Development of a pressure-ulcer-preventing mattress based on ergonomics and Kansei engineering

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M. Nagamachi, S. Ishihara, M. Nakamura, K. Morishima. Development of a pressure-ulcer-preventing mattress based on ergonomics and Kansei engineering. Gerontechnology 2013;11(4):513-520; doi:10.4017/gt.2013.11.4.003.00 Ergonomics and Kansei engineering were applied to the development of a new mattress that can prevent pressure ulcers (PUs). A variety of lower rebound mattresses are believed to be better for heavy body pressure. The risk factors of PUs are body pressure, friction between the body and mattress surface, pressure-induced blood flow inhibition, moisture caused by urination, and poor nutrition. The main contributing factor is gangrenous skin as a result of blood flow inhibition. We conducted a variety of measurements to find the best mattress to maintain blood flow based on the principles of Ergonomics and Kansei Engineering. We found the best material made of polyester fibers, which have a higher spring function or resiliency with higher ventilation. Finally we developed a superior mattress for preventing PUs and we verified that the new mattress supports smooth blood flow under body pressure. In addition, we obtained such good results that five national hospitals are reporting having no more PU patients following the introduction of the new mattress.

Keywords: Kansei product, development, pressure-ulcer preventing mattress

Many countries are experiencing an aging population, especially an increase in the number of elderly people over 65 years old. In Japan, the percentage of elderly over 65 years old is 23.3%[1], and Japan also has the highest worldwide percentage of patients suffering Pressure Ulcers (PUs, decubitus ulcer). Japanese statistics indicate that the frequency of PUs is 23.1% for in-hospital patients and the frequency is even higher for patients with severe illness[2]. In the USA, the prevalence rates range from 4.7 to 32.1% in hospital settings and from 8.5 to 22% in nursing homes[3]. In Canada, the prevalence rate is reported to be 25.1% and PUs are associated with an increased risk of death in the elderly[4,5].

The present paper is concerned with the development of a new pressure-ulcer preventing mattress. Pressure sources (*Figure 1*) are a long-running medical problem. When a patient lies in a bed for long time, s/he will develop a skin condition, particularly on his/her back or around the ankles, typically known as PUs. In some cases, the ulcers emerge very quickly after only a few hours of keeping the same body posture on the bed. Medical personnel have long believed that this condition was caused by body pressure and so

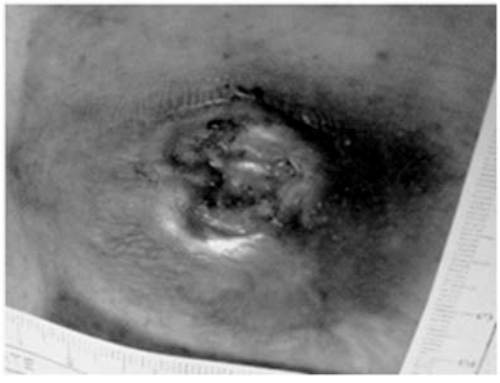

Figure 1. An example of a stage III-IV Pressure Ulcer (PU)

they have been eager to ensure very soft patient mattresses to reduce the effects of body pressure. However, this focus on the pressure aspect is incorrect, as PU is actually an ergonomic problem.

Pressure ulcers

The percentage of elderly PU patients is increasing. Japan's elderly percentage of people who are over 65 years old is now 25% of the national population and the percentage is still increasing. Thus, all hospitals have to contend with the large possibility of their patients developing PUs.

Any area of body with thin skin between the skin surface and bone can develop PUs. When this area of skin is squeezed between a hard mattress or cushion and a bone of the body, PUs can develop. In the USA, it is estimated that 1.3 million to 3 million adults suffer from PUs. Particular body areas developing PUs include the sacrum, the elbows, and the ankles among others. The risk factors for developing PUs include pressure, friction between the body and bed (or chair), moisture and poor nutrition. The most fundamental risk factor for PUs is the inhibition of blood flow due to body pressure[5,6,7]. Inhibited blood flow occurs when skin is rubbed against a bed, chair or other hard object. If the skin condition is very bad (for instance, surrounded with wet clothes and/or clothes soiled by incontinence or the patient is suffering from malnutrition), the skin can be easily broken.

PUs are categorized by stages;
Stage I: The skin reddens, but it remains unbroken.
Stage II: Redness, swelling, and blisters develop.
Stage III: A shallow open wound (called a pocket) develops on the skin.
Stage IV: The ulcer deepens, spreading through layers of skin and fats down to the muscle tissue.
Stage V: Muscle tissue is broken down.
Stage VI: The underlying bone is exposed.
The medical severity increases with the numbers.

PUs mattress research

First step

We started our survey of hospital mattresses by examining typical mattress materials. The mattresses used in hospitals and in home care are mostly made of polyurethane, except for air mattresses. The mattresses exhibit a range of softness from very soft to very hard. The Japanese Society of Pressure Ulcers suggests that all medical mattresses should exert an average body pressure value under 32mmHg/cm^2 and the society recommends that every patient be turned every two hours to ensure a posture change. They also suggest that hospitals use a good mattress that is able to evenly distribute body pressure over the whole mattress. However, this average value of 32mmHg/cm^2 is useless, because pin-point heavy pressure under bone still carries a risk of causing a PU. The primary solution for preventing PUs is to find a good mattress that is able to maintain the smallest body pressure overall and to support the blood flow under the patient's body.

We surveyed a variety of mattress materials except polyurethane-based materials. Such materials were excluded, because though they will maintain the requisite lower body pressure, they do not support blood flow well because of their softness. Instead, we found a new material named 'Breathair', which has a three-dimensional spring fiber structure made of polyester. Breathair has a cushion mechanism, similar to a wire spring (*Figure 2*). In addition, we can control the size (length, width and height), density and spring strength of the material during manufacturing.

First, we requested that the patent holder, Toyobo Co., supply us with a large amount of Breathair material with a variety of different functions, and we selected 22 different single-layer mattresses with different heights and densities. In addition, we combined two and three layers of materials, and then we constructed 51 different multi-layer mattresses. We also bought 12 polyurethane mattresses, which are well known in the health care market in Japan. Thus, we had 63 different experimental material samples for the first stage of experimentation. We conducted a Kansei evaluation in the Kansei Engineering Laboratory of Hiroshima International University[9].The Kansei evaluation involved evaluating each of the selected materials with a modified 5-point SD scale using Kansei phrases. We constructed a Kansei SD scale with the following 8 Kansei phrases; (i) flat and soft feeling, (ii) body sinking feeling, (iii) rapidly achieving a good sleep, (iv) easily rolling over on the mattress, (v) comfortable, (vi) feels premium, (vii) feels elegant, and (viii) feels expensive.

Figure 2. Breathair with complex fibers that produce a spring function(PU)

Figure 3. Force Sensitive Application (FSA) measurement of each mattress

Experimental procedure

We employed seven subjects, including students and elderly persons, with a body weight range from 40kg to 108kg. Each subject laid on each of the test mattresses, which were covered with FSA sheet (Force Sensitive Applications, Visa Medicals Ltd). The FSA sheet consists of piezo-type resistance sensors. The FSA sheet is able to measure body pressure in mmHg/cm^2. We measured each subject's body pressure with regards to their upward and side postures after twenty minutes on the bed and recorded the body pressure values, the average and the highest pressure. Each subject lay on the bed in upward and side positions and s/he rolled over the bed a few times. After that, the subject recorded his/her feelings about each mattress using the 5-point SD scale sheets with the eight Kansei phrases[10-13].

After the experiment, we divided all mattresses into two categories; superior and inferior from the viewpoint of FSA measurement and the Kansei survey results. We found seven mattresses were superior among the 22 single-layer mattresses and we found 21 superior mattresses among the 51 multi-layer mattresses. To be a superior mattress required a score of 5 points or more on the Kansei evaluation and the exertion of very light body pressure. The inferior mattresses scored less than 3 points on the Kansei evaluation and exerted very heavy pressure. Figure 4 illustrates an example of an inferior (left) and superior mattress being subjected to FSA measurement.

As a result of the first stage survey, the lower resilience or rebound mattresses resulted in subjects sinking deep into the mattress and hard body movement. On the other hand, the high rebound mattresses were able to support a body evenly over the whole mattress and made it easy to roll over on the bed. The latter is more comfortable for bed rest based on the Kansei evaluation. Self-movement on the mattress several times an hour is necessary to prevent PUs. However, the soft mattresses mentioned above are very hard to roll over on, and thus, the mattresses easily promote PUs.

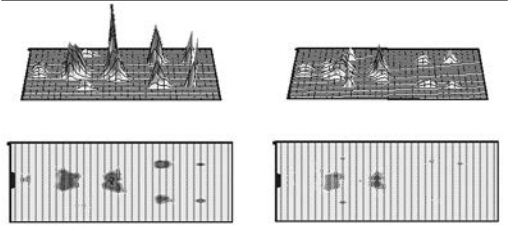

Figure 4. Force Sensitive Application (FSA) measurement of an inferior (left) and superior mattress (right); spikes depict pressure strength

Second research step

The objective of the second step of research was to find good mattresses comfortable for both light and heavy people. In regards to the Kansei evaluation of 'comfortable', the seven superior single-layer mattresses were significantly different ($p<0.001$) with regards to this attribute, compared with the other inferior mattresses. Mattress A4555BS was the best of the single-layer type mattress and very suitable for a person heavier than 60kg.

We compared seven single-layer mattresses for light vs. heavy subjects and five selected combinations of multi-layer mattresses for light vs. heavy subjects. The subjects were divided into two groups; heavier than 60kg and lighter than 60kg. In addition, we compared the mattresses with the different covers, because the kinds of cover can affect body pressure values. As a result of these evaluations, mattress HB5230 was designated the best for the light group and A4555BS the best for the heavy group with statistically meaningful differences. The combination of HB 5230 + A4555BS was also the best combination for both groups. In particular, HB5230/A4555BS (HB5230 upper and A4555BS bottom) was appropriate for the light group and vice versa for the heavy group. As a consequence, a combination HB5230 /A4555BS could be used as 'a reversible mattress' according to body weight.

Third research step

The objective in this step was a comparison of the Kansei candidate mattresses with other already commercially available mattresses. We aimed to compare our new Kansei products with the competitors. There are many competitor mattresses, and we decided to select twelve mattresses among the most well-known on the market. We again conducted the Kansei evaluation experiment for the twelve competitors and for three reversible mattresses with different covers. We performed the Kansei evaluation and measured the body pressure using FSA measurement. We employed the same students and elderly subjects and used the same SD scale Kansei evaluation sheet.

After getting the Kansei score and FSA data (*Table 1*), we analyzed the data using Principal

Component Analysis (PCA, Statworks software). Typically, for body pressure data, the average and maximum body pressures are used. Figure 5 shows the distribution of Kansei phrases and a sample scatter diagram, depicting the results of the PCA analysis. The arrows indicate the vectors of Kansei phrases. The horizontal line indicates the principal component 1 and the vertical line indicates the principal component 2. The two principal components contribute a total of 82% in cumulative contribution and then they are sufficient to explain the data. There are many Kansei phrases related to 'premium' and 'high-grade' around the principal component 1. In addition, there are Kansei phrases related to 'lacking pressure', 'not sinking', and 'rolling over' around the principal component 2.

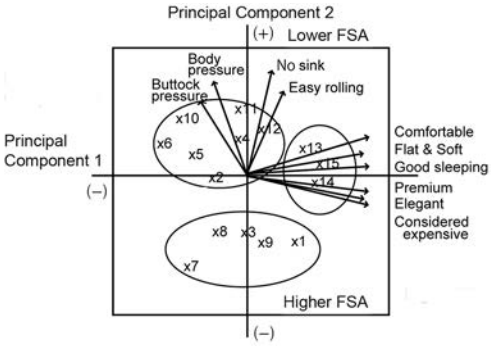

Figure 5. Principal Component Analysis (PCA) chart for vectors 1 and 2; Numbers of 1 to 18 indicate mattress samples; ○1 to ○12 are samples purchased from existing commercial sources

The principal component 1 as the main factor is associated with the Kansei evaluation data related to being comfortable, providing 'good sleep' and 'being high-grade' and 'premium'. We can describe this axis as 'Kansei factor'. On the other hand, the principal component 2 as the second factor relates to a continuity of 'not sinking' and 'low pressure'. We can describe it as 'sinking and high-low factor'. The principal component 2 is also concerned with the Kansei 'ease of rolling'.

The new mattresses 13 to 15 (*Figure 5*) were developed using Kansei engineering. The keywords expressed in this figure reference the Kansei phrases used for the Kansei evaluation. We can see that there are three clusters of sample groups, with cluster 1 consisting of 4, 5, 10 to 12, cluster 2 of 1, 3, 7 to 9, and cluster 3 of 13 to 15. All samples of 1 to 12 are made of polyurethane. The samples in cluster 1 are scattered in the area close to the principal component 2(+); these samples present lower body pressure and are associated with a negative attribute, 'deep sinking' and 'difficulty in rolling over', as based on the scores in the 5-point Kansei evaluation continuum. Similarly, these samples are close to 'without pressure', indicating that subjects evaluated the mattresses as being lower in pressure.

The characteristics of cluster 2 exist in the lower side of the principal component 2, the negative side. This indicates that mattresses in cluster 2 are hard and do not permit body sinking. These mattresses have very high body pressure on the surface. These results indicate that these mattresses are not suitable for the prevention of PUs.

Table 1. Evaluation of 15 mattresses, arranged in reverse order of efficacy; #13, 14 and 15 (the last 3) are newly developed mattresses according to Kansei principles, taking into account body pressure on the mattress; a=Maximum; b=Average

#	Average Kansei score	Scores of individual Kansei items								Body pressure [a]	Buttock pressure [b]
		Rapid good sleep	No sinking feeling	Flat & soft feeling	Easy roll over	Com-fortable	Considered premium	Feels elegant	Considered expensive		
6	1.6	1.8	1.0	1.6	1.0	1.4	2.0	1.8	2.4	39.2	19.8
5	2.1	1.2	4.2	1.2	4.4	1.4	1.4	1.4	1.2	39.4	35.5
8	2.5	3.2	1.4	3.2	2.4	2.4	2.8	2.0	3.0	57.0	42.3
3	2.8	2.0	4.8	1.8	4.4	1.8	2.2	2.4	2.6	36.8	27.7
2	2.1	1.2	4.2	1.2	4.4	1.4	1.4	1.4	1.2	39.4	35.3
12	2.5	2.6	2.6	2.6	2.0	2.2	2.6	2.4	2.6	27.2	26.0
1	2.8	2.2	4.8	1.6	4.8	2.2	2.0	1.8	2.6	60.6	37.3
10	2.9	3.2	2.4	3.2	3.4	2.6	2.8	2.8	2.6	24.8	16.7
11	3.0	2.2	3.2	2.6	3.6	2.4	3.4	3.0	3.6	18.4	13.6
4	3.2	3.6	1.6	3.4	2.6	3.0	3.6	3.8	4.0	31.0	29.0
9	3.4	3.0	4.8	3.2	4.6	3.2	2.6	2.6	2.8	56.4	4.3
7	3.5	4.2	3.4	4.0	3.6	3.6	3.0	3.2	3.2	64.0	43.5
13	4.3	4.4	4.2	4.8	4.4	4.8	4.0	3.8	4.0	28.4	20.4
14	4.4	4.6	4.2	4.8	4.6	4.8	4.2	4,0	4.0	29.4	21.5
15	4.5	4.8	4.4	4.6	4.6	4.6	4.4	4.2	4.4	34.8	26.5

However, 1 is located in the direction of the Kansei factor, which implies that this is a moderately suitable mattress that supports body movement on the bed. On the other hand, 13 to 15, which are newly developed with different covers, are made of polyester fibers and these are in the medium body pressure level (in the middle position on the principal component 2) between cluster 1 and 2. These are located directly on the principal component 1, which indicates the Kansei factors such as 'being comfortable', 'rapid achievement of sleep', 'ease in rolling over' and so on. As mentioned earlier, rolling over or moving on the bed is a very important factor for supporting smooth blood flow and important in preventing the occurrence of PUs.

We summarized the results of the PCA. Figure 6 is a mosaic map of Figure 5. We can see there are crossed lines in the center of the map, where the horizontal line indicates the principal component 1. This is the Kansei factor that contains the Kansei phrases related to 'comfort', 'ease in getting to sleep', 'ease in rolling over' and so forth. The vertical line indicates the principal component 2, which represents body pressure, 'ease of sinking' and 'softness'. Cluster 1 is the soft mattress group, but these are not suitable for preventing PUs, because they are not able to support movement over the bed and inhibit blood flow, which leads to the occurrence of PUs. Cluster 2 is the hard mattress group and it is suitable because of its higher body pressure values. On the other hand, cluster 3, the new mattress group, which contains mattresses made of polyester fibers, is located in the middle level of body pressure and can support blood flow. Accordingly, the new mattresses should be able to prevent the occurrence of PUs. Now it was necessary to prove that this is correct.

Blood flow evaluation

As mentioned earlier, the greatest risk factor for PUs is the interruption of blood flow because of body pressure. The blood flow between the bone and skin is, in such a situation, impeded because of body pressure, which results in a decrease or sometimes even the halting of the delivery of nutrition and oxygen to the body. Then, skin necrosis emerges. A caregiver should turn a patient's body on an ordinary bed every two hours, and s/he should be particularly attentive to doing this in care situations where the patients are not capable of moving on the bed themselves. After a long surgical operation, for instance, a procedure lasting for long many, the patient will often have large PUs for the afore-mentioned reason[10].

We selected some well-known mattresses from cluster 1 and measured the blood flow using

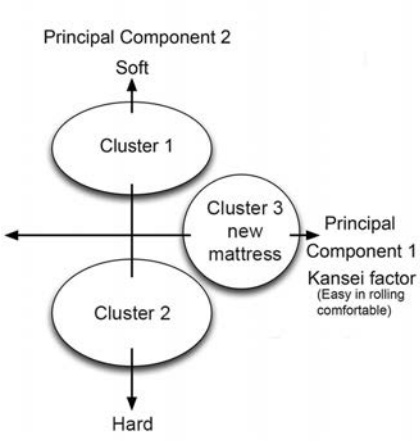

Figure 6. A mosaic map of the Principal Component Analysis (PCA) indications of Figure 5

blood measurement and compared this with the results of the blood flow permitted for the new mattresses. A small and flat sensor was inserted just under the sacrum of elderly male patients. Figure 7 shows the blood flow results for an 83 years old subject as an example. The subjects laid on the commercially purchased mattress and on the new mattress, the HB5230/A4555BS double. We generated blood flow charts from the data, with the upper chart in Figure 7 presenting the commercial mattress results and the lower chart presenting the new product results. The commercial mattress was regarded to be good in terms of exerting very light body pressure. Because the mattress is a rubber-like ma-

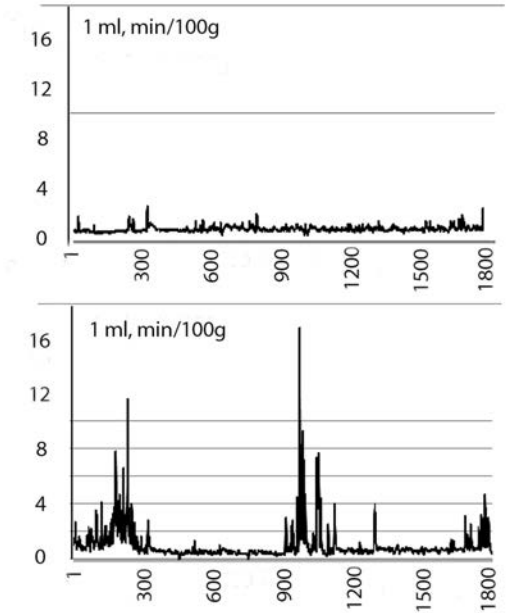

Figure 7. 30min blood flow volume on a commercial mattress (above) and on the new pressure-ulcer preventing mattress HB5230/A4555BS (below)

terial made of polyurethane, the mattress surrounds a whole body softly, and thus, the patient finds it very hard to move on the mattress. The upper blood flow chart in Figure 7 illustrates a small blood flow for 30 min. On the other hand, our new product, HB5230/A4555BS, allowed plenty of blood flow shown in the lower chart owing to self-movement over 30 min. Though the soft mattress presented lower body pressure, the softness prevents patient body movement. On the other hand, a higher rebound mattress, our new product, is located at the medium level of body pressure, and it clearly allowed smooth body movement on the mattress and smooth blood flow. The measurement method used to determine blood flow volume was almost the same for the other mattresses of cluster 1. We were successful in proving that even if the soft mattresses with lower body pressure are not assumed to cause PUs, they still carry a risk of causing PUs by interrupting blood flow[9].

Verification of effectiveness

The final stage of our research verified the practical effectiveness of our new mattress in reducing PU incidence. In Japan exists the Japan Society of PUs and all JSPU members believe that a soft mattress with lower body pressure made of polyurethane is the best choice to reduce PUs. The society has very strong authority, as it comprises medical doctors and nurses. They are very conservative and it is very hard to persuade the society members that a higher rebound mattress will be very useful and effective in preventing PUs. We donated 50 new mattresses (*Figure 8*) to five national organizations, four national hospitals and a welfare facility for the elderly. Those institutions have in total approximately 1,300 beds and approximately 30% of their patients are over 60 years old.

The Japanese hospital system is likely to transfer patients to other smaller institutions after two or three weeks of care and so it is not easy to survey PU recovery for a long period. We asked those five medical organizations to organize an in-house committee of PU research, the head of which was the organization's vice-president. Each committee consisted of a cosmetic surgeon and a few medical doctors, nurses, a physical therapist and pharmacists, with a total of 5-6 members. We suggested to the members to follow the JSPU standard treatment for patients. However, we assured that each care system differed slightly from the others in the five participating organizations, and we decided not to analyze the totality of the patient data using statistical methods.

We found a very good hospital, which had 250 beds, the Akita labor Accident Hospital. The hospital cares for all patients with the same medical treatment system and we were able to find 12 PU patient examples. Some of them died due to unrelated illness and some were transferred to other small institutions during the verification research. We are very happy to describe the provided data from the hospital concerning the seven surviving patients, who used our new mattress. We ensured compliance with the Japanese Act on the 'Protection of Personal Information'. This hospital kindly asked each patient to give us his/her permission before providing their private information. In addition, we obtained permission from all patients in this hospital. Therefore, we could survey all the patient recovery processes to verify the effects of our new mattress on PUs.

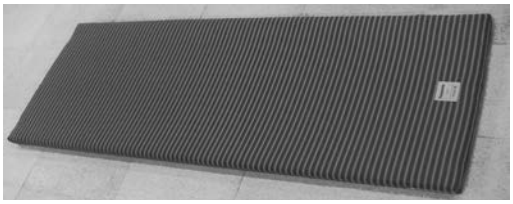

Figure 8. The new pressure ulcer-preventing mattress developed with Kansei engineering

We started the verification research at the end of August, 2008 and we continued it to the end of March, 2009, a total of 7 months. This hospital had 12 PU patients at the beginning of the verification, and among them, three patients died due to non-PU-related illness. Two patients were transferred to other smaller hospitals. One patient developed extremely severe PU, in stage VI and so she was transferred to an air mattress for a while. When her PU reduced in severity, we planned that she would use the new mattress.

In this paper, we utilize the Japanese severity scale of PUs, DESIGN-R, which was developed by JSPU, in which the letters stand for the following; D (depth), E (exudates), S (size), I(infection), G(granulation), N (necrosis), and Pocket. The R stands for Revised. Anyone is able to score PUs utilizing DESIGN-R scale items, and the instrument has a range of 0 to 66 points[14]. Seven patients recovered from PU completely due to utilizing the new mattress. They were divided into two groups according to the length of duration until complete recovery, short or long period. The short period group consisted of five patients and the long period group consisted of two patients. The short period group required 18-50 days (average 26.6 days) to recover and the long period group required 123-158 days (average 140.5 days, 4.6 months) to recover. The difference in recovery time was significant ($p<0.01$); the latter group required over five times as long to recover as the former. The short period group consisted of patients who had the Stage II-III PUs, but the long

period group patients had Stage III-VI PUs. We can note that the difference in PU between Stage II and VI is a significant difference in severity, and this index has important medical implications. One patient from the long period group recovered from a PU at first, but due to poor treatment at the hospital, the PU again returned to a more severe stage. This became a factor that prolonged the patient's recovery period.

Conclusions

The concern of the present paper is to demonstrate the implication of Ergonomics/ Kansei engineering and an application of this process in the development of a new mattress for preventing PUs. Kansei engineering is a client-oriented product development process. The Kansei process implies human want, need, expectation, feeling and emotion, which are part of the human mind. If we are able to grasp human feelings and emotion, and to integrate them in a new design of a product, the customers will be satisfied with getting the product, as the new product will match with their feelings, emotion and expectations. We have developed more than fifty new products through Kansei engineering so far. All Kansei products developed to date have been successful and have sold well in the market. We have developed a variety of methodologies to apply to different design areas including the present product[13]. In the present product, we are concerned with ergonomics, which is related to an ergonomic product development approach. In general, the integration of ergonomics in product development is inevitable when designing any type of product from the point of view of ease of operation and handling. However, when a new product development process more strongly needs to incorporate the Kansei aspect, then the necessary method would be described as Kansei ergonomics. The development of this new mattress preventing PUs is a typical example of this approach.

There are many commercial mattresses for PUs, but the manufacturers believe that a soft and low rebound mattress is suitable for patients, because it is able to result in low body pressure[15]. This way of thinking leads to misunderstandings. PUs develop for many reasons, including body pressure, friction, moisture, and poor nutrition. The major risk factor is a blood flow stoppage under the skin. Most manufacturers believe that a low rebound mattress also reduces body pressure. This is incorrect. Low rebound mattresses do not always reduce body pressure (*Figure 7*). In addition, the level of body pressure should not be too low. Rather the most important consideration in preventing PUs is to maintain blood flow. To maintain such a condition, patient self-movement should be supported on the mattress.

We now have identified several important principles in developing a good Kansei product suitable for preventing PUs;
(i) The product maintains body pressure distribution, which means it supports the body weight with the broader area of mattress surface, not only with the area directly touching the body.
(ii) The product assists and promotes easy and soft body movement on the mattress; such movement is key to promoting smooth blood flow.
(iii) A wet mattress influences severity of PU. Thus, we developed a porous mattress to help maintain ventilation.
(iv) A soiled mattress soils the skin and can lead to skin infection. It is very important that a mattress should be kept in good sanitary condition. The new mattress is very easy to wash in a shower and is easy to dry.
To satisfy these principles, we developed a polyester fiber three-dimensional spring mattress. This mattress's higher rebound properties are appropriate for maintaining an even body pressure distribution, which assists smooth blood flow. The mattress also has a porous structure to ensure ventilation and airflow inside. Accordingly,

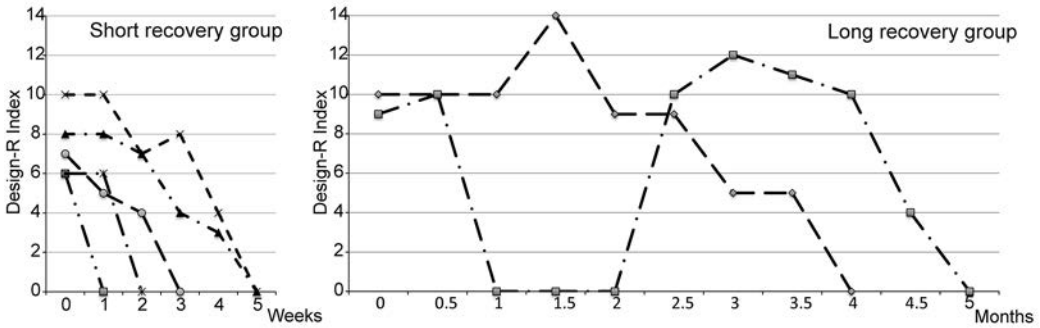

Figure 9. Verification results of the new pressure ulcer-preventing mattress under real hospital conditions; To the left the patient group that recovered within a short period; To the right the patient group that needed a long recovery period

it is very easly to clean out and to dry. It received an antibacteria treatment and is very sanitary. As the mattress is very lightweight, a nurse can easily move and otherwise handle it.

We followed a few steps to reach our final result. We felt the new mattress should be made of a high rebound material and decided to utilize a polyester fiber named 'Breathair', which can be made to produce any type of three-dimensional shape. Following the ergonomic methods, we decided to measure body pressure using FSA measurement, with a flat pressure measurement sensor and a computer, and to use an Omuron Healthcare HBF-362 device for measurement of blood flow[16]. During the first stage of our research we attempted to find the polyester materials that resulted in the lowest body pressure. Then, we applied Kansei engineering to select very comfortable material that provided for good sleeping and easy rolling over. Lastly we found the best combination to be of two prototype mattresses, HB5230/A4555BS, with the upper mattress being soft and the lower mattress hard. To verify the effectiveness of the new mattress with regards to the prevention of PUs, we donated 10 new mattresses to each of five national medical facilities and surveyed the resulting PU recovery process.

From the beginning of this research, we had a desire to combine data from all five organizations. Because of the Japanese Act 'On the Protection of Personal Information' and the different treatments of the respective medical environments, we decided to analyze PU recovery at only one hospital, which had the highest number of PU patients. All seven patients recovered completely from their PUs, though the duration of recovery differed. The recovery duration depended on the initial level of PU severity. In addition to these data, all five national hospitals informed us prior to the writing of this report that they had no PU patients anymore, because all patients completely recovered from PUs due to utilizing the new mattress. In general, medical doctors, nurses and others have misunderstood some aspects of PUs and they were so conservative in their way of thinking that they have long hindered an innovative change in the ergonomic treatment of care of patients. There is currently a worldwide movement to decide on a standard certification for a PU mattress, but medical professionals should focus on the main two principles used to prevent PUs; maintenance of low or medium body pressure and assisting blood flow under the skin.

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