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Cutaneous Resonance Running Time Varies with Age, Body Site and Gender in a Normal Chinese Population

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Abstract

Background/objectives—One phenomenon of skin aging is loss of cutaneous elasticity. Measurement of cutaneous resonance running time (CRRT) is a method to assess skin elasticity. Yet, information regarding directional changes of CRRT associated with age, body sites and gender is not yet available. In the present study, we assessed whether changes in CRRT vary with age, body sites and gender in a normal Chinese population.

Methods—A Reviscometer was used to measure CRRTs in various directions on the left dorsal hand, the forehead and the left canthus of 806 normal Chinese volunteers, aged 2.5–94 years.

Results—With aging, CRRTs decreased in all directions on the hand, the forehead, and the canthus. A more dramatic reduction of CRRTs on the forehead and the canthus were observed at both the 2–8 and 3–9 o'clock directions. CRRTs in males aged 11–20 years old were longer than those in females at some directions on all three body sites. Females between 21 and 40 years old showed longer CRRTs than males in some directions of the hand. There were no gender differences in subjects aged 0–10 (except on the canthus) and over 81 years old.

Conclusion—CRRTs vary with age, body sites and gender.

Keywords

Age; Gender; Skin; Resonance Running Time

Introduction

Skin biophysical properties, including stratum corneum (SC) hydration, sebum content, transepidermal water loss (TEWL), and skin surface pH reflect cutaneous biological functions. Measurement of these properties is a valuable approach to evaluate the efficacy of therapeutic and skin care products [1–4]. In addition, dramatic changes in skin biophysical properties have been found in some skin disorders. For example, decreased SC hydration and increased skin surface pH exist in atopic dermatitis and cured leprosy subjects [5,6], and decreased SC hydration and barrier function occur in psoriatic lesions [7–9]. Systemic disorders can also influence skin biophysical properties. For example, decreased SC hydration occurs in both diabetes and hemodialysis subjects [10–13], and hemodialysis

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subjects also have higher skin pH [14]. Changes in thyroid-stimulating hormone levels correlate negatively with SC hydration [15]. Moreover, changes in skin biophysical properties also occur as a sign of aging. Our prior studies have demonstrated that skin surface pH is increased in aged humans and correlates positively with age [16–18]. Gender differences in skin surface pH and sebum content can also occur [17–21].

Measurement of cutaneous resonance running time (CRRT) is a non-invasive approach to assess skin biophysical property. CRRT, which is mainly influenced by collagen fibers in the papillary layers of dermis, correlates negatively with skin stiffness [22,23]. At higher frequency (>2000Hz), the effects of skin thickness and subcutaneous fat on CRRT are negligible [24]. Although no age-dependent changes in CRRTs were found on the forearm [23], some other studies have shown that the maximum CRRT on the forearm increases in older skin [22,25,26]. However, directional changes of CRRTs during lifetime, which could reflect the dermal biophysical property at various ages, have not been documented yet. CRRTs vary with body site, especially with aging [22,23]. Additionally, systemic conditions can also affect CRRTs. For example, CRRTs on both the forearm and the forehead are increased in diabetic subjects [27], and haemodialysis significantly increases CRRTs on the forearm [26]. Moreover, although sex hormones have a significant impact on collagen metabolism [28,29], there are no data available about gender-specific differences in CRRTs.

In the present study, we assessed CRRTs at various directions on the hand, the forehead, and the canthus in a normal Chinese population. Variations of CRRTs with age, gender and body sites were further determined.

Materials and Methods

Subjects

A total of 806 volunteers, 408 males and 398 females aged 2.5 to 94 years old, were enrolled in this study (Table 1). The subjects were divided into following groups: 0–10, 11–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80, and over 80 years old. All subjects had no skin disorders at the study sites or systemic conditions known to affect CRRTs. No skin care products were applied to the measured sites 24 hours prior to the measurement taken, and the measured sites were not washed with soaps or surfactants for at least 2 hours prior to study.

Measured Sites and Methods

A Courage-Khazaka Reviscometer RVM600 was used to measure the CRRTs on the central dorsum of left hand, the forehead, and the canthus. Measurements were begun at the 12 o'clock position, which was determined with the hands laying on the table as described previously [30]. Measurements were then taken clockwise at every 1 hour interval or at every 30 degrees. These measurements provide the CRRTs at the directions of 0 to 6 o'clock, 1 to 7, 2 to 8, and so on. All subjects remained inactive at 24–26°C, at a relative humidity of 50–55% for 30 min before measurements were taken. All studies were completed between the months of July and October, 2008, correlating to Summer and earlier Autumn in northern China.

Statistics

Data were expressed as means $\pm$ SEM. Unpaired two tailed student's T test with Welch's correction was used to determine the significance between two groups. And ONE-way ANOVA test with Tukey correction was used to analyze the significance when three or more groups were compared. $P < 0.05$ was considered to be a significant difference. The GraphPad Prism 4 software was used for all statistical analysis.

All human research protocols were approved by the Human Research Subcommittee of Dalian Skin Disease Hospital.

Results

Change of CRRTs over Lifetime

Since previous studies have shown that CRRTs change with age, we first assessed the change of CRRTs over lifetime (22,25). In general, a gradual decrease of CRRT values can be observed with aging especially on the hands. As seen in Figure 1a and d, CRRTs on the hand of both males and females correlate negatively with age in all measured directions. However, the reduction of CRRTs at 0–6 and 1–7 o'clock directions seem more significant with aging in males ($r^2=0.4198$ and 0.4228 for 0–6 and 1–7 o'clock directions, respectively), and at 1–7 and 5–11 o'clock directions in females ($r^2=0.4568$ for 1–7 o'clock direction; $r^2=0.4858$ for 5–11 o'clock direction). A lesser reduction of CRRTs with aging was observed at 3–9 o'clock direction in both males and females ($r^2=0.2751$ and 0.2770 for males and females, respectively).

In contrast to the hand, age-related changes of CRRTs are less dramatic on the forehead in both males and females (Figure 1b and e). The change in CRRTs at 3–9 o'clock direction is more prominent as compared with other directions on the forehead of both genders ($r^2=0.04855$ and 0.05652 for males and females, respectively; $p<0.0001$ for both genders). No significant change of CRRTs over lifetime is observed at 1–7 and 5–11 o'clock directions on the foreheads of both males and females.

On the canthus of both males and females, changes of CRRTs at all directions are negatively correlated with age (Figure 1c and f). In males, more significant decline of CRRTs over the lifetime is found at 2–8 and 3–9 o'clock directions ($r^2=0.1169$ and 0.1187 , respectively). However, in females, the reductions of CRRTs at 0–6 and 2–8 o'clock directions are more significant as compared with other directions ($r^2=0.1211$ for 0–6 o'clock direction; $r^2=0.1221$ for 2–8 o'clock direction).

Change of CRRTs with Body Sites

We next analyzed the differences of CRRTs in different body sites. As seen in Figure 2, on the hand of males aged 0–20 years old, CRRTs at 0–6 and 5–11 o'clock directions, are significantly longer than those on both the forehead and the canthus of age-matched groups (Figure 2a,b). CRRT at the direction of 0–6 o'clock on the hand of males aged > 60 years old is significantly shorter than that on the forehead of age-matched groups (Figure 2g–i). CRRT at 2–8 o'clock direction on the hand is significantly shorter than that on the canthus in all age groups (Figure 2a–i). Additionally, CRRT at 2–8 o'clock direction is also significantly shorter on the hand than that on the forehead in groups aged over 30 years old (Figure 2d–i). CRRT at 2–8 o'clock direction on the forehead is significantly shorter than that on the canthus in groups aged 0–20 and 31–40 (Figure 2a, b, and d).

As seen in Figures 3, in females, CRRTs at 0–6 and 5–11 o'clock directions are significantly longer on the hand of aged 0–20 years old than those on both the forehead and the canthus of age-matched groups (Figure 3a,b). And CRRT at 5–11 o'clock directions is significantly longer on the hand in the groups aged 21–30 and 41–50 years old than those on both the forehead and the canthus of age-matched groups (Figure 3c, e). Additionally, CRRT at 0–6 o'clock directions is significantly shorter on the hand in the groups aged 51–60 and over 70 years old than that on the forehead of age-matched groups (Figure 3f–i). Furthermore, CRRT at 5–11 o'clock directions is also significantly shorter on the hand in the groups aged over 50 years old than that on the forehead of age-matched groups (Figure 3f, h, i). However, CRRT at 2–8 o'clock direction is longer on the hand than that on the canthus in

all age groups (Figure 3a–i). In contrast to the hand, CRRT at 3–9 o'clock direction is significantly longer on the canthus than that on the hand and in all age groups except 31–40 year old (Figure 3a–i). These results demonstrate the CRRTs change with body sites.

Change of CRRTs with Gender

We next determined whether there is a gender difference in CRRTs. On the hand, there was no gender difference in CRRTs in any direction in the groups aged 0–10, 41–50, 61–70 and over 80 years old (Figure 4). However, CRRTs at some directions in females aged 11–20, 51–60 and 71–80 years old are significantly shorter than those in age-matched males. In contrast, CRRT at 4–10 o'clock direction in females aged 21–30 is significantly longer than that in age-matched males. And in 31–40 years old group, CRRTs at 2–8 and 3–9 o'clock directions are also longer in females than in males.

On the forehead, no significant gender difference in CRRTs in any direction is observed in groups aged 0–10, 21–30, 31–40, 51–60, 61–70 and over 80 years old (Figure 5). CRRTs at all directions except 0–6 and 3–9 o'clock aged 11–20 years old are significantly shorter in females than in age-matched males. And in the 41–50 year-old group, CRRTs at the directions of 0–6, 1–7 and 2–8 o'clock are also significantly shorter in females than in age-matched males. In addition, CRRTs at directions of 0–6 and 5–11 o'clock are shorter in females of age 71–80 years old than that those in age-matched males.

On the canthus, CRRTs at the directions of 2–8 and 3–9 o'clock in 0–10 years old group are significantly shorter in females as compared with those in age-matched males (Figure 6). In addition, CRRTs at the directions of 4–10 and 5–11 o'clock in the group aged 11–20 years old directions are significantly shorter in females than in males. However, CRRTs at 4–10 o'clock direction in the group aged 31–40 years old is significantly longer in females than in males. In 41–50 and 71–80 year-old groups, CRRTs at the directions of 3–9, 4–10 and 5–11 o'clock are also significantly longer in females than in males. These results demonstrate that CRRTs vary with gender, too.

Discussion

Previous studies have shown that there are age-dependent changes in CRRTs on the forearm (22,25). CRRTs vary with measurement directions. When CRRTs were measured at various directions, the maximum CRRT value on the volar forearm, upper inner arm and the forehead correlated positively with age (22,25,26). However, our studies here do not show positive correlation of CRRTs with age in all three measured sites. In contrast, significant negative correlation of CRRTs with age is observed on the hand, which is in agreement with other studies (23,31). These resultant differences may be due to the measurement method. We took measurement at every 30° for a total of 360° while others measured at every 45° for a total of up to 315° (25,26). The later method has bigger measurement intervals which may miss some critical information about CRRTs at the missed directions. In addition, the different results may also reflect the ethnic and/or skin type differences. The subjects participating in present studies are Chinese while the majority of subjects, if not all of them, in other studies are Caucasians. Previous studies have demonstrated skin biophysical properties vary with race and skin type (32–38). Regarding the mechanisms that account for the decreased CRRTs in aged subjects, it is most likely due to alterations of dermal collagen fibers (22). CRRTs correlate negatively with skin stiffness and tension (23,39). As aging progresses, dermal collagen network configuration changes and elastin network defragmentation occurs, which could decrease skin elasticity and increase skin stiffness (23,40,41). Studies have demonstrated significant negative correlations of CRRTs and skin elasticity with age (31,40–42). Moreover, decreased SC hydration may also be attributable to the reduction of CRRTs at some directions. SC hydration decreases in aged skin (19).

Both skin elasticity and CRRTs measured with Cutometer and Reviscometer, respectively, decrease when SC hydration is reduced (43). Re-hydration of SC on the forearm increases CRRTs at 0–6 o'clock direction (23).

It has been reported that CRRTs are body site-dependent (22,23). Our results indicate that the variation of CRRTs with body site is also age-dependent. The mechanism underlying this phenomenon is not clear. However, studies have shown that CRRTs is influenced by skin microrelief, which differs in body sites (22). Skin tension and gravitational force, which influence CRRTs, also vary with body site (44). Moreover, CRRTs could also be affected by skin stiffness and SC hydration, both of which vary with body site (45,46). Furthermore, other determinants of CRRTs such as collagen content and elasticity also vary with body site (47,48). Among these three measured sites in this study, the most dramatic reduction in CRRTs with aging is observed on the hand. This may be due to the fact that the hand suffers more external damage from agents such as UV and detergents, both of which are known to exacerbate skin aging. People generally do not put sun-screen on the hand, especially in China. Therefore, the body site difference in CRRTs is due to variations of local cutaneous structure and function.

Although gender differences in skin biophysical properties such as skin surface pH, transepidermal water loss, sebum content, and SC hydration have been well documented (18,49,50), the difference in CRRTs between males and females is largely unknown. In present studies, we have demonstrated that there are indeed gender differences in CRRTs. Generally, CRRTs, especially on the forehead, are shorter in females than in males. Several factors attribute to this gender differences. Firstly, skin thickness correlates positively with CRRTs and skin is thinner in females than in males (24,48,51). Secondly, collagen fibrils have significant impact on CRRTs and fibril diameters are significantly smaller in females than in males (52). Additionally, studies have shown that androgens up-regulate expression of skin collagen genes and collagen synthesis (53–55). Furthermore, previous studies have demonstrated that SC hydration correlates positively with CRRTs; SC hydration on the forehead of females aged 13–35 is lower than that in males (18,23,43). Thus, the difference in SC hydration may also attribute to the difference in CRRTs between males and females.

In summary, in present studies we have demonstrated that CRRTs vary with age, gender, and body site. Measurement of CRRTs could be another valuable non-invasive approach to evaluate both cutaneous function and the efficacy of some skincare products.

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Figure 1. Change of CRRTs over Lifetime

1a. CRRTs on the hand of males; 1b. CRRTs on the forehead of males; 1c. CRRTs on the canthus of males; 1d. CRRTs on the hand of females; 1e. CRRTs on the forehead of females; 1f. CRRTs on the canthus of females. Significant differences are shown in the figure.

Figure 2. Change of CRRTs with Body Site in Males

2a. CRRTs in 0–10 years old group; 2b. CRRTs in 11–20 years old group; 2c. CRRTs in 21–30 years old group; 2d. CRRTs in 31–40 years old group; 2e. CRRTs in 41–50 years old group; 2f. CRRTs in 51–60 years old group; 2g. CRRTs in 61–70 years old group; 2h. CRRTs in 71–80 years old group; 2i. CRRTs in group aged over 80 years old. Numbers of subjects in each group are listed in Table 1. One-way ANOVA with post Tukey correction was used to determine significances. All significances are indicated in the figure.

Figure 3. Change of CRRTs with Body Site in Females

3a. CRRTs in 0–10 years old group; 3b. CRRTs in 11–20 years old group; 3c. CRRTs in 21–30 years old group; 3d. CRRTs in 31–40 years old group; 3e. CRRTs in 41–50 years old group; 3f. CRRTs in 51–60 years old group; 3g. CRRTs in 61–70 years old group; 3h. CRRTs in 71–80 years old group; 3i. CRRTs in group aged over 80 years old. Numbers of subjects in each group are listed in Table 1. One-way ANOVA with post Tukey correction was used to determine significances. All significances are indicated in the figure.

Figure 4. Comparison of CRRTs on the Hand between Males and Females

Numbers of subjects in each group are listed in Table 1. Unpaired Two-tailed Student's T-test with post Welch correction was used to determine significances. All significances and age groups are indicated in the figure.

Figure 5. Comparison of CRRTs on the Forehead between Males and Females

Numbers of subjects in each group are listed in Table 1. Unpaired Two-tailed Student's T-test with post Welch correction was used to determine significances. All significances and age groups are indicated in the figure.

Figure 6. Comparison of CRRTs on the Canthus between Males and Females

Numbers of subjects in each group are listed in Table 1. Unpaired Two-tailed Student's T-test with post Welch correction was used to determine significances. All significances and age groups are indicated in the figure.

Table 1

Characteristic of Subjects

Age	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	Over 80	Total
Males	70	50	36	40	40	52	28	50	42	408
Females	58	40	38	50	40	50	40	40	42	398
Total	128	90	74	90	80	102	68	90	84	806