논문 2010-47SC-5-7

손등 피부 마찰계수를 이용한 태음인과 소양인 간의 체질구별

(Constitutional Classification between Tae-eumin and Soyangin Types by Measurement of the Friction Coefficient on the Skin of the Human Hand)

송 한 욱*, 박 연 규*

(Han Wook Song and Yon-Kyu Park)

요 약

최근 피부의 마찰계수를 이용하여 한의학에서의 체질을 구별하는 연구가 활발히 이루어지고 있다. 피부의 마찰계수는 여러 고문헌에서도 알려져 있듯이 태음인과 소양인의 체질을 구별하는 인자로 활용되고 있다. 본 연구에서는 다축 로드셀과 일정하중식 접촉 프로브를 이용하여 피부의 마찰계수를 정량적으로 측정하는 장비를 개발하였고 이의 측정 불확도를 측정하였다. 개발된 장비의 상대 반복도는 2 %였다. 태음인과 소양인의 체질진단 구분을 위해 왼속 손등을 측정부위로 선택하여 실험한 결과 약지를 따라 측정하는 것이 가장 효과적임을 알 수 있었다. 20명의 피험자를 대상으로 임상측정을 한 결과, 개발된 장비의 경우 3 % 이내의 측정 불확도를 가지고 태음인과 소양인의 체질 구분을 할 수 있었다.

Abstract

The use of the friction coefficient is known to provide good discrimination ability in the classification of human constitutions, which are used in alternative medicine. In this study, a system that uses a multi-axis load cell and a hemi-circular probe is designed. The equipment consists of a sensor (load cell type, manufactured by the authors), an x-axis linear-bush guide motorized mobile stage that supports the hand being analyzed, and a signal conditioner. Using the proposed system, the friction coefficients from different constitutions were compared, and the relative repeatability error for the friction coefficient measurement was determined to be less than 2 %. The direction along the ring finger line was determined to be the optimum measurement region for a constitutional diagnosis between Tae-eumin and Soyangin types using the proposed system. There were some differences in the friction coefficient between the two constitutions, as reported in ancient literature. The proposed system is applicable to a quantitative constitutional diagnosis between Tae-eumin and Soyangin types within an acceptable level of uncertainty.

Keywords : Constitution, Friction coefficient, multi-axis load cell

I. Introduction

A wealth of studies on constitutions has been published. Examples include the dichotomy of Hippocrates, the quartering method of Hall, the three constitution theory of Sigauard, the cosmic dual-force fifty people principle (陰陽五十人論) of Huang Di Nei Jing (黃帝內經), and three docha theory popularized in India[1]. Among constitution theories, Sasang constitutional medicine was initiated by Lee Je-Ma, a ancient dynasties. Sasang constitutional medicine focuses on the different constitutional manifestations of the nature and emotions of an individual. Nature and emotions drive the ascent and descent of Qi in

* 정회원, 한국표준과학연구원
(Korea Research Institute of Standards and Science)

※ 본 연구는 지식경제부 산업원천기술개발사업의 일환인 "오감형 진단시스템개발 (No. 10028438)" 과제의 지원을 받아서 수행되었습니다.
접수일자: 2010년7월6일, 수정완료일: 2010년9월7일

the body. The dynamics of the ascent and descent of Qi shapes the different types of structure, functions, and properties of human body types, that is, Taeyangin, Soyangin, Tae-eumin, and Soeumin[2]. There are a variety of diagnosis methods of the Sasang constitution[3~4]. However, it is very difficult to standardize traditional diagnosis methods, as they are dependent on qualitative judgments of oriental medicine doctors using senses such as sight, hearing, and so on. Therefore, it is necessary to develop equipments for constitutional diagnoses in order to make it possible to solve these problems using the functional sensors of each human sense.

Constitutional diagnoses using human skin in Oriental medicine are classified using the concept of palpation. From Sasang constitutional medicine, which follows Oriental medical principles, humans can be classified according to the properties of their skin, including its texture, roughness, hardness, and elasticity[5~7].

From Dongeusoosebowoon[5], the properties of different types of human skin were categorized into 'If a Tae-eumin has hard and dense skin that does not sweat, this person is likely very sick. If a Soeumin has hard and dense skin without sweat, he is very healthy. A Tae-eumin has solid skin and a Soeumin has smooth skin (太陰人 陽剛堅密 則大病也, 少陰人 陽剛堅密 則完實也, 太陰人肌肉 堅實, 少陰人肌肉 浮軟, in the original Chinese characters)'. Ancient Korean Oriental medicine doctors recorded the following[6]: We inspect human skin. The skin of Tae-eumins is generally thick and rough; sometimes Tae-eumins have soft skin. People who are Soeumins generally have soft skin. Soyangins also seem to have slippery and thin skin. Taeyangins show similar properties to Soeumins.

However, in Sasangyolam[7], ancient Korean doctors also described the constitutional skin status: We inspected skin. The skin status of Soyangins is slippery and thin, but occasionally some Soyangins have thick skin. The skin of Tae-eumins is thick and stiff; but Tae-eumins occasionally have soft skin. The skin of Soeumins is buoyant and soft.

From these examples of ancient literature and from clinical research[8], it is possible to classify the traditional tactile sensation of human skin as either 'thick and thin skin', 'hard and soft skin', 'rough and fine skin', or 'buoyant and slippery skin'.

Skin is an indispensible organ for humans, as it contributes to metabolism using its own biochemical functions and protects the human body from external stimuli. The research topics for skin properties include its roughness, elastic coefficient, moisture content, oil content, color, and surface friction coefficient. However, the last topic has been scarcely researched compared with other listed topics. Moreover, there have been few studies on the quantitative measurement of the skin friction coefficient[9~13].

The friction coefficient is known to provide excellent discrimination ability in the classification of the aforementioned human constitutions. Lee[8] etal. hold that Soyangin can be clinically distinguished from other constitutions using the tactile properties of human skin on the basis of distinct physical quantities pertaining to tactile sensation as a frictionc oefficient. However, relatively littler esearch has been conducted focusing on quantification of the friction coefficient of human skin.

In this study, a system that uses a multi-axis load cell and a hemi-circular probe is designed. The friction coefficient of the skin on human hands is measured repeatedly for palpation, an important factor in Oriental medicine. The optimum diagnosis region using the proposed system was inspected on the skin of the human hand.

Ⅱ. Experimental Setup

Fig. 1 shows the inspection system for the skin of the human hand. This system is composed of three sections: a sensing section containing a multi-axis load cell and a contact probe as denoted with the red solid line(designed by the authors), a stage

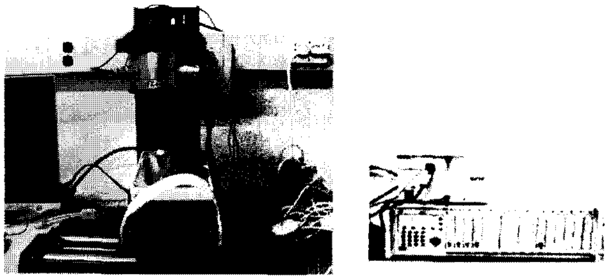


그림 1. 측정장비의 개략도
Fig. 1. Schematic diagram of the equipment.

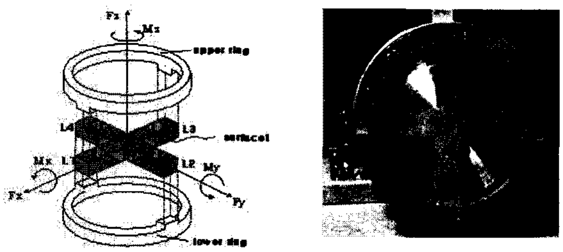


그림 2. 쌍안형 다축 로드셀의 구조와 실제 모습
Fig. 2. Configuration of the binocular-type multi-axis load cell.

(KS122-300, Suruga Seiki) with a jig to transfer the hand to be inspected (green dotted line), and a signal conditioner (MGC plus, HBM) with measuring modules (ML10, HBM, blue dot-dash line) for the measured data.

To measure the friction coefficient of skin, it is necessary to simultaneously measure the forces in both the normal and moving directions. For these measurements, a sensor was used to measure the forces in arbitrarily directions on a x-y plane as well as the force in the normal z direction. Fig. 2 shows the configuration of the binocular-type multi-axis load cell. The sensing unit has upper and lower rings, each of which has lots of diametrical and opposite connectors and locking holes. The sensing unit also has a cross beam that has horizontal and vertical sections crossing at a right angle. In the cross beam, numerous vertical and transverse binocular openings are formed on the horizontal and vertical sections, and each opening has a binocular cross-section. The horizontal and vertical sections of the cross beam are spaced apart from the lower and upper rings, but are connected to the upper and lower

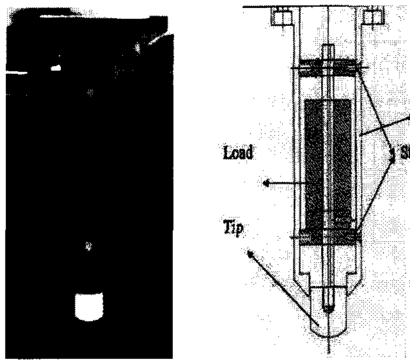


그림 3. 일정하중형 프로부
Fig. 3. Constant load probe.

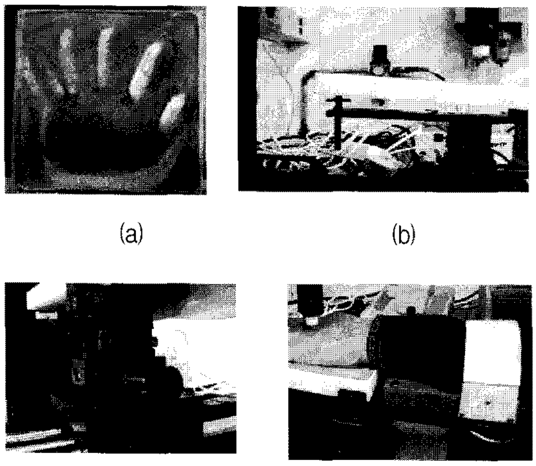
rings through connectors, thus integrating parts of the sensing unit into a single structure. The ends of the horizontal section of the cross beam are attached to the upper ring, and the ends of the vertical section are attached to the lower ring. This results in different boundary conditions between horizontal and vertical sections.

Therefore, the load cell is asymmetric in the horizontal and vertical directions, although the sensing element of the cross beam has symmetrical geometry of 90^{o}[14].

The contact probe was designed to follow the flexion of the back skin surface of the hand by maintaining a constant load, as shown in Fig. 3.

The guide is made of stainless steel and the middle bar of aluminum. The tip and stoppers are made of Teflon, which is similar in terms of mechanical properties to human skin.

The carrying stage for the hand is an axis linear stage with a travel distance of 300 mm in one direction. The load capacity is 196 N and the moving speed varies up to 20 mm/s. For the perpendicular contacts between the tips and the hands, a carrying jig (Fig. 4) was fabricated and then tilted to obtain maximum flatness of the contact point. The lower part of the arm is fastened so as not to move during the measurement, as shown in Fig. 4. The measured data is sampled at the signal conditioner and transferred to a computer via a GPIB cable. The entire measuring system is controlled using software designed by NI-LabView Version 8.2.



(a) (b)

(c) (d)

그림 4. 측정용 손을 수납하기 위한 지그:
(a) 손 수납부, (b) 수직방향에 대한 조정나사,
(c) 수평면에 있어서 x, y 방향에 대한 조정나사
(d) 팔의 하박부를 고정하기 위한 고정부

Fig. 4. Jig to carry the hand being analyzed:
(a) the hand placeholder, (b) the tilting screw for the vertical direction, (c) the tilting screws for the x and y directions on the horizontal plane and (d) fixing part for the lower arms.

(a) (b)

그림 5. (a) 실제 측정예
(b) 장비 제어를 위한 소프트웨어.

Fig. 5. (a) Measurement example and
(b) software for equipment control.

Fig. 5 shows an example of the measuring process and the controlling software.

III. Evaluation of equipment : Uncertainty

Before the comparison between the Soyangin and Tae-eumin types, the measurement ability of the proposed system was evaluated. Table 1 shows the calibration results of the load cell, obtained using a method incorporating a dead weight, a wire, and a pulley. The maximum interference error among

표 1. 로드셀의 교정 결과

Table 1. Calibration results of the load cell.

Load cell		Fx	Fy	Fz
Rated load (N)		10	10	10
Rated output (mV/V)		0.3837	0.3902	0.6069
Interference error	Fx = 10 N	-	0.13%	0.74%
	Fy = 10 N	0.39%	-	-0.25%
	Fz = 10 N	-0.34%	0.00%	-

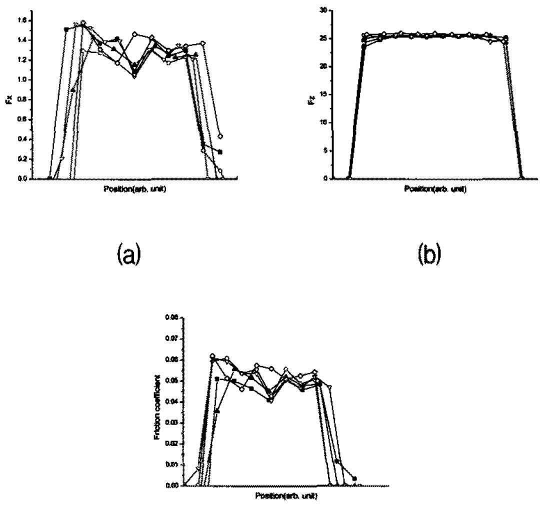
theforce signals for each direction was 0.74%. The interference error was defined as the ratio between the force component in the loaded direction and the force component force in each separate direction. The capacity of the sensor was 10 N for the force components.

The friction coefficient is defined as the ratio between the normal force and the force in the moving direction. It is expressed by Eq. (1):

$$\text{Friction coefficient} = \frac{\text{Horizental Force}}{\text{Normal Force}} \tag{1}$$

Constant load type probes were adopted, as shown in Fig. 3. While normal force for an fixed probe was affected by both factors as the normal force was directly transferred to the load cell in this type during a contact event, the normal force was dominated by the mass in the probe for the constant load type movable probe, which had a buffering effect during the contact and was not affected by the thickness and the slope of subjects tested.

To verify the accuracy of the system, the friction coefficient of a Teflon plate was measured, because the friction coefficient between two items consisting of Teflon is known to be approximately 0.1 according to the physical status of the Teflon used[15]. The plate was attached to the jig using commercial 3M tape, and the sensor tip then made contact with the plate. The friction coefficient between the Teflonpr obeand the Teflon plate was measured five times using round-trip motions. Fig. 6 and Table 2 show the measurement results. With these data, the uncertainty



(a) (b)

(c)

그림 6. 테플론 구조물간에 작용되는 (a) 수평력, (b) 수직력, (c) 마찰계수.
Fig. 6. (a) Horizontal force, (b) normal force, and (c) friction coefficient between the Teflon parts.

of the proposed system was calculated.

The expanded uncertainty (W_p) for Teflon is expressed as given in Eq. (2)[16]:

$$W_p = k \cdot w_{c,p}(\%),\ \text{k=2 (95\%)}, \quad (2)$$

where $w_{c,p}$ is the relative combined uncertainty for the plate. It is defined in Eq. (3):

$$w_{c,p} = \sqrt{w_{rx,p}^2 + w_{rz,p}^2 + w_{a,p}^2 + w_s^2}\ (\%) \quad (3)$$

In Eq. (3), $w_{rx,p}$, $w_{rz,p}$, $w_{a,p}$, and w_s are the uncertainties due to the resolution of the force measurements in the moving direction, the resolution of the force measurements in the normal direction, the relative repeatability, and the uncertainty of the load cell, respectively. The first three uncertainty values are defined by Eqs. (4), (5), and (6), respectively.

표 2. 테플론구조물간의 마찰계수
Table 2. Friction coefficients of the Teflon parts.

Time	1	2	3	4	5	Mean
Average Value	0.052	0.051	0.051	0.052	0.052	0.051

$$w_{rx,p} = \frac{r}{2\sqrt{3} \cdot F_x} \times 100\ (\%) \quad (4)$$

r: resolution of signal conditioner,
F_x: force in moving direction,

$$w_{rz,p} = \frac{r}{2\sqrt{3} \cdot F_z} \times 100\ (\%) \quad (5)$$

r: resolution of signal conditioner,
F_z: force in normal direction,

$$w_{a,p} = \frac{(u_{max} - u_{min})}{2\sqrt{3} \cdot u_{aver.}} \times 100\ (\%) \quad (6)$$

u_i: friction coefficient.

If r is assumed to be 0.02 N (the data from the manufacturer) and ws is 0.1%, $w_{rx,p}$, $w_{rz,p}$, and $w_{a,p}$ are 0.29%, 0.023%, and 0.60%, respectively, using the aforementioned calculations and Fig. 6. The value of wc,p is 0.67% and that of Wp is 1.35%. These results show that the proposed system reliably measures the friction coefficient.

Before measuring the forces at the contact point between the probe and a hand, the effect of the slope at the contact point was offset using screws, as shown in Fig. 4. The friction coefficient has the geometrical factor(k), as shown in Eq. (7), and k approaches 1 when α << 1°. Therefore, the effect of the contact angle on the friction coefficient using screws, as shown in Figs. 5(b) and 5(c), can be ignored.

$$u_\alpha \propto k u_o = \frac{\cos^2\alpha}{1 + \sin\alpha\cos\alpha} u_o, \quad (7a)$$

Here, u_o is the friction coefficient of the perpendicular contact and α is the contact angle (for an ascent).

$$u_\alpha \propto k u_o = \frac{\cos^2\alpha}{1 - \sin\alpha\cos\alpha} u_o \quad (7b)$$

Additionally, uo is the friction coefficient for a perpendicular contact and α is the contact angle (for a descent).

Ⅳ. Clinical Evaluation Ⅰ : Optimum Condition

Using the proposed system, the measurability of the system was tested using human hands. The inspection region was the region on the back of the left hand and the tip crossing the middle of the hand, as shown in Fig. 7. The scan sequence is also shown in Fig. 7. At the beginning of the scan, the probe was moved downwards to make contact with the hand. After contact, the jig was moved and the force data in each direction were collected. Finally, the probe was moved upwards, breaking contact with the hand. The scan length was 1 cm and the scan speed was 0.3 cm/s. The subjects were controlled to ensure they had the same shoulder height so as to eliminate the need to move the jig to make contact with the subjects' hands.

Fig. 8 shows the friction coefficient of the skin of a hand from a male subject. The hand was inspected five times. However, some fluctuations may be induced by finger bones and blood vessels. The averaged friction coefficient of each measurement is summarized in Table 3. The expanded uncertainty of the proposed system for this measurement (W_h) was 2.0 %, as calculated using Eqs. (2)-(6). From this data, it was concluded that the proposed system functions as reliable inspection equipment capable of determining the friction coefficient of the hand skin.

Two male subjects in their twenties were selected to find the optimum skin region of the human hand for a quantitative diagnosis using the proposed system. The first was a Soyangin type and the second was a Tae-eumin type, as determined through pre-testing and diagnosis of their constitution by doctors of oriental medicine. Before the measurement, the conditions of the subjects' hands, such as the temperature and the humidity, were synchronized, because the mechanical properties of human skin are typically affected by the temperature and the humidity of the skin itself.

The measurement region was defined as the area of the width between the index finger and the ring finger of the left hand and the height between three middle fingers of the right hand, overlain onto the middle point of the middle finger bone of the left

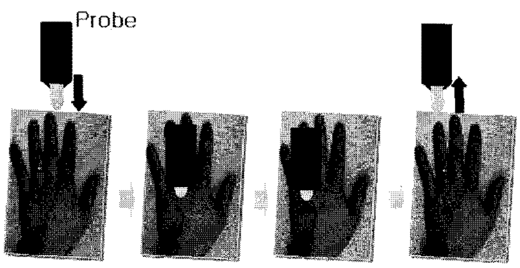


그림 7. 측정 순서.
Fig. 7. Measurement sequence.

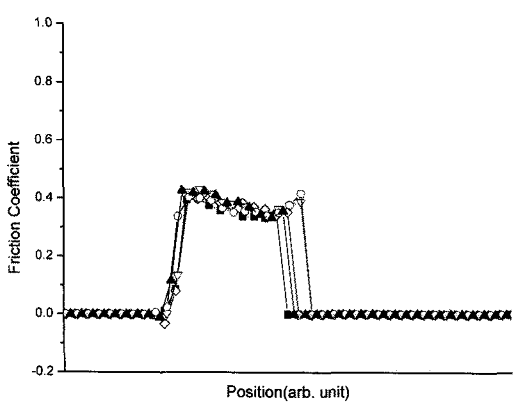


그림 8. 손표면의 마찰계수
Fig. 8. Friction coefficients of hand skin.

표 3. 사람 손 피부에 마찰 계수
Table 3. Friction coefficients of the skin of a human hand.

Time	1	2	3	4	5	Mean
Average Value	0.38	0.38	0.39	0.39	0.38	0.38

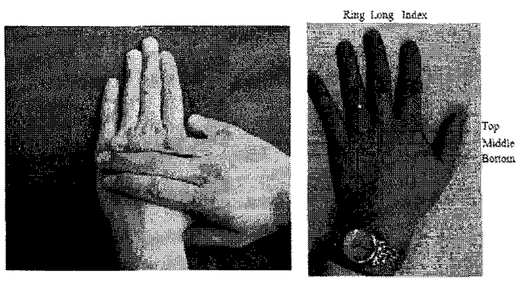


그림 9. 왼쪽 손등의 측정 부위
Fig. 9. Inspection regions in the back of left hand.

hand, as shown in Fig. 9. This region was chosen because an Oriental medicine doctor commonly palpates this region for a constitutional diagnosis and this aspect was intensively pre-studied in our previous research[17]. There were nine contact points in the region to find the optimum contact point for quantitative palpation, and they were coordinated as (Top, Index), (Top, Long), (Top, Ring), to (Bottom, Ring).

The comparison between Tae-eumin type and Soyangin type was done by the system. The

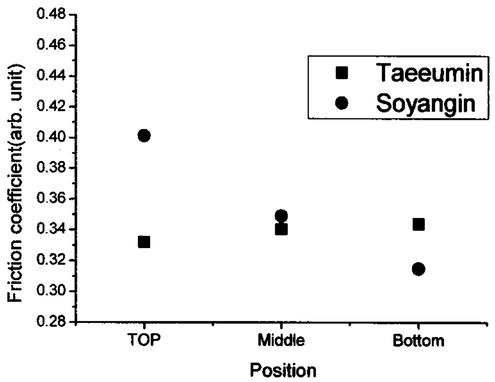


그림 10. 태음인과 소양인에 대해 집게손가락선을 따르는 측정부위에 있어서 횡방향으로 측정된 마찰계수의 비교결과

Fig. 10. Comparison of the friction coefficients between Tae-eumin and Soyangin along the index finger line in the transverse scan direction.

measurement was conducted five times repeatedly for the nine contact points noted above. There were two scan directions. The first is the direction traversing the finger bones, at which point a doctor of Oriental medicine generally palpates the human hands, and the second is the direction along the bones, which will simplify the measurements owing to the flatness of the scan path.

For the traversing direction, the Tae-eumin type had higher friction coefficients than the Soyangin type for the (Top, Ring), (Middle, Ring) and (Bottom, Ring) measurements. This is in good agreement with the qualitative measurements of an Oriental medicine doctor and several sources from antiquity[3~5] (Fig.10). However, there were no consistent relationships in the remaining coordination measurements(Fig. 11 and Fig. 12). From these results, the region along the ring finger was determined to be optimum for the diagnosis, which is in good agreement with the traditional method used in oriental medicine.

For the direction along the finger bones, the measurement was carried out only along the middle line to verify that the results were in good agreement with the palpation diagnosis by a doctor of Oriental medicine. From the results, the Tae-eumin type had

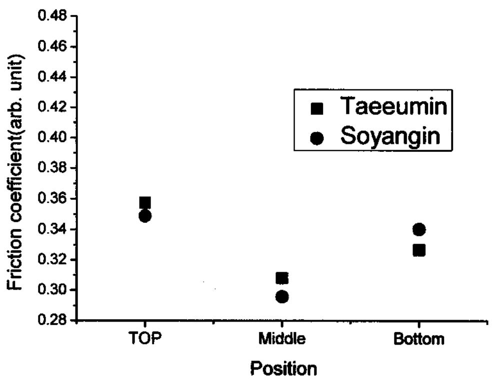


그림 11. 태음인과 소양인에 대해 가운데손가락선을 따르는 측정부위에 있어서 횡방향으로 측정된 마찰계수의 비교결과

Fig. 11. Comparison of friction coefficients between Tae-eumin and Soyangin along the long finger line in the transverse scan direction.

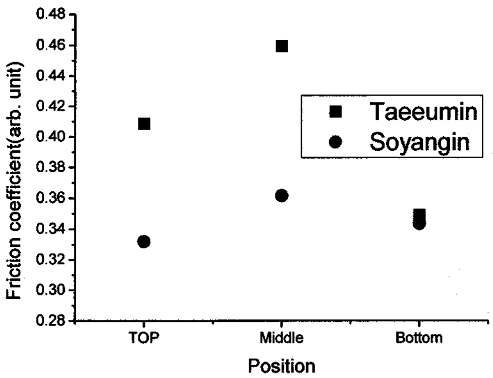


그림 12. 태음인과 소양인에 대해 넷째손가락선을 따르는 측정부위에 있어서 횡방향으로 측정된 마찰계수의 비교결과

Fig. 12. Comparison of friction coefficients between Tae-eumin and Soyangin along the ring finger line in the transverse scan direction.

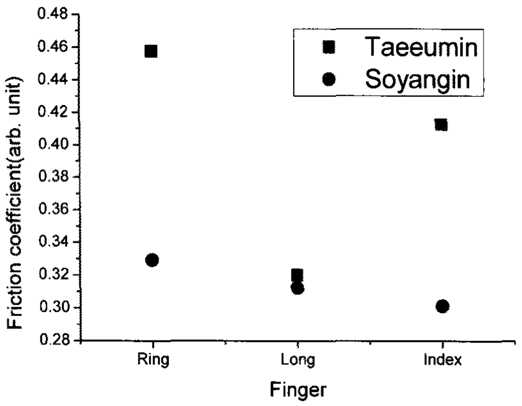


그림 13. 태음인과 소양인에 대해 손가락뼈에 평행하게 한 측정된 손가락별 마찰계수의 비교결과

Fig. 13. Comparison of friction coefficients between Tae-eumin and Soyangin types along the finger bones.

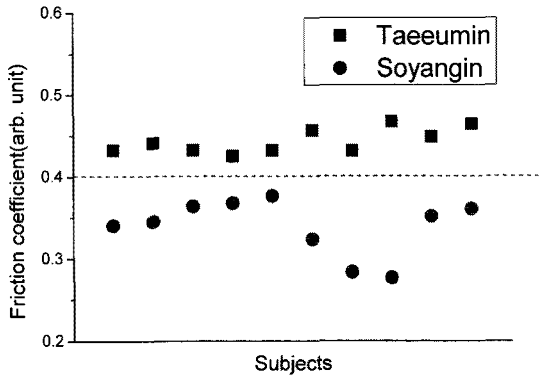


그림 14. 태음인과 소양인에 대해 체질별 마찰계수의 임상결과

Fig. 14. Clinical data pertaining to the friction coefficients between Tae-eumin and Soyangin types.

a higher friction coefficient than the Soyangin type in the directions along the ring finger line and along the index finger line. This closely matched the palpation diagnosis by a doctor of Oriental medicine (Fig. 13). On the other hand, there was no difference between the Tae-eumin and Soyangin types in the direction along the long finger line. Therefore, the direction along the ring finger line was determined to be the optimum region for a constitutional diagnosis between the Tae-eumin and Soyangin types.

V. Clinical Evaluation II : Comparison between Tae-eumin and Soyangin

Using the proposed system, the friction coefficients from two constitutions were compared. Each data point was collected from 20 Tae-eumin and Soyangin male subjects of twenties pre-diagnosed by the East-West Neo Medical Center at Kyung Hee University using the contact point of (Middle, Ring).

Fig. 14 shows the distribution of the friction coefficient for each constitution, and Table 4 summarizes the average values of the friction coefficients and the degree of uncertainty. Although deviations due to the individual characteristics for each subject within each constitution (such as those

표 4. 두 체질간의 마찰계수결과

Table 4. Friction coefficients from the two constitutions.

Constitution	Tae-eumin	Soyangin
Average value	0.44	0.34
Uncertainty	2.00 %	2.40 %

by the age, height, and weight of the subjects) are considered, Tae-eumins show a higher friction coefficient than Soyangins within an accepted level of uncertainty, and this tendency is in good agreement with the findings reported in the literature[3-5]. Additional clinical data will be collected and used in future study, and biological reasons for the differences between the Tae-eumin and Soyangin types wil lbe discussed in subsequent research.

VI. Conclusion

A measuring system for the friction coefficient of human skin was formulated using a multi-axis load cell for the purpose of realizing a constitutional diagnosis method. Using this system, the expanded uncertainty for the measurement of the friction coefficient was less than 2%. The direction along the ring finger line was determined to be the optimum measurement region for a constitutional diagnosis between the Tae-eumin and Soyangin types using this system, and this result was shown to be in good agreement with the ancient literature and with diagnosis methods adopted by doctors of Oriental medicine. Using the proposed system, the friction coefficients from two constitutions among 20 subjects pre-diagnosed by the East-West Neo Medical Center at Kyung Hee University were compared. Even considering the deviations that result from the individual characteristics of each subject within each constitution, Tae-eumins show a higher friction coefficient compared to Soyangins within an acceptable level of uncertainty, and this tendency matches the findings of ancient studies. It can be concluded that the proposed system is applicable to quantitative constitutional diagnoses between Tae-eumin and Soyangin types within an acceptable level of uncertainty. Additional clinical data will be collected in subsequent research.

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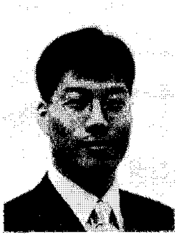
―――― 저 자 소 개 ――――

송 한 욱(정회원)
1995년 KAIST 무기재료공학과 학사 졸업.
1998년 KAIST 재료공학과 석사 졸업.
2002년 KAIST 재료공학과 박사 졸업.
2002년 9월~2005년 12월 LS 전선 광통신연구소 선임연구원
2006년 1월~현재 한국표준과학연구원 기반표준본부 역학센터 선임연구원
<주관심분야 : 압전재료, 인체역학, 진공표준>



박 연 규(정회원)
1991년 KAIST 기계공학과 학사 졸업.
1993년 KAIST 기계공학과 석사 졸업.
1998년 KAIST 기계공학과 박사 졸업.
1998년 3월~현재 한국표준과학연구원 책임연구원
2003년 3월~2004년 2월 독일 연방물리청(PTB) 방문연구원
2007년 5월~2007년 12월 국무조정실 의료산업 발전기획단 전문위원
<주관심분야 : 역학표준, 인체역학, 오감센서>