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# Research on the Correlation Between Skin Elasticity Evaluation Parameters and Age

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**Abstract:** This study aims to explore the impact of aging on skin elasticity, a key biomechanical property that diminishes over time, using the Cutometer to assess viscoelastic parameters. Methods: Researchers analyzed 22 viscoelastic parameters from the facial skin of 60 women aged 18 to 70. Key Results: The findings indicate that relaxation phase parameters, particularly biological elasticity (R7), exhibited the strongest negative correlation with age ($r = -0.62$), signifying a notable decline in biological elasticity as women age. In contrast, maximum deformation during the first cycle (R0) and the total area under the upper curve after 10 cycles of deformation (F4) also showed significant negative correlations with age ($r = -0.47$, $r = -0.48$), suggesting that younger skin typically presents higher values. These correlations raise questions regarding practical applications, as the presence of moisturizers and emollients may alter the stratum corneum's properties, thus impacting these measurements. Additionally, the ratio of delayed deformation to instantaneous deformation (R6) demonstrated a positive correlation with age ($r = 0.49$), indicating its potential as a marker for skin aging. Conclusions: This study highlights the critical role of relaxation phase parameters in accurately reflecting skin elasticity changes associated with aging. The results offer valuable insights for evaluating cosmetic efficacy, reinforcing the need for a nuanced understanding of how various parameters interact. These findings contribute to the ongoing development of more effective anti-aging treatments and products.

**Keywords:** skin elasticity; firmness; skin aging; age; Cutometer; correlation

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## 1. Introduction

Being exposed to the environment, the skin, the body's largest organ, undergoes both intrinsic and extrinsic aging. Skin aging manifests as wrinkles, loss of elasticity, sagging, and a rough appearance [1]. Intrinsic aging results from biological changes over time, characterized by various histological, physiological, and biochemical modifications, influenced by genetic factors (such as gender and ethnicity), differences in skin location, and hormonal changes [2–4]. From a mechanical perspective, the skin functions as a layered composite, exhibiting structural instability when subjected to stress, with the most apparent manifestation being the formation of wrinkles [5–8]. As age increases, the gradual reduction of elastic fibers significantly decreases the skin's ability to bend, leading to a reduction in its stability against wrinkling to a quarter of its original capacity [9]. This further emphasizes the critical role of skin elasticity in the aging process. As global demographic shifts and improvements in quality of life continue, anti-aging cosmetic technologies have become a prominent focus in international beauty and medical research. Skin elasticity, as an important biomechanical indicator for assessing skin health and youthfulness, has become a core objective of many anti-aging treatments [8,10,11].

Skin elasticity, firmness, and softness are critical biomechanical indicators for assessing skin health and youthfulness [8]. The Cutometer, a non-invasive instrument for measuring skin elasticity, operates by applying negative pressure to the skin and assessing its mechanical deformation. Using a non-contact optical measurement system, the Cutometer accurately evaluates the skin's ability to recover its shape after being subjected to mechanical stress [12–14]. It has multiple parameters, including Ue (elastic deformation), Uv (viscous deformation), Uf (total deformation), Ur (elastic recovery), and Ua (viscous recovery), along with R and Q parameters, which offer insights into the viscoelastic properties of the skin [15–18].

As a globally recognized tool, the Cutometer has been widely adopted in dermatology, cosmetic product development, efficacy evaluations, and studies of pathological skin conditions. One of its major advantages is the standardized measurement it offers, allowing for comparative studies across different populations and regions [14,19–22]. Additionally, the Cutometer is user-friendly, provides rapid results, and has minimal requirements regarding the skin condition of the subjects being tested [15,19].

Despite its extensive application in assessing skin elasticity and firmness, the Cutometer has some limitations; for example, the pressure of the operator during measurement, the temperature and humidity of the environment, the test position of the subject, and the maintenance of the instrument will all affect the results [18,23]. The results may also be influenced by the subject's skin condition and environmental factors, such as health status, temperature, and humidity. Variations in these conditions can affect skin properties like hydration and elasticity, thus impacting the accuracy and reproducibility of the measurements. While the Cutometer offers various parameters, the biological significance and clinical relevance of some of these parameters are not always clear, and further research is needed to better interpret and validate these measurements. With the advancement of technology, new skin measurement techniques and devices, such as optical coherence tomography (OCT) and multiphoton tomography (MPT), are emerging. For specific research objectives, it may be necessary to combine these techniques to obtain a more comprehensive assessment of skin conditions.

The Cutometer plays a significant role in practical applications, yet there are inconsistencies in the understanding and application of its tested parameters. In recent years, some internationally renowned cosmetics companies have focused on efficacy evaluations of their products and made these a necessary condition for product launch, further promoting the development of relevant industry group standards. In human efficacy evaluation tests, the R0 or F4 values may be used to evaluate skin firmness, while the R2, R5, or R7 values can serve as parameters for skin elasticity and the Q parameters may be applied to assess tightening efficacy. Based on previous experience, the trends of these parameters may differ during project testing. For instance, in terms of elasticity, R2 values may show a significant difference, while R5 values do not. This highlights the variability in practical applications.

Studies show that the R2, R5, and R7 parameters are associated with anti-aging, while R4, R6, and R7 are correlated with age [24–26]. Additionally, some studies have utilized Cutometer parameters to improve or summarize the methods for evaluating skin elasticity and firmness [27]. However, most of the existing research focuses primarily on the R parameters, and there is a lack of studies specifically addressing the facial skin of Chinese women. This study utilizes the Cutometer to test the facial skin of multiple Chinese women and analyzes the correlation between the measured parameters and age, discussing their application in cosmetic efficacy evaluations. It aims to provide a reference for the use of the Cutometer in skin research and cosmetic efficacy evaluations.

In summary, the Cutometer is a globally recognized tool for assessing skin elasticity, offering valuable insights for skin research and cosmetic development. Although it has certain limitations, its value in skin elasticity evaluations is undeniable. This study aims to analyze the correlation between various viscoelastic parameters and age in Chinese women by using the Cutometer. It specifically focuses on the effectiveness of relaxation phase parameters in assessing skin elasticity. Additionally, the study examines the applicability and limitations of commonly used Cutometer parameters in evaluating skin firmness and the anti-aging effects of cosmetic products.

## 2. Materials and Methods

### *2.1. Subjects*

This study recruited 60 healthy Chinese female volunteers aged between 18 and 70 years, with an average age of 41.2 years, all residing in Eastern China. Before the start of the experiment, all participants received detailed information regarding the study's purpose, procedures, potential risks, participant rights and obligations, as well as expected benefits. Informed consent was obtained from all participants. The selection of subjects was carried out strictly according to the methods outlined in Chapter 8 of the Cosmetic Safety and Technical Standards (2015 Edition) for human efficacy evaluation (Table 1).

**Table 1.** Subject inclusion and exclusion criteria.

| Criteria | Details | |
|---|---|---|
| | **Inclusion Criteria** | **Exclusion Criteria** |
| | ① Willing to participate and provide written informed consent;<br>② Healthy females aged 18–70 years;<br>③ No use of anti-inflammatory drugs on the test area in the past two months and no laser treatment in the past three months;<br>④ No participation in other clinical trials in the past three months;<br>⑤ Skin in the test area must be free of scars, birthmarks, atrophy, or other conditions that could affect the test results;<br>⑥ Ability to understand the study requirements and willingness to cooperate in completing all testing procedures. | ① Use of antihistamines in the past week or immunosuppressants in the past month;<br>② Currently undergoing facial treatment or use of products to improve facial skin condition in the past month;<br>③ Presence of untreated inflammatory skin diseases;<br>④ Insulin-dependent diabetes;<br>⑤ History of cancer chemotherapy in the past six months;<br>⑥ Immune deficiencies or autoimmune diseases;<br>⑦ Participation in other clinical trials;<br>⑧ Pregnant or breastfeeding women. |

These strict inclusion and exclusion criteria ensured the scientific rigor and reliability of the study results, providing a standardized and well-controlled group for assessing the efficacy of cosmetic products.

### *2.2. Instruments*

The Cutometer Dual MPA 580, manufactured by Courage + Khazaka (Koln, Germany), was used in this study to measure skin elasticity. The probe diameter was 2 mm, and the software version was Cutometer Dual 2.1.2.1.

### *2.3. Methods*

The laboratory environment was maintained at a constant temperature and humidity, regulated by precision air-conditioning systems designed for human efficacy evaluation experiments. The environment was continuously monitored by temperature and humidity detectors. A total of 60 qualified subjects were selected based on the inclusion and exclusion criteria. Before the experiment, participants were instructed to cleanse their faces using a designated facial cleanser and dry their skin with non-woven paper towels. After the cleaning, subjects waited for 30 min in this environment to stabilize their skin condition before testing. This resting period of 30 min is in accordance with the requirements outlined in Chapter 8 of the Cosmetic Safety and Technical Standards (2015 Edition) for human efficacy evaluations.

During the test, researchers used the Cutometer Dual MPA 580 to measure skin elasticity on the cheekbone area of the face. The instrument was set to mode 1 with a negative pressure of 450 mbar, and both the "on-time" and "off-time" were set to 2.0 s. During the "on-time", negative pressure was applied to draw the skin into the probe, and during the "off-time", the pressure was released, allowing the skin to gradually recover. This suction-release cycle was repeated 10 times to collect skin elasticity data.

The test produced 22 viscoelastic parameters (R0–R9, Q0–Q3, F0–F4), which reflect the biomechanical properties of the skin based on the displacement observed during the suction and recovery phases. Detailed descriptions of the parameters and the corresponding skin deformation curves are provided in Table 2 and Figures 1–3 [28].

**Table 2.** The available parameters for the Cutometer.

| Parameter Name | Parameter Description | Parameter Significance |
|---|---|---|
| R0 = Uf | Maximum deformation during the first cycle | Represents the skin's extensibility. |
| Ue | Instantaneous deformation | Deformation 0.1 s after applying negative pressure, reflecting the skin's immediate elasticity. |
| Ur | Instantaneous retraction | The immediate retraction of the skin after the release of negative pressure. |
| Uv | Delayed deformation | The skin's deformation during the delayed retraction phase, reflecting the viscous component of the skin. |
| R1 = Uf − Ua | Remaining deformation after the first cycle | The skin's residual deformation after the first cycle, indicating the skin's elastic limit. |
| R2 = Ua/Uf | Ratio of total retraction to maximum deformation; total elasticity | The ratio of total retraction to maximum deformation, representing overall skin elasticity. A value closer to 1 indicates better elasticity. |
| R5 = Ur/Ue | Ratio of instantaneous retraction to instantaneous deformation; net elasticity | The ratio of instantaneous retraction to instantaneous deformation, reflecting the skin's net elasticity. |
| R6 = Uv/Ue | Ratio of delayed deformation to instantaneous deformation | Reflects the ratio of viscous to elastic components under negative pressure. |
| R7 = Ur/Uf | Ratio of instantaneous retraction to maximum deformation; biological elasticity | The ratio of instantaneous retraction to maximum deformation, indicating the skin's biological elasticity. |
| R8 = Ua | Total retraction after the first cycle | The total retraction of the skin after the first cycle. |
| Q0 | Maximum deformation area | The area under the curve for R0, calculated as Q0 = 200 × R0. |
| Q1 = QE/Q0 | Ratio of the area formed by instantaneous retraction to maximum deformation area | Reflects the immediate elasticity recovery. |
| Q2 = QV/Q0 | Ratio of the area formed by delayed retraction to maximum deformation area | Reflects the delayed elasticity recovery. |

**Table 2.** *Cont.*

| Parameter Name | Parameter Description | Parameter Significance |
|---|---|---|
| Q3 = (QE + QV)/Q0 | Ratio of total retraction area to maximum deformation area; overall elasticity | Indicates the overall elasticity of the skin. |
| F0 | The area between the actual curve and the Uf value during the negative pressure phase. | - |
| F1 | The area between the actual curve and the residual deformation (R1) during the relaxation phase. | - |
| F2 | The area between the actual curve and R3 after 10 cycles of deformation. | - |
| F3 | The area between the upper and lower curves after 10 cycles of deformation. | - |
| F4 | The total area under the upper curve after 10 cycles of deformation. | - |
| R3 | Maximum deformation after 10 cycles | The maximum deformation of the skin after the 10th cycle. |
| R4 | Residual deformation after 10 cycles | The residual deformation after the 10th cycle. |
| R9 = R3 − R0 | Difference between maximum deformation in the 10th and 1st cycles | Represents the change in maximum deformation between the first and 10th cycles. |

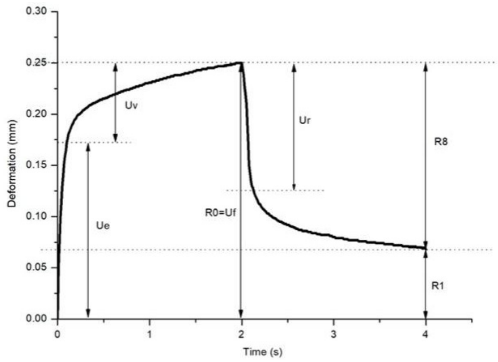


**Figure 1.** Skin deformation curve obtained by one repetition.

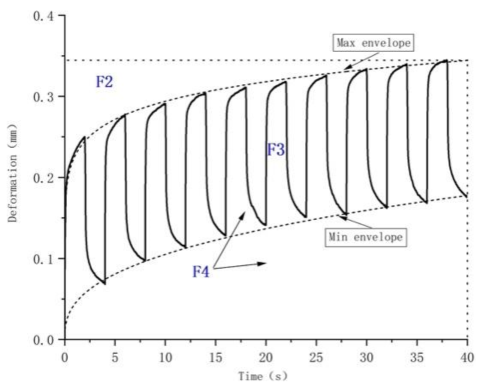


**Figure 2.** Skin deformation curve obtained by ten repetitions.

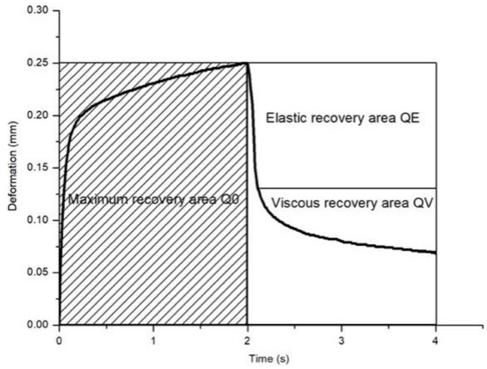


**Figure 3.** Figure for Q parameters.

### *2.4. Statistical Analysis*

Descriptive statistics for each indicator were obtained using R 4.2.2 software. The Shapiro–Wilk Test was employed to assess the significance of data normality; a significance level (two-tailed) greater than 0.05 indicates a normal distribution. A Pearson correlation analysis was conducted to examine the relationship between the test indicators and age, calculating the Pearson correlation coefficient and generating correlation heatmaps and scatter plots, with a significance level set at $\alpha = 0.05$.

## 3. Results

In this study, we performed a detailed analysis of skin elasticity parameters on the facial skin of 60 healthy female volunteers using the Cutometer to investigate the relationship between skin elasticity and age.

### *3.1. Correlation Analysis Results*

Figure 4 presents a heatmap showing the correlation between 23 skin viscoelasticity parameters and age. The heatmap visually represents the strength of the correlation for each parameter. Generally, most parameters displayed a negative correlation with age, with several demonstrating a significant inverse relationship. The depth of the colors in the heatmap reflects the strength of the correlation, with darker shades indicating stronger correlations and lighter shades indicating weaker or no correlation.

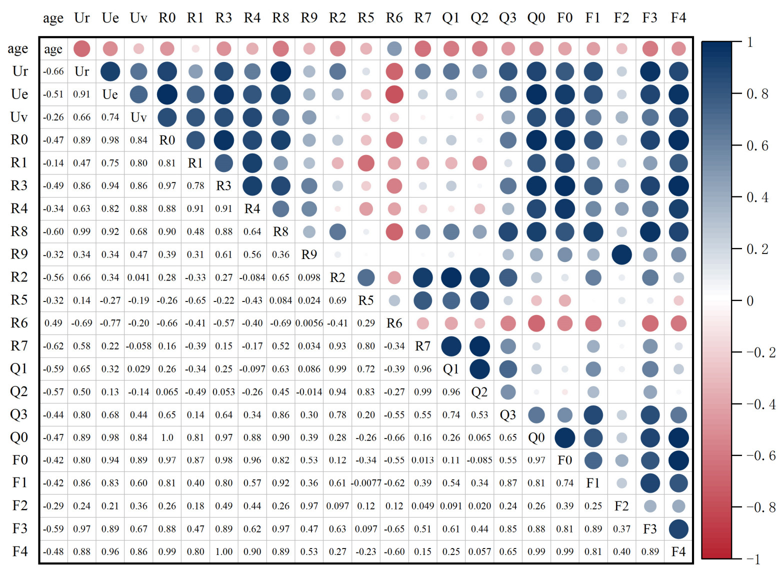


**Figure 4.** Correlation heatmap of 23 parameters (positive correlation in blue and negative correlation in red).

### 3.2. Top 10 Parameters with the Strongest Correlation with Age

Table 3 lists the top 10 skin viscoelasticity parameters most strongly correlated with age, along with their Pearson correlation coefficients. Ur (r = −0.66), R7 (r = −0.62), and R8 (r = −0.60) exhibited the strongest negative correlations with age, suggesting that these parameters significantly decrease with age, likely reflecting a decline in skin elasticity. Q1 (r = −0.59), F3 (r = −0.59), and Q2 (r = −0.57) also demonstrated strong negative correlations. Notably, R6 (r = 0.49) was the only parameter that showed a positive correlation with age, indicating that this increases with age, potentially due to other biomechanical changes associated with skin aging.

**Table 3.** The top 10 parameters with the strongest correlation with age.

| Parameters | Ur | R7 | R8 | Q1 | F3 | Q2 | R2 | Ue | R3 | R6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Pearson correlation | −0.66 **,[1] | −0.62 ** | −0.60 ** | −0.59 ** | −0.59 ** | −0.57 ** | −0.56 ** | −0.51 ** | −0.49 ** | 0.49 ** |

[1] Indicates significant correlation at the 0.01 level (two-sided test). **: $p \leq 0.01$

### 3.3. Scatter Plot Analysis of Age with Ur, R8, and R7

Figure 5 presents scatter plots of the relationship between age and three key parameters (Ur, R8, and R7):

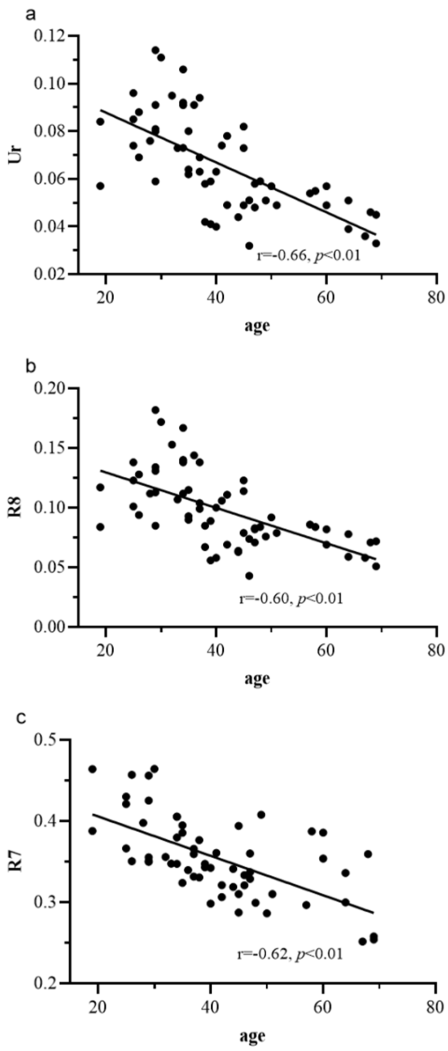


**Figure 5.** Correlation curve between age and the three parameters: (**a**) scatter plots of Ur vs. age; (**b**) scatter plots of R8 vs. age; (**c**) scatter plots of R7 vs. age.

Ur vs. age (Figure 5a): The Ur values showed a clear and significant decline with age, with a well-defined negative correlation (r = −0.66).

R8 vs. age (Figure 5b): R8 also exhibited a declining trend with age, with a relatively concentrated distribution supporting its strong negative correlation (r = −0.60).

R7 vs. age (Figure 5c): Similarly, R7 decreased progressively with age, presenting a strong negative correlation (r = −0.62), consistent with the data presented in Table 3.

## 4. Discussion

### *4.1. Analysis and Discussion of Ur, R7, R8, Q1, Q2, and R2*

In this study, Ur had the strongest correlation with age among the 22 skin elasticity parameters (r = −0.66, $p < 0.01$), followed by R7 and R8, with correlation coefficients of r = −0.62 and r = −0.60, respectively. Scatter plots for Ur, R7, and R8 are shown in Figure 5. These results align with previous research. Ryu et al. found that R7 had the strongest correlation with age (r = −0.712) in their study on 96 healthy Korean women aged 20–75, though R8 showed a weaker correlation (r = −0.261) [26]. In contrast, Ohshima et al. identified R8 as the parameter most strongly correlated with age (r = −0.603), with R7 as the second strongest (r = −0.510) [16]. Similarly, Luebberding et al. demonstrated that R7 had the highest correlation with age (r = −0.787) in their study on 150 Caucasian women, while R2 also showed a strong negative correlation (r = −0.782); their study also found a significant negative correlation between Ur and age (r = −0.692) [29]. Likewise, Langeveld et al. confirmed strong correlations between R7, Ur, and age in their research [23]. Therefore, the results of this study regarding R7, R8, and Ur are consistent with previous findings. It is worth noting that Ryu et al.'s study did not find a strong correlation between R8 and age, likely due to differences in ethnicity, skin type, or other physiological factors [26].

Table 3 lists the 10 skin parameters with correlation coefficients $|r| > 0.49$ with age, including Ur, R7, R8, Q1, F3, Q2, R2, Ue, R3, and R6. Notably, the first eight parameters (Ur, R7, R8, Q1, Q2, R2, Ue, R6) were all derived from the first testing cycle, and the top six parameters (Ur, R7, R8, Q1, Q2, R2) were associated with the relaxation phase. Ur, the instantaneous retraction in the relaxation phase, had the highest correlation (r = −0.66), while R8 represented the total retraction during the relaxation phase. R2 and R7, respectively, represent the ratio of total retraction (R8) to maximum deformation (Uf) and the ratio of instantaneous retraction (Ur) to maximum deformation. In addition, Q1 and Q2 represent QE/Q0 and Qv/Q0, respectively, both of which are related to skin retraction during the relaxation phase.

Therefore, retraction parameters during the relaxation phase, including Ur, R7, and R8, serve as more reliable indicators of skin elasticity compared to suction-phase parameters. This finding aligns with previous studies, which have demonstrated that relaxation-phase parameters offer more accurate insights into skin elasticity, while suction-phase parameters are more influenced by external factors, such as skin moisture or the use of cosmetic products [14,16,18,21,22]. Therefore, in skin elasticity studies and cosmetic efficacy evaluations, greater emphasis should be placed on relaxation-phase parameters, particularly Ur, R7, and R8, as they offer valuable reference points for predicting skin aging and elasticity changes.

### *4.2. Analysis and Discussion of R0, F4, F3, R3, and Ue Parameters*

In skin firmness evaluations, R0 and F4 are commonly used as key indicators. R0 represents the maximum deformation during the first cycle, while F4 represents the total area under the upper curve after 10 cycles. Typically, smaller R0 and F4 values indicate firmer skin [30,31]. However, in this study, R0 and F4 demonstrated negative correlations with age, with correlation coefficients of r = −0.47 and r = −0.48, respectively, suggesting that younger skin had larger R0 and F4 values. This finding contrasts with the conventional interpretation of these parameters in skin firmness assessments, where a significant reduction in R0 or F4 after 28 days of product use is typically considered an improvement in skin firmness in cosmetic efficacy studies.

There is limited literature on the correlation between F4 and age, with most studies focusing on the R, U, and F3 parameters. Since F4 represents the area under the upper curve, it is theoretically strongly correlated with R0 (Uf), F3, and R3. In this study, F4 showed high correlations with Uf (r = 0.99), F3 (r = 0.89), and R3 (r = 1), indicating similar trends. Numerous studies have reported significant negative correlations between R0, F3, R3, and age [16,26,28,32,33], which aligns with the findings of this study. Therefore, the negative correlation between F4 and age may not have been adequately addressed in previous studies. It is important to note that this study used Cutometer Dual software version 2.1.2.1, whereas in a newer version (MPA CTplus 1.1.6.4), F4 is defined as the area under the lower curve (equivalent to F4-F3 in this study). In this updated version, F4 exhibited a weaker and less significant negative correlation with age ($r = -0.259$, $p = 0.046$).

Additionally, F3 showed a strong correlation with age ($r = -0.59$, $p < 0.01$). F3 represents the middle area between the upper and lower curves. As age increases, the F3 area decreases, indicating that younger skin has greater resilience and recovers more effectively after 10 cycles of deformation.

R0 represents the maximum deformation during the first cycle, while R3 represents the maximum deformation after 10 cycles. In this study, R0 and R3 were significantly positively correlated ($r = 0.97$, $p < 0.01$), and both showed negative correlations with age, with correlation coefficients of −0.47 and −0.49, respectively. These results are consistent with the findings of Ohshima et al., who observed a decrease in R0 and R3 in facial skin with increasing age [16]. This phenomenon may be related to Ue (instantaneous deformation), which reflects the skin's elasticity under suction and is associated with skin thickness and firmness. In contrast, Uv represents delayed deformation, primarily reflecting the skin's viscoelasticity. Younger skin typically has higher Ue values, indicating stronger elastic recovery, and since R0 is the sum of Ue and Uv, younger skin tends to exhibit larger R0 values.

It is important to note that R0 reflects not only the skin's elastic recovery but also its extensibility or expandability. Studies have shown that the use of moisturizers or emollients can increase both Ue and Uv, due to the softening of the skin and the increased plasticity of the epidermis [12,16,33]. Therefore, interpreting R0 solely as a measure of skin firmness, with lower values being better, can be misleading. In certain cases, particularly in immediate post-application evaluations, products that increase skin firmness may reduce the maximum deformation under suction, leading to a lower R0 value. Thus, the interpretation of R0 needs to be context-dependent, and the evaluation of skin firmness should consider other parameters as well as the specific skin condition.

In conclusion, while R0 and F4 are widely used in firmness evaluations, their relationship with skin elasticity and firmness may vary in different contexts. Future research should further explore the behavior of R0 and related parameters under different skin conditions and product applications to better understand their reflection of skin's biomechanical properties.

### *4.3. Analysis and Discussion of R2, R5, R6, and R7 Parameters*

In skin elasticity testing, R2, R5, and R7 are three key parameters that are commonly measured by the Cutometer to represent different aspects of skin elasticity. R2 indicates total elasticity (Ua/Uf), R5 represents net elasticity (Ur/Ue), and R7 reflects biological elasticity (Ur/Uf). The closer the correlation values are to 1, the better the skin's elasticity. In this study, R2, R5, and R7 showed correlations with age of $r = -0.56$, $r = -0.32$, and $r = -0.62$, respectively, with R7 demonstrating the strongest negative correlation. These results suggest that biological elasticity is the most significantly affected parameter with advancing age, consistent with previous findings by Ryu et al., who identified R7 as one of the most sensitive parameters for skin aging in Korean women [26].

R6 (Uv/Ue) represents the ratio of the viscous component to the elastic component of the skin, specifically the ratio of delayed deformation to instantaneous deformation. In this study, the R6 values for all 60 participants were less than 1, indicating that instantaneous deformation (Ue) was greater than delayed deformation (Uv), with the elastic component dominating. Furthermore, R6 was positively correlated with age (r = 0.49, $p < 0.01$), indicating that as age increases, R6 rises. This suggests that the viscous component of the skin increases with age, while the elastic component decreases. The increase in R6 is linked to the decline in Ue and the rise in Uv, a trend observed in previous studies on skin aging. Similar patterns have also been observed in studies of photoaged skin [18,26,33–35].

R2, R5, and R7 reflect different dimensions of skin elasticity. R2, as a measure of total elasticity, integrates the total deformation and maximum deformation, providing a comprehensive assessment of overall skin elasticity. R5 indicates net elasticity, focusing on the skin's recovery ability, particularly the relationship between immediate retraction and elastic recovery. R7, which reflects biological elasticity, captures the relationship between maximum deformation and immediate retraction, making it a key parameter in anti-aging research. The study found that R7 had the strongest correlation with age, highlighting its importance as the most sensitive indicator of skin aging. This further supports the notion that biological elasticity is the most responsive feature in the aging process [36–39].

Overall, the increase in R6 and the decrease in R7 together reflect the transition in aging skin from strong elastic recovery to enhanced viscous properties. As skin's viscoelasticity increases, its ability to return to its original state diminishes significantly. These findings are consistent with other aging-related studies, which show that skin gradually shifts from being predominantly elastic to being more viscous with age [3,40–42].

This study confirms the significance of R2, R5, R7, and R6 in evaluating skin elasticity and the aging process, particularly emphasizing R7 as a sensitive marker for skin aging and the efficacy of anti-aging products. The positive correlation of R6 further supports its role in understanding changes in skin viscoelasticity, highlighting the importance of the viscous component as a key factor in skin aging.

### *4.4. Future Directions*

Alterations in skin elasticity and firmness serve as critical indicators of skin aging. A deeper understanding of the role of skin elasticity in the physiological aging process can inform the development of more effective anti-aging treatment strategies. In recent years, the widespread use of non-invasive skin measurement instruments has allowed for the assessment of skin aging characteristics from multiple dimensions, such as the physiological parameters of the skin surface, including pigmentation, barrier function, and glossiness. Moreover, skin imaging technologies—such as ultrasound imaging, optical coherence tomography, confocal microscopy, and two-photon microscopy—can be used to visualize aging characteristics at various depths of the skin [43].

This study analyzes the mechanical characteristics of aging solely based on Cutometer test parameters, with a research sample limited to Chinese women. It is recommended that the sample size is expanded and studies on skin are conducted that include different ethnicities and genders. Additionally, combining measurements from skin hardness testers, skin moisture analyzers, skin oil content testers, and skin imaging technologies could help investigate the correlation between Cutometer parameters and skin softness, hydration levels, oil content, and structural characteristics, providing a more comprehensive understanding of the mechanical properties of skin aging. Furthermore, the effects of moisturizers, film-forming agents, and emollients in cosmetics on the mechanical properties of the skin could also be explored.

## 5. Conclusions

By using the Cutometer to assess the skin elasticity parameters of 60 Chinese women, this research analyzed the correlation between 22 viscoelastic parameters and age. The results showed that, except for R6, all other parameters were negatively correlated with age. Ur, R7, R8, Q1, Q2, and R2 exhibited the strongest correlations, with Pearson correlation coefficients of −0.66, −0.62, and −0.60, respectively. These parameters were all associated with the relaxation phase during testing, indicating that relaxation-phase parameters provide a more accurate reflection of skin elasticity compared to suction-phase parameters. This aligns with previous studies, further validating the importance of the relaxation phase as a sensitive stage for skin elasticity evaluations.

The study also found that R0 and F4 were negatively correlated with age ($r = -0.47$, $r = -0.48$), with younger skin showing higher R0 and F4 values. However, in practical applications, lower R0 and F4 values typically indicate firmer skin. Since R0 reflects skin extensibility or expandability and is closely related to skin hardness and thickness, moisturizers, and emollients may reduce R0 and F4 values by softening the stratum corneum or increasing epidermal extensibility. Therefore, relying solely on decreases in R0 or F4 to assess skin firmness may not be sufficient; it is necessary to consider the skin's specific condition and product use in a more detailed analysis.

Additionally, R2, R5, and R7, representing total elasticity, net elasticity, and biological elasticity, respectively, were all significantly negatively correlated with age, with correlation coefficients of $-0.56$, $-0.32$, and $-0.62$. R7 showed the strongest correlation, indicating that biological elasticity is the most sensitive indicator of aging. This is consistent with the previous literature, where R7 is widely used for assessing skin elasticity in anti-aging research.

R6, representing the ratio of the skin's viscous component to its elastic component, was positively correlated with age ($r = 0.49$, $p < 0.01$). This suggests that as age increases, the viscous component of the skin gradually increases, while the elastic component diminishes, further confirming the trend of elastic and viscoelastic changes during skin aging. The increase in R6 serves as an effective marker for the increasing proportion of viscoelasticity in aging skin.

In summary, the correlation analysis of multiple Cutometer parameters with age underscored the importance of relaxation-phase parameters in assessing skin elasticity, identifying R7 as a sensitive marker for skin aging. The limitations of R0 and F4 in evaluating skin firmness further emphasize the need for a comprehensive evaluation. These findings provide robust data support and a theoretical foundation for applying the Cutometer in skin aging research and cosmetic efficacy evaluations.

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