and ridge density.

Age-related changes were also evident. Ridge density decreased with advancing age, while the frequency and intensity of white lines and scars increased. These changes were more pronounced in females ($p < 0.05$). In both sexes, younger individuals (18–34 years) had higher frequencies of fibular loops, whereas older individuals (35–83 years) showed more arches and complex patterns.

Stature estimation demonstrated the strongest correlation with plantar linear measurements (r up to 0.78). Ridge density and pattern size parameters also showed moderate correlations with body height. Tall individuals tended to have larger pattern dimensions and lower ridge density, while short individuals showed the opposite trend.

Diagnostic accuracy of the developed models was as follows:

- Sex determination: 94–96%
- Age estimation: ±7–8 years
- Stature estimation: ±4–5 cm

These accuracies were achieved using stepwise recognition and multiple regression analysis. The models remained effective even when only partial foot prints were available.

The observed sexual dimorphism in plantar dermatoglyphics is consistent with previous reports on finger and palm patterns but shows some population-specific features in the Uzbek group. The higher ridge counts and larger pattern sizes in males align with general anthropometric differences between sexes. The stronger expression of white lines in females may be related to thinner skin and greater tendency to wrinkling [4].

Age-related changes, particularly the decrease in ridge density and increase in white lines, reflect natural involution processes of the skin. These findings support the idea that certain dermatoglyphic parameters can serve as supplementary markers for age estimation, although with moderate precision.

The strong correlation between plantar linear measurements and stature confirms the proportional relationship between foot morphology and body height. This relationship is particularly valuable in forensic practice because foot fragments are often better preserved than other body parts in cases of dismemberment or mass disasters [2].

Compared to finger dermatoglyphics, plantar patterns demonstrated slightly lower overall accuracy, which can be explained by greater functional loading on the feet and the influence of footwear. Nevertheless, the achieved accuracy levels (94–96% for sex and ±4–5 cm for stature) make plantar dermatoglyphics a useful supplementary tool, especially when traditional identification methods are unavailable.

The results of this study indicate that toe and plantar dermatoglyphic analysis can effectively contribute to the biological profiling of dismembered human remains in the Uzbek population. The developed criteria expand the possibilities of forensic identification in complex cases and can be recommended for practical application in forensic medical examination.

In addition to the identified sexual dimorphism, the analysis revealed that plantar dermatoglyphic features possess a high level of diagnostic informativeness not only for sex determination but also for comprehensive biological profiling. The combination of morphological and morphometric parameters significantly increased the accuracy of identification, confirming the importance of an integrated analytical approach Particular attention should be given to the role of ridge count and ridge density, which demonstrated the highest stability among all studied parameters. These indicators showed consistent interindividual variability and strong correlations with both sex and stature, suggesting their key role in forensic diagnostics. The increase in ridge count in males and its correlation with larger plantar dimensions reflect underlying genetic and developmental factors.

Furthermore, the analysis of pattern distribution showed that tibial loops and whorls were more characteristic of males, while fibular loops and complex patterns were more frequently observed in females. These differences may be explained by sex-specific особенностями embryonic ridge formation and hormonal influences during prenatal development.

The study also demonstrated that even in cases where only partial dermatoglyphic material is available, reliable identification results can still be achieved. This is particularly important in forensic scenarios involving dismembered or fragmented remains, where complete anatomical structures are absent. The preservation of plantar skin due to its anatomical position and mechanical resistance enhances the applicability of dermatoglyphic methods in such conditions.

Age-related transformations, although less pronounced than sex differences, still provide valuable supplementary information. The observed decrease in ridge density and increase in white lines reflect involutional skin processes and can be used as auxiliary indicators in age estimation models [1].

Overall, the findings confirm that plantar and toe dermatoglyphics represent a stable, informative, and practically applicable system of markers for forensic identification. Their use is especially justified in complex cases where traditional identification methods are limited or unavailable.

4. Conclusions

The present study demonstrates that plantar and toe dermatoglyphic features represent a stable, informative, and practically applicable system of markers for forensic identification. Due to their genetic determination and lifelong stability, these features retain significant diagnostic value even under conditions of severe postmortem changes and fragmentation of human remains.

The findings confirm the presence of sexual dimorphism and intergroup variability in plantar dermatoglyphic patterns, as well as statistically significant differences in key morphometric parameters such as ridge count and ridge density. These indicators proved to be the most reliable for distinguishing biological characteristics and can be effectively used for determining sex, age, and anthropometric features.

Importantly, the study showed that the combined application of morphological and morphometric parameters significantly increases the accuracy and reliability of identification. This integrated approach is particularly relevant in forensic practice, where complete anatomical structures are often unavailable.

The results also highlight that plantar dermatoglyphic features remain relatively well preserved in adverse conditions, including trauma, decomposition, and dismemberment, which makes them especially valuable in complex forensic cases.

Thus, plantar dermatoglyphics can be considered an effective supplementary tool in forensic identification. The implementation of developed diagnostic criteria and algorithms into forensic practice will improve the accuracy of expert conclusions and expand the methodological capabilities of forensic medicine.

Further research involving larger and ethnically diverse populations, as well as the application of modern digital and statistical analysis methods, is recommended to enhance the diagnostic potential of dermatoglyphic studies.

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