XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6–11, 2009, Lisbon, Portugal

DEVELOPMENT OF A MEASUREMENT SYSTEM OF THE FRICTION COEFFICIENT ON THE SKIN OF THE HUMAN HAND USING LOAD CELL

Han Wook Song[1] , *Yon Kyu Park*[2], *and Sam Yong Woo*[3]

[1]Korea Research Institute of Standards and Science,
Daejeon, South Korea, hanugi16@kriss.re.kr
[2]Korea Research Institute of Standards and Science,
Daejeon, South Korea, ykpark@kriss.re.kr
[3]Korea Research Institute of Standards and Science,
Daejeon, South Korea, sywoo@kriss.re.kr

Abstract – The constitutional diagnosis using human skins is classified to palpation in oriental medicines. From Sasang constitutional medicine which is one of oriental medicines, human could be divided by the properties of their skins such as texture, roughness, hardness and elasticity. Especially, the friction coefficient and roughness of skins have big discrimination ability in the classification of human constitutions But this classification has been dependent on the qualitative judgment of an oriental doctor. In this paper, we present the quantitative measurement method, equipment of the friction coefficient of human hands using the load cell for oriental medicine, and diagnosis standards of human constitution based on the principal of Sasang constitutional medicine. The expanded uncertainty for the measurement of the friction coefficient was below 2.0 %.

Keywords: Load cell, Friction coefficient, Skin

1. INTRODUCTION

The constitutional diagnosis using human skins is classified to palpation in oriental medicines. From Sasang constitutional medicine which is one of oriental medicines, human could be divided by the properties of their skins such as texture, roughness, hardness and elasticity. Especially, the friction coefficient and roughness of skins have big discrimination ability in the classification of human constitutions, especially between Tae-eumin type and Soyangin type [1-3]. Recently, the friction coefficient has been used as the decision index for the progress of bacterial aliments in skin physiology, and the importance of the friction coefficient has been emphasized in the skin care market due to the increased awareness of wellbeing issues [4-5]. In addition, the use of the friction coefficient is known to have a great discrimination ability in the classification of human constitutions, which are used in alternative and oriental medicines [6].

In this paper, we present the quantitative measurement method, equipment of the friction coefficient of human hands using the load cell for oriental medicine, and diagnosis standards of human constitution(especially between Tae-eumin and Soyangin) based on the principal of Sasang constitutional medicine.

2. 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 (designed by the authors, as denoted with the red solid line), a stage (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) for the measured data (blue dot-dash line).

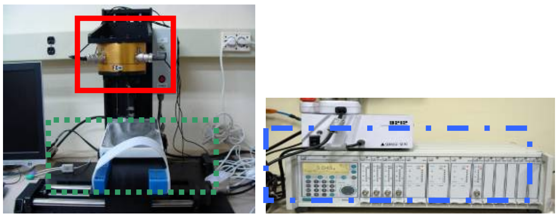


Fig. 1. Schematic diagram of the equipment.

To measure the friction coefficient of skin, it is necessary to measure the forces in both the normal and moving directions simultaneously. For these measurements, a sensor was used to measure the forces in arbitrarily moving x and y directions on planes 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 numerous diametrically opposite connectors and locking holes. The sensing unit also has a cross beam that has horizontal and vertical sections crossing at right angles. 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 rings through connectors, thus integrating 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.

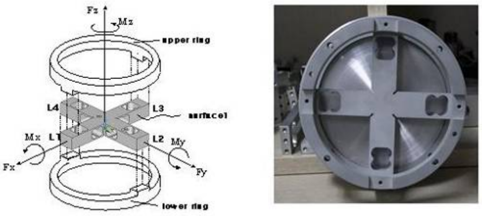


Fig. 2. Binocular-type multi-axis load cell.

This results in horizontal and vertical sections with different boundary conditions. Therefore, the load cell is asymmetrical in the horizontal and vertical directions, although the sensing element of the cross beam has symmetrical geometry of 90^{o}.

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

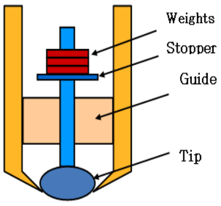
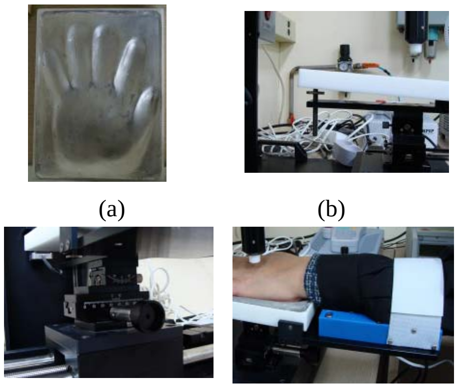


Fig. 3. Constant load type probe.

The carrying stage for the hand was an axis linear stage with a travel distance was 300 mm in one direction. The load capacity was 196 N and the moving speed could vary 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 the maximum flatness of the contact point. The lower part of arm was fastened so as not to move during the measurement, as shown in Fig. 4.


(a) (b)

(c) (d)

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.

The measured data was sampled at the signal conditioner and transferred to a computer via a GPIB cable. The entire measuring system was controlled using software designed by NI-LabView Version 8.2.

3. RESULTS AND ANALYSIS

Table 1 shows the calibration results of the load cell tested by a dead weight, wire, and pulley method. The maximum interference error among the force signals for each direction was 0.74%. The interference error was defined as the ratio between the component force for the loaded direction and the component force for each direction. The capacity of the sensor was 10 N for the force components.

Fig. 5 shows the friction coefficient of the skin of a hand. We also inspected the hand five times. However, some fluctuations may be induced by the finger bones and blood vessels. The averaged friction coefficient of each measurement is summarized in Table 2. With these data, the uncertainty of the proposed system was calculated.

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%	-

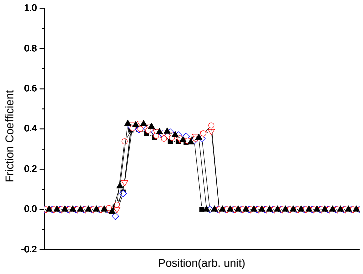


Fig. 5. Friction coefficients of hand skin.

Table 2. Friction coefficients of the skin of a human hand.

Time	1	2	3	4	5	Mean
Average Value	0.382	0.375	0.388	0.386	0.378	0.382

The expanded uncertainty (W_p) was expressed as in (1) [7]:

$$W_p = k \cdot w_c(\%),\ k=2\ (95\%) \tag{1}$$

where w_c is the relative combined uncertainty for the plate. It is defined in (2):

$$w_c = \sqrt{w_{rx}^2 + w_{rz} + w_a^2 + w_s^2}\ (\%) \qquad (2)$$

In Eq. (2), w_{rx}, w_{rz}, w_a, 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. (3), (4), and (5), respectively.

$$w_{rx,p} = \frac{r}{2\sqrt{3}\cdot F_x}\times 100\ (\%)$$ r: resolution of signal conditioner,

F_x: force in moving direction, (3)

$$w_{rz,p} = \frac{r}{2\sqrt{3}\cdot F_z}\times 100\ (\%)$$ r: resolution of signal conditioner,

F_z: force in normal direction, (4)

$$w_{a,p} = \frac{(u_{\max} - u_{\min})}{2\sqrt{3}\cdot u_{aver.}}\times 100\ (\%)$$ u_i: friction coefficient. (5)

If we assumed r to be 0.021% and w_s to be 0.12%, w_{rx}, w_{rz}, and w_a are 0.29%, 0.023%, and 0.60%, respectively. The value of w_c is 0.67% and that of W_p is 2.0%.

Two male subjects of 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 which was the constitution types in Sasang constitutional medicine [1], 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 which overlain onto the middle point of the middle finger bone of the left hand, as shown in Fig. 6. This region was chosen because an oriental medicine doctor

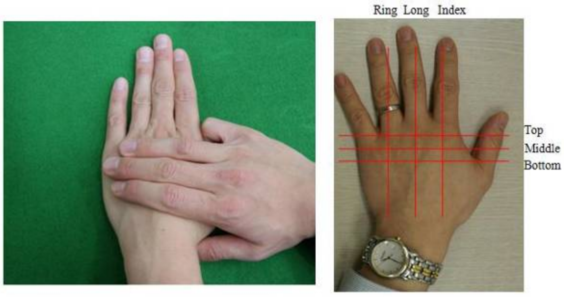


Fig. 6. Inspection regions in the back of left hand.

There were nine contact points in the region to find the optimum contact point for a quantitative palpation, and they were coordinated as (Top, Index), (Top, Long), (Top, Ring), to (Bottom, Ring).

The comparison between a Tae-eumin type and a Soyangin type was done by the system. The measurement was conducted by five times repeatedly for the nine contact points mentioned above. There were two scan directions. The first is the direction traversing the finger bones at which point a doctor oriental of 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, a Tae-eumin type had higher friction coefficients than a Soyangin type for the (Top, Ring), (Middle, Ring) and (Bottom, Ring) measurements, which is in good agreement with the qualitative measurements of a oriental medicine doctor and several sources from antiquity [1-3] (Fig. 7). However, there were no consistent relationships in the remaining coordination measurements (Fig. 8 and Fig. 9). From this result, the region along the ring finger was optimum for the diagnosis, which is in good agreement with the traditional method used in oriental medicine.

Using the proposed system, the friction coefficients from two constitutions were compared. Each data point was collected from the 20 Tae-eumin and Soyangin male subjects pre-diagnosed by the East-West Neo Medical Center at Kyung Hee University using the contact point of (Middle, Ring). Fig. 10 shows the distribution of the friction coefficient for each constitution, and Table 3 summarizes

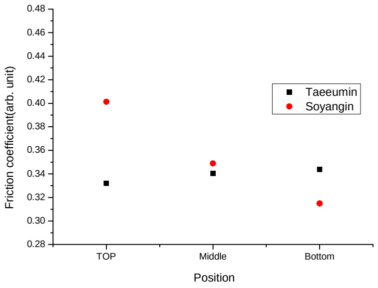


Fig. 7. Comparison of the friction coefficients between Tae-eumin and Soyangin along the index finger line in the transverse scan direction

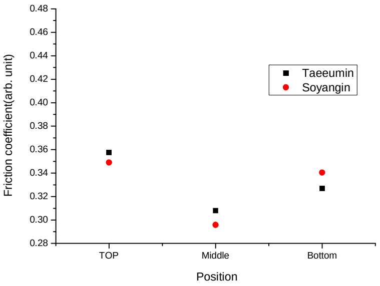


Fig. 8. Comparison of friction coefficients between Tae-eumin and Soyangin along the long finger line in the transverse scan direction

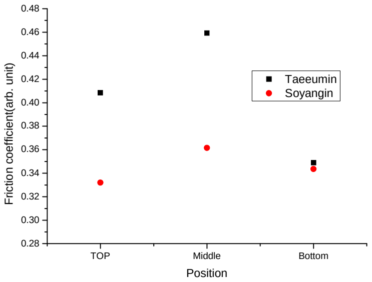


Fig. 9. Comparison of friction coefficients between Tae-eumin and Soyangin along the ring finger line in the transverse scan direction

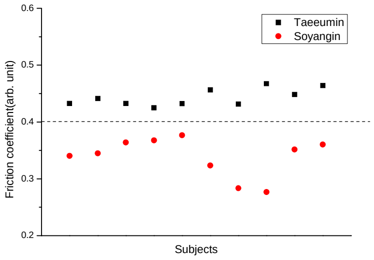


Fig. 10. Data pertaining to the friction coefficients between Tae-eumin and Soyangin types

Table 3. Friction coefficients from the two constitutions

Constitution	Tae-eumin	Soyangin
Average value	0.443	0.339
Uncertainty	1.99 %	2.41 %

the average value 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 by the age, height, 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 of ancient literatures [1-3]. Additional clinical data will be collected and used in a future study, and biological reasons for the differences between the Tae-eumin and Soyangin types will be discussed in subsequent research.

4. CONCLUSIONS

A measuring system for the friction coefficient of human skin was formulated using a multi-axis load cell for the purpose of a constitutional diagnosis method. Using this system, the expanded uncertainty for the measurement of the friction coefficient was less than 2.0%.

ACKNOWLEDGMENTS

This work was funded by the project of “Development of diagnosis systems using the senses (No. 10028423)” supported by the Ministry of Knowledge Economy and the project of “The development of new standards on demands” supported by KRISS of KOREA..

REFERENCES

[1] J. M. Lee. *Dongeusoosebowoon(Longevity & Life Preservation in Oriental Medicine).* Kyuhg Hee Univ. Press, Seoul, 1996.

[2] I. S. Park, *Dongeusa sangyogyul*, SoNaMoo, Korea, 1992.

[3] D. G. Lee, *Sasangyolam*, WoonBoolGyo, Korea, 1995

[4] H. P. Dobrev, “In vivo study of skin mechanical properties in patients with systemic sclerosis” *J. Am. Acad. Dermatol.*, vol. 40, pp.436-442, 1999.

[5] H. P. Dobrev, “In vivo study of skin mechanical properties in scleredema of Buschke”, *Acta. Derm. Venereol.*, vol. 78, pp. 103-106, 1998.

[6] S. H. Lee, J. C. Joo, Y. S. Yoon, and J. Y. Kim, “Clinical Study of the Relations of the Refiness and the Tactile of Back Skin of the Hand to Sasang Constitutions Depending on Sex and Age.”, *Korean J. Oriental Physiology & Pathology*, vol. 19, n. 2, pp.536~543, 2005.

[7] GUM (Guide to the Expression of Uncertainty in Measurement), ISO, 1993