# Developments of Home Electric Appliances with Kansei Ergonomics – SANYO cases: Kansei and Kinematic considerations on Washer-Dryer and Electric Shaver

Shigekazu Ishihara
Keiko Ishihara
Mitsuo Nagamachi
School of Psychological Science
Hiroshima International University, Japan
i-shige@he.hirokoku-u.ac.jp

Masato Sano
Yoshihisa Fujiwara
Masahiro Naito
Sanyo Electric, Co. Ltd

Kenichi Ozaki
KTH Royal Institute of Technology

**Abstract**

**Purpose –** Development of “Washer-Dryer” and “New shaped electric shaver” with Kansei ergonomics.

**Methodology/Approach –** Recently, the "Washer Dryer" type washing machines with horizontal or slant drums are becoming popular in Japan. We measured and analyzed posture while using the washing machines with 3 dimensional motion capture measurement devices. Subjective Kansei and usability questionnaires were also used. After the measurement, measured working postures were analyzed with the human kinematic model (3D SSPP) that can estimate theoretical value of the muscle tension and loads on the lumber vertebrae, knees and ankles. Three types of washers (European type; box shape and horizontal drum, Conventional Japanese type; a vertical drum, New type; slant drum with higher profile) were used for the experiment. 12 female participants aged between 22 and 43 took evaluation.

On electrics shaver, electromyogram of lower arm and pressure to the face was measured.

**Findings –** On Washer-dryer, theoretical muscular forces (%MVC; percent of maximum voluntary contraction which is a percentage of the maximum muscular force of 50 percentile female) on elbow, hip, knee and ankle were estimated. Sum of the %MVC of the new type was 116, European type was 133 (knee tension is high) and conventional Japanese type was 284 (ankle tension is 110, which exceeds the limit). The new type requires only 40% of the muscular force required for the conventional Japanese type. From the subjective evaluation, the new type was better

than the European type washer and conventional type on subjective fatigue evaluation and general evaluation, with statistical significance with one-way ANOVA.
On shaver, EMG was reduced 20% from conventional shape and it was and statistically significant. Pressure force to the face skin was reduced 85% and also significant.

**Originality/Value of paper –** The practical case examples of improvement with Kansei ergonomics, through the commercial product development

**Keywords** *Kansei ergonomics, product development, washer-dryer machine, electric shaver*

**Paper type** *Research paper*

## 1. INTRODUCTION

*Kansei Ergonomics*: In the beginning era of Kansei engineering from 1970s to mid 1990s, research results were published and presented mainly in several societies of Ergonomics. In Ergonomics, ensuring safety and removing unpleasant things are immediate task. Physical traits such as torque, acceleration and vibration, physiological measurements like electromyography are main measurement techniques. Prof. Nagamachi originated Kansei engineering, by combining psychological Kansei measurement and analysis methodologies to ergonomics. We have been applied Kansei engineering to many product development projects from 1980s.

In 2000s, we have been involving to many more product developments and we have recognize again that Kansei engineering and Ergonomics are indivisible. Attractive product can not made only from ergonomics, and Kansei engineering needs eloquent evidences those shown in figures. Thus, Prof. Nagamachi and us are proclaiming the needs of Kansei Ergonomics. In this paper, we show two examples of Kansei-Ergonomics based product developments.

*Washer and Washer-Dryer machine*:

Recently, "Washer-Dryer" type of washing machines with horizontal or slant drum is becoming popular in Japan. Traditionally, Japanese washing machines have had vertical drums and these types are still popular. Users of vertical drum washer have to bend their back and stretch their arm to put in and take out laundry. Meanwhile in Europe, horizontal drum type washing machines have always been popular. This type requires the crouching posture for putting in and taking out laundry because of its lower height.

The “washer-dryer” has rather different mechanisms to the vertical drum washing machines, and therefore require a completely new mechanical design. These new washer-dryers have horizontal or slanted rotational axis of the drum. Thus, the shape of the washing machine was greatly changed; to make loading operations easier, the door position was modified.

In this research, physical loads and usability between the washer-dryer, the traditional drum type and European type washing machines were compared. This comparison was performed using subjective evaluations, 3D motion capture and estimation of body part loads using a human kinetics computer model.

*New Shaped Electric Shaver*: Home electric appliances are changing from low-price & mass production to decent price & high-function. Mechanism of electric shaver has inner blade, which reciprocatory moves inside of the mesh outer blade. Thus, adding more pressing to face, shaving becomes the more blunt with adding load to inner blade. Although conventional stick shape shaver tends user to add pressure to his face. SANYO engineer thought bending shaver head and grasping it with pen-grip like T-shape razor will solve the problem. We have verified the idea with experiments and measurements.

## 2. METHOD OF THE WASHER EVALUATION EXPERIMENT

In the experiment, we requested the participants to take out laundry from the machine. As a laundry model, two towels were placed at the bottom of the drum, and two blankets (each 1.6 kg) were placed on the towels. These items were dry.

The participants were asked to open the door, take out the laundry piece by piece, put them into a basket that was placed on the floor, and then close the door.

The participants were 12 females aged 20s to 40s. Four subjects were smaller height (148 to 153cm), 5 subjects were around 158cm (Japanese female average) and 3 taller subjects were around 165cm.

Three laundry machines were used: a European floor-type box-shaped washing machine (SANYO AWD-500; referred to below as “EU type”), a typical vertical-drum washing machine (SANYO ASW-800; referred to as “vertical drum”), and a slanted-drum fully-automatic washer-dryer machine (SANYO AQ-1; referred to as “slanted drum”). Height to the center of the opening was 47.5 cm for the EU-type machine, 90 cm for the vertical-drum machine, and 81 cm for the slanted-drum machine. Note that the opening of the vertical-drum machine faces straight up, which means that laundry will have to be lifted higher than the actual height of the door.

Fig.1. Washers and a New Washer-Dryer; European (EU) type AWD-500, Vertical Drum type ASW-800 and Slanted Drum type washer-dryer AQ-1(Left to Right).

## 3. RESULTS OF WASHER SUBJECTIVE EVALUATION

Subjective evaluation was carried out by asking the participants a set of questions each time the required task was completed. Of these questions, 5 were related to fatigue, 5 on usability and a final question on the general usability of the washing machine. Table 1 lists the questions asked. Each question was answered on a 5-level basis.

Table 1 Questions for Subjective Evaluation

1. How tired does your entire body feel?
2. How tired are your neck or shoulders?
3. How tired are your upper arms?
4. How tired are your back?
5. How tired are your knees?
6. How easy was it to pushing the door open button?
7. How easy was the machine to opening and closing the door?
8. How easy was the machine to checking inside the drum?
9. How easy was the machine to inserting a hand or arm inside the drum?
10. How easy was the machine to taking out laundry?
11. How easy was the machine to use?

We used one-way analysis of variance to investigate whether differences in the evaluations from one machine to another were significant. We found that differences between machine types for the question "How tired does your entire body feel?" were indeed significant ($F(2,33)=11.68$, $p=0.0001$) and that the evaluations rated the slanted-drum machine as best followed by the vertical-drum machine and the EU-type machine.

For post-hoc pair-wise comparison, we used Tukey-Kramer Honestly Significantly Different (HSD) test, it was found that the slanted-drum machine and vertical-drum machine were evaluated significantly better than the EU-type machine ($p<0.05$).

There are significant differences between washing machines on following questions; "How tired are your neck or shoulders?" ($F(2,33)=9.85$, $p=0.0004$), "How easy was the machine to use?" ($F(2,33)=22.30$, $p<0.0001$), "How easy was it to opening and closing the door?" ($F(2,33)=7.98$, $p=0.0015$), and "How easy was the machine to checking inside the drum?" ($F(2,33)=9.48$, $p=0.0006$). Similarly, a HSD test revealed that the slanted-drum machine and vertical-drum machine were evaluated significantly better than the EU-type machine ($p<0.05$).

There were also differences between the machines for "How easy was the machine to taking out laundry?" ($F(2,33)=7.98$, $p=0.0015$). For this question, the machines were highly evaluated in order of slanted drum, EU type, and vertical drum, and a HSD test revealed a significant difference between the slanted-drum and vertical-drum machines ($p<0.05$).

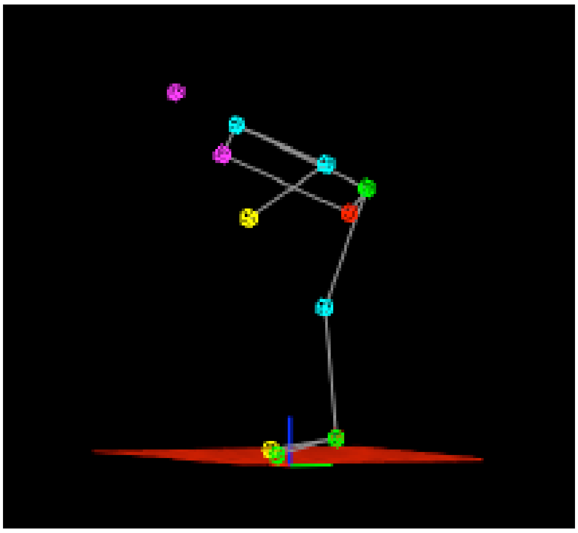
The question "How easy was the machine to pushing the door open button?" applied only to the slanted-drum and EU-type machines that have door buttons, and it was found that the former was evaluated significantly higher than the latter ($F(1,19)=14.31$, $p=0.001$).

The above results indicate that the slanted-drum machine was evaluated higher for all questions and that the EU-type machine was inferior in a statistically significant manner in terms of fatigue and ease of use. It was also found that the vertical-drum machine, which has been widely used in Japan until recently, was not very good for taking laundry out from the drum. We will investigate the relationship between these results and working posture as determined by motion capture described next.

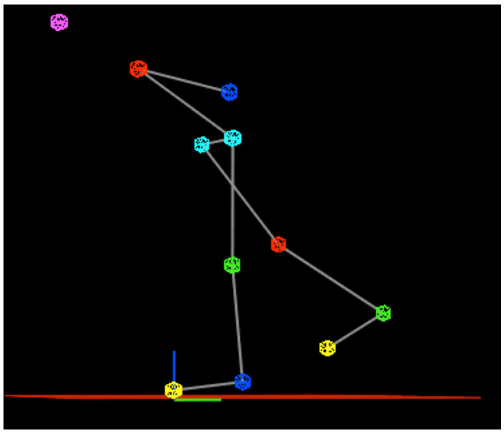
## 4. MEASUREMENT OF WORKING POSTURES WITH WASHERS BY MOTION CAPTURE AND ANALYSIS OF JOINT ANGLE

We have measured working postures with 3D motion capture system. The system was Proreflex system (Qualisys Inc., Sweden) which has 5 IR cameras. Using a 3D motion-capture system employing infrared cameras, we measured working posture in terms of coordinate values for various parts of the body. Sampling rate was set at 120 samples/s and spatial resolution setting during measurements was 5 – 10 mm. Figure 2 shows the posture of a subject with a height of 158 cm (the average for Japanese women) during maximum bending of the body when removing a towel from the drum.

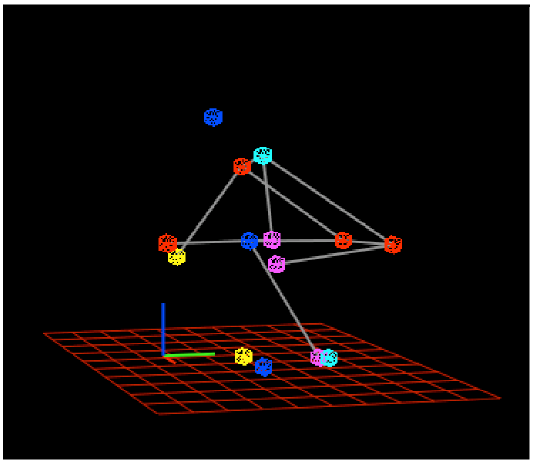
Markers were set at 15 locations on the subject's body: head, left and right shoulders, left and right elbows, back (dorsal) of each hand, left and right greater trochanter, left and right knees, left and right ankles, and left and right toes (on the subject's slippers).



Slanted drum



Vertical drum



EU type

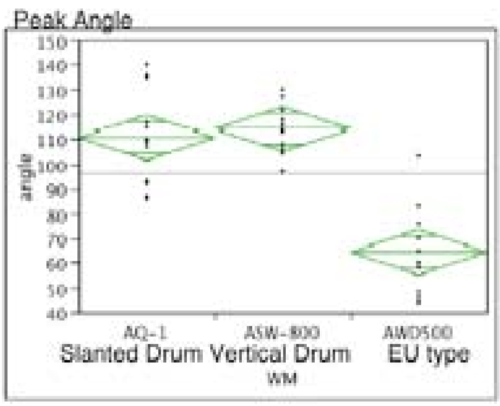



Figure 2: Posture during maximum bending of body (158cm young female) and graph of Angles formed by the knee, greater-trochanter and shoulder for different machines

Using data from motion capture, we measured and analyzed the angle formed by the knee, greater-trochanter and shoulder. This angle was 100 degrees (averaged between subjects) for the slanted drum, 114 degrees for the vertical drum, and 64 degrees for the EU type (Fig. 2). Since standing posture is near to 180 degree, the larger angle is better.

One-way analysis of variance indicated that differences between machines were significant ($F(2,33)=37.622$, $p<0.0001$). Results of a HSD test revealed a significant difference between the slanted-drum and EU-type machines and between the vertical-drum and EU-type machines ($p<0.05$).

The angle formed for the slanted drum was 110/64=1.71 times larger than that of the EU type, which can be interpreted as a 70% improvement. For the EU type, the capture screen showed that laundry could not be put in or taken out without squatting completely. This is the reason for the poor evaluations given to the EU-type washing machine for the questions “How tired does your entire body feel?”, “How tired are your knees?”, and “How easy was the machine to use?” The vertical drum gave a posture closer to the vertical stance than that of the slanted drum, but since the vertical drum is deep, almost all of the participants reach the towel at the bottom of the drum without raising one foot off the ground and stretching inside the drum. This is why the vertical drum was poorly evaluated with respect to “How easy was the machine to taking out laundry?” The relationship between the subjective evaluation and working posture has therefore been clarified by measuring body posture through motion capture and calculating the angle of body bending in the above way.

It has been shown that the vertical drum requires an off-balanced posture. The entire body load at this time cannot be estimate solely on the basis of coordinate and angle data obtained through motion capture. The load on the lumber vertebra that cannot be directly measured is also a decisive factor. Accordingly, giving due consideration to the mass of various parts of the body, we attempted to estimate such loads using a kinematic model.

## 5. ESTIMATION OF STATIC LOAD USING A KINEMATIC MODEL

We have estimated the load on various parts of the body using a kinematic model. To perform our calculations, we used the 3D Static Strength Prediction Program (3D SSPP) developed by a research team lead by Professor Don Chaffin at the University of Michigan. Professor Chaffin has been researching kinematic models of the human body and applying them to posture analysis of assembly of production lines for about 30 years.

As shown in Fig. 3, the Chaffin model features a human body with a basic structure consisting of 7 links. Links are; forearm, upper arm, torso (shoulder to lumbar vertebra), sacral vertebra to pelvis, femoral head to knee, shank and foot.

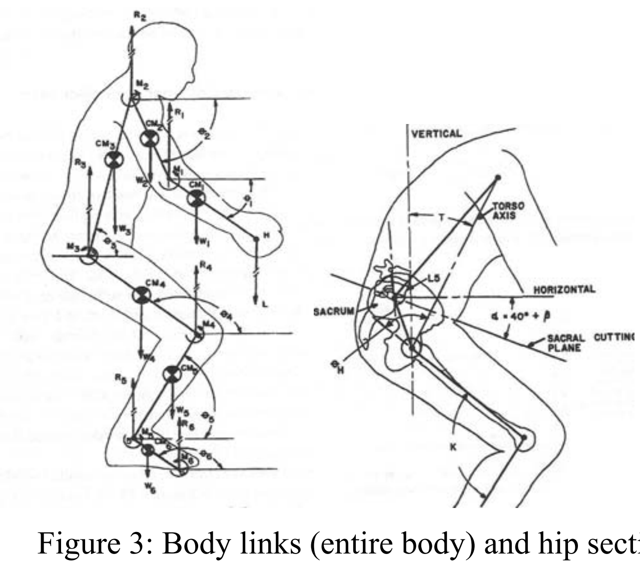



Figure 3: Body links (entire body) and hip section [1]

The model takes the following values as main parameters; load, own weight, height and joint coordinates. Center of gravity is determined by each part's size and weight. For the example, a load of 5 kg (49N) is held in the hand with the combined weight of the forearm and hand is 15.8N (Fig.3).

The upper arm from the elbow up holds up this load with force $R_{elbow}$ in a stationary position. This can be expressed as $-49N-15.8N+R_{elbow}=0$, which means that $R_{elbow}$ can be calculated to be 64.8N in the upward direction.

Rotation moment $M_E$ is in equilibrium with the (center of gravity of the upper arm X the weight of the upper arm and hand) + (length from the joint to the grip X the load). This can be expressed as $17.2cm(-15.8N) + 35.5cm(-49N) + M_E=0$.

This gives $M_E=2011.3Ncm$ (20.113Nm). This assumes the forearm to be in a horizontal position, so any deviation from the horizontal in the form of $-\square_E$ will give a result of $\cos\theta_E(M_E)$.

For the upper arm, the upward pulling force at the shoulder can be expressed as $RS=W_{UA}+R_{elbow}$, where $W_{UA}$ is the upper arm's own weight. The torque at the shoulder can be expressed as $MS = -(SCM_{UA})(W_{UA}) -(S_E)(R_{elbow}) -(M_E)$, where $SCM_{UA}$ is the distance from the shoulder to the center of gravity of the upper arm, and SE is the length of the upper arm.

Lowering the upper arm from the horizontal gives a result of $\cos\theta\ \square M_S\square$. In the above way, load and joint moments can be progressively calculated for various parts of the body (Fig. 4).

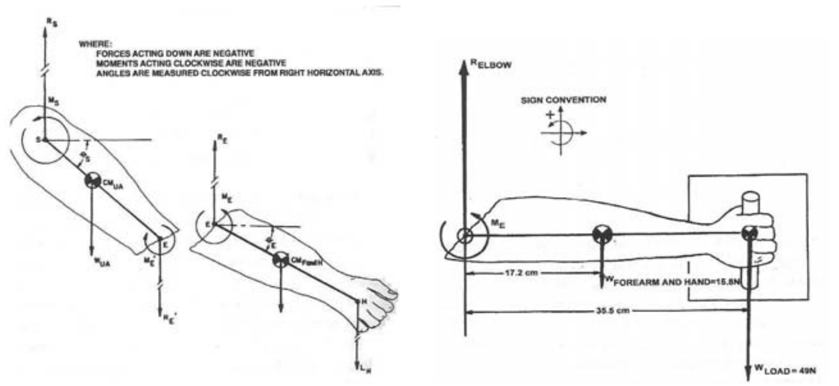



Figure 4: Left :Forearm and load, Right: Upper arm and forearm (from Ref. [1])

Table 2: Values estimated by model (158cm young female)

| Subject: 158cm/53 kg | L4/L5 Comp | %MVC(50%ile) elbow | hip | Knee | Ankle | Sum (%MVC) | Sum(%MVC) / 400 |
|---|---|---|---|---|---|---|---|
| Slanted drum | 1732 | 12 | 54 | 25 | 25 | 116 | 0.29 |
| EU type | 1801 | 17 | 31 | 59 | 26 | 133 | 0.3325 |
| Vertical drum | 1431 | 8 | 75 | 91 | 110 | 284 | 0.71 |

Using this model, we estimated the pressure (N) on the disk between the fourth and fifth lumbar vertebra and the maximal voluntary contraction (%MVC) for the muscles involved in the elbow, hip, knee, and ankle joints for the posture corresponding to maximum bending of the body (for a 158-cm, 53-kg participants). Participants' height and weight were used for estimation. Referring to Table 2 and Fig. 5, the slanted drum exhibited smaller muscle strengths except for the hips. For the vertical drum, the pressure on the inter vertebrae disk was smaller than that of the other two machines since the back was not bent very much. On the other hand, laundry cannot be removed from the bottom of a vertical drum without raising one foot so that the load on the ankle of the other foot exceeded 100%. The load on the hip and knee was likewise high.

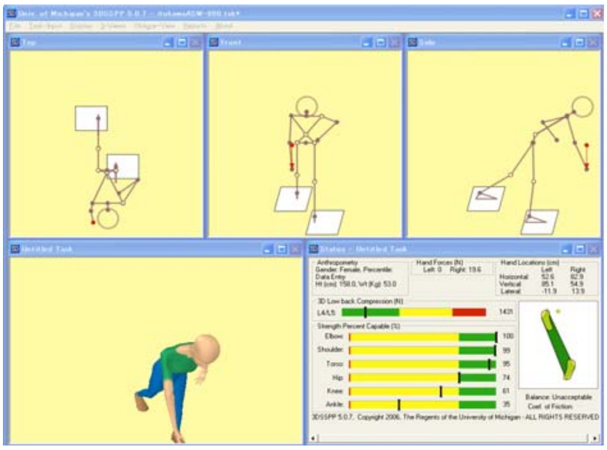


Figure 5: Calculation screen for vertical drum (158cm young female)

## 6. RESULT OF LOAD ESTIMATION OF WASHERS

Summing up individual %MVCs and comparing overall %MVC between the different machines revealed that the slanted drum was smallest with a muscle load about 60% smaller than that of the vertical drum. On comparing the slanted drum and the EU type, it was found that the latter exhibited a smaller load on the hip but 2.36 times the load on the knee due to the fact that a squatting posture must be taken. The above results demonstrate that the slanted drum provides improved posture.

## 7. MEASUREMENT OF SHAVER EXPERIMENT

We have used two types of shavers; conventional stick type and new prototype of pen-grip shaver. These two shavers have same grip part, thus their grip length and diameter are identical. Stick type has its head at 15 degree from the grip and pen grip prototype has at 80 degree. The latter can use with pen grip by larger bending of its head.

*Electromyogram (EMG) measurement*:

Factor of the experiment is difference of EMG between NS1 (existing Stick type) and Pen grip prototype (based on NS1).

Electrodes are attached on flexor digitorum superficialis and on flexor digitorum profundus with bipolar derivation. Measurement was done with 2 channels and the earth was taken on elbow joint bone. Measurement device was Biopac MP30 (Biopac Inc.) and its sampling rate was 500 Hz.

*Pressure to face measurement*: Piezo pressure sensor was attached behind the blade of the shaver.

Factor of the experiment is difference of pressure to the face between stick type and pen grip prototype. Measurement was also done with Biopac MP30.

*Instruction to the participants*: An instruction paper which has applying to the face and shaving direction was given to the participant. Task is moving shaver 3 times at the 7 different sites; midst of the under the chin, right and left of it, on the chin, under the nose, right cheek, left cheek. Subjects are 7 men in their 20s.

*Result of EMG measurement*: As shown in Figure 6, Pen grip prototype has smaller voltage. EMG integral values (mV×Sec/500(Hz)) of 2 shavers (sum of 7 sites) were compared with measurements of 7 participants. The ratio between pen grip prototype and stick (averaged between subjects) are; 0.60 at flexor digitorum superficialis, 0.95 at flexor digitorum profundus, 0.78 at combining both muscles. Thus, 22% EMG reduction was shown on pen grip prototype.

Statistical distribution of differences between pen-grip and stick was not along standard distribution, by investigating with Shapiro-Wilk W test. This is the paired data since the same subject used both shavers. Thus, we had tested with Wilcoxon signed-rank test, which performs non-parametric test of paired data. As the result of the test, difference of EMG integral value between two shavers is statistically significant ($p$<0.0001).

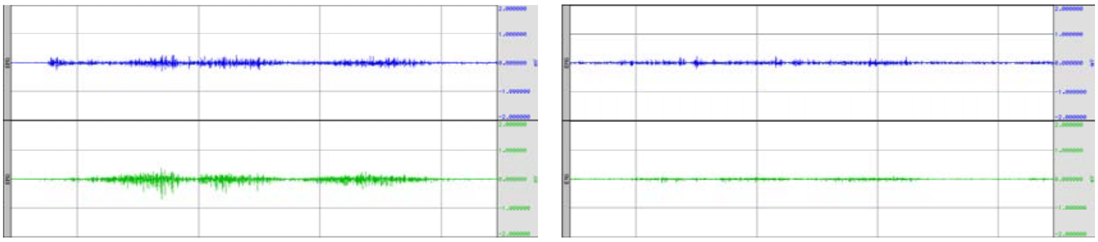


Figure 7. Examples of EMG on midst of under the chin. Left is stick type and right is pen-grip prototype, from the same subject. Upper row is flexor digitorum superficialis; lower row is flexor digitorum profundus. 1 tick on $y$-axis is 1mV. 1 tick on $x$-axis is 2 seconds.

*Result of pressure to face measurement*: As shown in Figure 7, Pen grip prototype has smaller pressure.

Pressure integral values (mV×Sec/500(Hz)) of 2 shavers (sum of 7 sites) were compared with measurements of 7 participants. The ratio between pen grip prototype and stick (averaged between subjects) is 0.15. Thus, 85% pressure reduction was shown on pen grip prototype.

Statistical distribution of difference between pen-grip and stick was along standard distribution. Thus, we had tested with paired t-test. As the result of the test, difference of pressure integral value between two shavers is also statistically significant ($p$<0.0001).

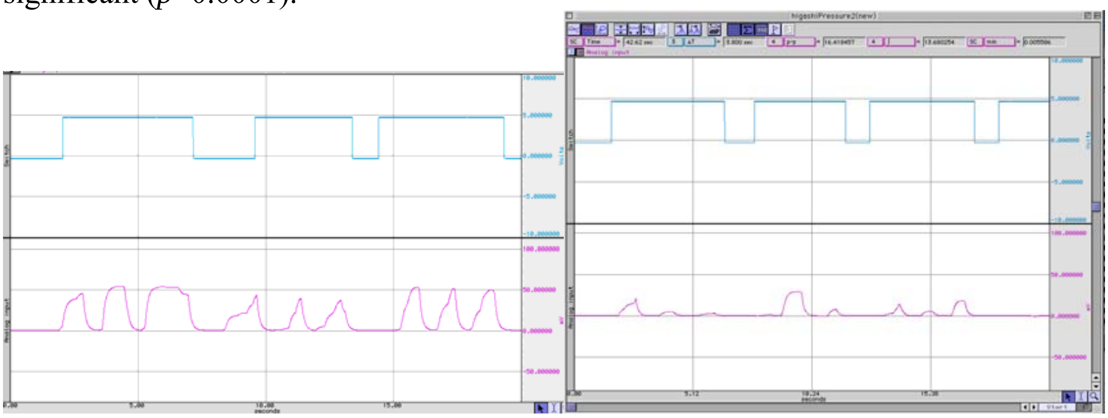


Figure 8. Example of Pressure to the face, midst, right and left of under the chin. Left is stick type and right is pen-grip prototype, from the same subject. 1 tick on *y*-axis is 50mV.

## 8. RESULT OF SHAVER EXPERIMENT AND THE PRODUCT

From the experiment, we obtained the result that pen grip prototype reduced 22% of forearm EMG and 85% reduction of pressure to the face. Statistical tests have shown the significance of reduction. Then development of the pen grip type shaver was confirmed.

The new pen-grip shaver was launched in March 2008, and has large sales in fairly high price (around 60 Euro).

Figure 9. Commercial realization of the pen-grip shaver (SANYO SV-GS1)

## 9. CONCLUSION

We have shown practical case examples of improvement with Kansei ergonomics, through the commercial product development. Consumer potentially demands both scientific evidence and attractiveness of the product. We believe Kansei ergonomics is indispensable methodology for successful product development.

## REFERENCES

[1] Chaffin, D.B., Andersson, G.B.J. & Martin, B.J.: Occupational Biomechanics (Fourth Edition), Wiley, 2006.