

BIOMECHANICS OF SKIN: AGE-RELATED CHANGES IN YOUNG'S MODULUS

Sattorov Yorqin Karimovich

Lecturer at the Department of Biomedical Engineering,
Informatics and Biophysics Tashkent State Medical University

Ahmadjonova Jahonzoda Xurshid qizi

Student of Tashkent State Medical University

Abstract: This study investigates the age-related variations in the Young's modulus of human skin tissue, providing a quantitative assessment of how biomechanical properties change with aging. The research was conducted at the Department of Biophysics, Tashkent State Medical University, in collaboration with 10 medical students under the supervision of senior academic staff. The experimental stage involved the use of non-invasive elastometric and ultrasound-based measurements to determine skin elasticity in participants of different age groups ranging from 18 to 70 years.

Results revealed a gradual decrease in the Young's modulus with increasing age, indicating a significant loss of dermal collagen density and structural organization. The study confirmed that skin stiffness and elasticity are directly correlated with the structural integrity of connective tissue fibers, hydration levels, and metabolic activity within the dermal matrix.

From a biophysical standpoint, the decline in the Young's modulus reflects molecular degradation of elastin and collagen cross-linking, which are essential for maintaining tissue elasticity. These findings contribute to a deeper understanding of the mechanobiology of skin aging, offering potential diagnostic and therapeutic insights for dermatology, geriatrics, and regenerative medicine.

Keywords: Young's modulus, skin elasticity, biomechanics, aging, collagen, elastin, biophysics, tissue stiffness, dermal structure, non-invasive measurement.

Introduction

The mechanical properties of the skin are essential indicators of its structural and functional integrity. Among these properties, the Young's modulus serves as a key biophysical parameter that reflects the elasticity and stiffness of skin tissue under mechanical stress. Skin elasticity plays a vital role not only in dermatological and cosmetic applications but also in clinical diagnostics, such as the assessment of aging, wound healing, and connective tissue disorders.

The skin is a complex multilayered organ composed primarily of the epidermis, dermis, and subcutaneous tissue, each contributing differently to its overall mechanical behavior. The dermis, rich in collagen and elastin fibers, provides tensile strength and resilience. However, with advancing age, the dermal extracellular matrix undergoes biochemical and structural degradation, leading to decreased elasticity and increased stiffness. These changes are primarily



driven by collagen fragmentation, elastin depletion, reduced hydration, and altered fibroblast activity.

Numerous studies in biophysics and biomechanics have emphasized that the Young's modulus of the skin increases in early adulthood, reaches a stable phase, and then gradually declines with aging. This trend corresponds to cellular senescence, oxidative stress, and reduced biosynthesis of extracellular matrix proteins. Investigating these variations offers valuable insight into the mechanobiology of human aging, contributing to early diagnostics of age-related skin disorders and the development of regenerative or anti-aging therapies.

In the present study, conducted at the Department of Biophysics, Tashkent State Medical University, we performed an experimental assessment of the Young's modulus of skin tissue across different age groups using non-invasive measurement techniques. By correlating mechanical properties with biological age, the study aims to quantitatively characterize age-dependent changes in skin elasticity and to establish a biophysical basis for clinical applications in dermatology and gerontology.

Methods

The experimental research was carried out at the Department of Biophysics, Tashkent State Medical University, under the supervision of academic instructors and with the participation of 10 senior medical students. The primary objective of the study was to measure and compare the Young's modulus of skin tissue among individuals of different age groups in order to analyze the effect of aging on skin elasticity.

Participants

A total of 40 volunteers were selected for the study, divided into four age groups:

- Group I: 18–25 years (young adults)
- Group II: 26–40 years (early middle age)
- Group III: 41–55 years (late middle age)
- Group IV: 56–70 years (elderly)

All participants were healthy, non-smokers, and had no dermatological or systemic diseases that could affect skin elasticity.

Measurement Techniques

Skin elasticity was evaluated using two complementary non-invasive methods:

1. Elastometric analysis — performed with a cutometer-type elastometer, which measures the vertical deformation of the skin surface when subjected to a controlled suction force.
2. Ultrasound elastography — applied to determine the depth-dependent mechanical response of dermal and subdermal layers.

Measurements were taken at standardized anatomical regions: the volar forearm and the cheek area, where skin thickness and exposure to environmental factors differ significantly. Each measurement was repeated three times, and the mean values were used for further analysis.



Data Analysis

The Young's modulus (E) was calculated using the formula:

$$E = \frac{\sigma}{\epsilon}$$

where σ represents stress (Pa) and ϵ denotes strain (unitless deformation).

All data were statistically processed using SPSS software (version 25.0). One-way ANOVA and Pearson correlation tests were applied to determine the relationship between age and skin elasticity. Results were considered statistically significant at $p < 0.05$.

Ethical Considerations

The study followed the ethical standards of the Helsinki Declaration (2013 revision) and was approved by the university's institutional ethics committee. All participants provided written informed consent prior to the measurements.

Results and Discussion

The experimental data demonstrated a progressive decline in skin elasticity with age, reflected by a significant increase in the Young's modulus (E) values in older groups.

In young adults (18–25 years), the mean Young's modulus of forearm skin was approximately 0.42 ± 0.05 MPa, indicating a high degree of tissue compliance and water retention.

In contrast, participants aged 56–70 years exhibited a mean modulus of 0.95 ± 0.08 MPa, reflecting reduced elasticity and increased stiffness of dermal collagen fibers.

Statistical analysis confirmed a strong positive correlation ($r = 0.82$, $p < 0.001$) between age and skin stiffness, consistent across both forearm and facial measurements. The results reveal that age-related collagen cross-linking, loss of elastin integrity, and reduced dermal hydration are the principal factors influencing mechanical changes in the skin.

Comparative Analysis

Ultrasound elastography results complemented the elastometric findings, showing a marked reduction in subdermal viscoelastic response among older participants. The epidermal layer exhibited minor changes, while the dermal and hypodermal regions demonstrated significant mechanical degradation with age.

These findings align with previous studies by A.V. Hill (1938) and Fung (1993), who established the exponential relationship between biological tissue stiffness and age-related biochemical modifications. The observed mechanical pattern also supports the biophysical aging model, which links molecular alterations in collagen fibrils to macroscopic mechanical decline.

Medical and Clinical Relevance

From a biomedical perspective, these results have practical importance in dermatology, reconstructive surgery, and gerontology. Understanding the quantitative changes in the Young's modulus of skin tissues can assist clinicians in assessing wound healing capacity, aging progression, and skin graft compatibility.



Furthermore, the integration of elastometric and ultrasound techniques provides a reliable diagnostic approach for evaluating age-dependent tissue biomechanics without invasive intervention.

Conclusion

The study demonstrated that skin tissue elasticity decreases progressively with age, as evidenced by a significant rise in the Young's modulus across all examined anatomical regions. These results confirm that the biophysical properties of the skin—particularly elasticity, resilience, and viscoelastic behavior—are directly affected by age-related structural and biochemical alterations in collagen and elastin fibers.

The combined use of elastometric and ultrasound elastography methods proved effective for quantitatively evaluating these changes in vivo, providing an objective, non-invasive assessment of tissue mechanics.

From a medical standpoint, the obtained data hold diagnostic and prognostic value in clinical dermatology, plastic surgery, and gerontology, where understanding tissue biomechanics is essential for evaluating wound healing potential, skin regeneration, and anti-aging interventions.

Furthermore, the research underscores the importance of biophysical education and experimental research in medical training, highlighting how interdisciplinary approaches can enhance clinical precision and innovation in modern medicine.

References:

1. Fung, Y. C. (1993). *Biomechanics: Mechanical Properties of Living Tissues* (2nd ed.). Springer-Verlag.
2. Silver, F. H., & Freeman, J. W. (2001). Deformation and mechanics of skin: viscoelasticity, plasticity, and aging. *Journal of Biomechanics*, 34(2), 199–210.
3. Daly, C. H., & Odland, G. F. (1979). Age-related changes in the mechanical properties of human skin. *Journal of Investigative Dermatology*, 73(1), 84–87.
4. Hendriks, F. M., Brokken, D., & van Eemeren, J. (2003). A numerical–experimental method to characterize the non-linear mechanical behaviour of human skin. *Skin Research and Technology*, 9(3), 274–283.
5. Agache, P., & Humbert, P. (Eds.). (2004). *Measuring the Skin: Non-Invasive Investigations, Physiology, Normal Constants*. Springer.
6. Cua, A. B., Wilhelm, K. P., & Maibach, H. I. (1990). Elastic properties of human skin: relation to age, sex, and anatomical region. *Archives of Dermatological Research*, 282(5), 283–288.

