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Analysis of Human Body Suitability for Mattresses by Using the Level of PsychoPhysiological Relaxation and Development of Regression Model

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Objective: The purpose of this study is to find the level of physical relaxation of individual subject by monitoring psychophysiological biofeedback to different types of mattresses. And, the study also aims to find a protocol to make a selection of the best mattress based on the measured information.

Background: In Korea, there are an increasing number of people using western style bed. However, they are often fastidious in choosing the right mattress for them. In fact, people use their past experience with their old mattress as well as the spontaneous experience they encounter in a show room to finally decide to buy a bed.

Method: Total five mattresses were tested in this study. After measuring the elasticity of the mattresses, they were sorted into five different classes. Physiological and psychological variables including Electromyography (EMG), heart rates (HR), oxygen saturations (SaO2) were used. In addition, the peak body pressure concentration rate was used to find uncomfortably pressured body part. Finally, the personal factors and subjective satisfaction were also examined. A protocol was made to select the best mattress for individual subject. The selection rule for the protocol considered all the variables tested in this study.

Results: The result revealing psychological comfort range of 0.68 to 0.95, dermal comfort range of 3.15 to 6.07, back muscle relaxation range of 0.25 to 1.64 and personal habit range of 2.0 to 3.4 was drawn in this study. Also a regression model was developed to predict biofeedback with the minimal use of biofeedback devices. Moreover results from the proposed protocol with the regression equation and subjective satisfaction were compared with each other for validation. Ten out of twenty subjects recorded the same level of relaxation, and eight subjects showed one-level difference while two subjects showed two-levels difference.

Conclusion: The psychophysiological variables and suitability selection process used in this study seem to be used for selecting and assessing ergonomic products mechanically or emotionally.

Application: This regression model can be applied to the mattress industry to estimate back muscle relaxation using dermal, psychophysiology and personal habit values

Keywords: Mattress selection, Physical relaxation, Psychophysiological variables, Peak body pressure

1. Introduction

1.1 Background

Sleep is an important part relieving human body fatigue, and recovering the vitality of the following day in modern life. Because, most people spend time equivalent to 1/3 of whole life in a bed, sleep in a comfortable bed is essential to health (Cooper et al., 1980; Eden, 1961). Yang (2001) said growth hormone and anabolic hormones including prolactin, testosterone and progesterone show sleep-related secretion rhythm, which supports the stamina recovery theory. Namely, he asserted that taking enough sleep in a comfortable bed recovers day's physical and mental fatigue through physiological recharge process for cerebral restoration.

There are various factors affecting sleep. Although, there are essentially internal problems within human body, various external factors are also related. Especially, Park (1995) said the most important thing to make sleep posture comfortable is the performance of a bed. When sleep posture is imperfect, due to the use of a bed unsuitable for human body, the effect spreads to muscles or each organ's hyper metabolism, and adds fatigue to human body, because no order is delivered to nervous system (Park, 2001). If the quality or quantity of sleep lacks, mental stress gets higher, as well as physical fatigue. If one does not take enough sleep, the person reaches to self-dissolution, hallucination and oblivion (Donaldson and Kennaway, 1991).

Suckling et al. (1957) identified a hard mattress not only disturbs sleep, but makes a person not have deep sleep, and toss and turn. Michael (2007) asserted more flexible mattresses relieve chronic pain, compared to than hard mattresses. Kanz and Gertis (1964) said a pillow and a mattress are the factors regarded as important in the sleep environment. Parsons (1972) said the mattress of a bed is good to have some degree of hardness.

Looking at preceding studies from an ergonomic aspect, the measurement of peak human body pressure distribution and user's subjective questionnaire evaluation were used in the studies on mattresses (Parson, 1972). In particular, peak body pressure distribution was described as one of the important variables (Bader and Engdal, 2000).

Kovacs et al. (2003) reported spinal part is not heavily bent or does not become gentle, only if peak body pressure is evenly distributed on the main parts of human body (head, body, waist and leg). Lahm and Iaizzo (2002) observed that the discomfort of back and waist muscles increases, if one does not maintain the straight shape of spine, when he/she lies down on a mattress.

Examining domestic study trend, studies were conducted, centered on physical characteristics and physiologic responses, such as sleep environmental status (Shin, 1983; Na, 1989), bed instrument and human body response (Kim and Choi, 1991; Lee et al., 2000). Recently, Kim et al. (2007) reported a mattress, in which the increase rate of skin temperature is low, increases subjective comfort, although dermal pressure is equal in various mattresses. Yu et al. (2009) measured physical indices (EMG, heart rate, oxygen saturation), psychological index (private property survey), peak body pressure and subjective satisfaction, and studied the relevance between physical and psychological indices and subjective satisfaction. However, an assessment of user suitability for a mattress, or an assessment method that can select a mattress is currently inadequate.

The purpose of this study is to identify whether psychopsysiological signals and peak body pressure occurring, when one lies down on a mattress, can reveal body responses well. The purpose is also to develop a method selecting the most comfortable mattress to human body and a mathematical prediction equation.

2. Methods

2.1 Hypothesis and procedure

Yu et al. (2009) performed a mattress suitability analysis using EMG, HR, oxygen saturations, private property survey and psychophysiological indices by measuring peak body pressure. As a result, they reported a comfortable mattress has significant correlation with peak body pressure concentration rate, back muscle relaxation, heart rate (HR) and subjective satisfaction. This study conducted an experiment with a study hypothesis that the mattress is likely to be a suitable one, if one's HR, EMG and peak body concentration rate decreases, and oxygen saturations increase, when one lies down on the mattress. To this end, this study measured the hardness of five mattresses with a hardness tester, and proposed a mathematical prediction equation, based on the result (Figure 1).

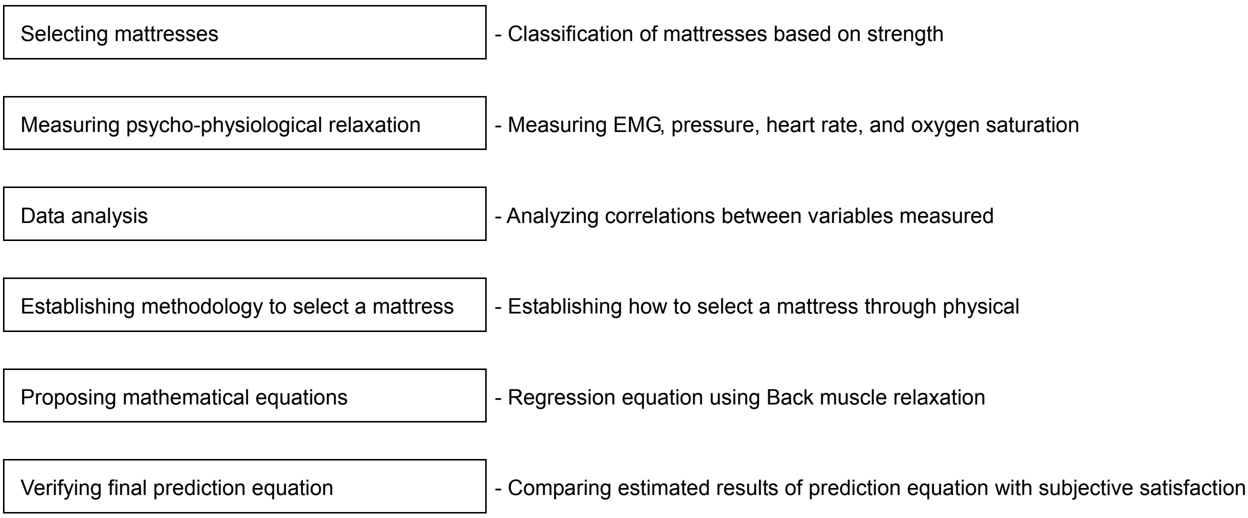

Figure 1. Flow-chart

2.2 Participants

In view of the characteristics of this study, 20 people aged 20~30 with good current health status and having no musculoskeletal disorders related with back for the past one year were collected for the experiment. The subjects were instructed not to do over-exercise and not to stay up all night before the experiment so that fatigue cannot be accumulated. The participants were sufficiently explained on the details and purpose of the experiment before the experiment, and the subjects participated in the experiment voluntarily, after filling out the experiment consent. All participants were males, and Table 1 shows anthropometric values.

Table 1. Information on participants (*N*=20 male)

	Age	Height (cm)	Weight (kg)
Mean	27.1	167.1	66.2
SD	±6.4	±7.2	±18.4

2.3 Design

The variables for the experiment consisted of psychophysiological variables (EMG, HR and oxygen saturations) and peak body pressure. Private property (subject satisfaction) on each mattress was used for comparison with and verification of the results selected by those variables (Table 2).

Table 2. Independent variables used to measure the comfort of the mattress

	Measured variables	Definition
Electromyography: EMG	Back muscle relaxation	Decrement of muscle activity before and after using a mattress
Heart rate: HR	Psychological comfort	Decrement of heart rate before and after using a mattress
Oxygen saturation: SaO2	Cardiac efficiency	Increment of oxygen saturation in peripheral vessels before and after using a mattress
Peak body pressure: PBP	Dermal comfort	The ratio of peak pressure to mean pressure when lying on a mattress

2.3.1 Private property survey

Before conducting the experiment, the participants were instructed to reveal their personal information, sleep posture and sleep time, and to answer whether they used a mattress. To find out the participant's habit of using a mattress, this study carried out a questionnaire survey. The questionnaire was designed to be divided into five items, and the experiment participants were to answer with 5-point scale (Table 3). The private property survey was used by converting name type to value type, namely one point for strongly disagree and two points for disagree. The questionnaire survey was conducted again, if a participant answered "I like a hard mattress" on question No. 1, and then, "I like a soft mattress" on question No. 3, regarding the person as not answering sincerely, through mutual verification on questions.

Table 3. Questionnaire for likert score regarding personal experience and preference (example)

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
(1) I like a hard mattress.		v			
(2) I have felt pain in the back while using the mattress.			v		
(3) I like a soft mattress.				v	
(4) I feel pain on a certain part after using the mattress.		v			
(5) I have used or use a rather hard mattress.		v			

2.3.2 Back muscle relaxation in EMG

For the back muscle relaxation measurement, electrodes were attached on the left and right of transverse abdominis between L4 (lumbar vertebra 4) and L5 (lumbar vertebra 5) of the participants using EMG measurement equipment, and extracted data for 60 seconds, respectively, when they stood and lied down on a mattress. To obtain stable signals from the extracted data, this study calculated IEMG (integrated EMG) by extracting last ten seconds' signals (50~60 seconds). This study calculated back muscle relaxation through Equation (1).

$$Back\ Muscle\ Relaxation_{\ i} = IEMG_{\mathrm{i\,(lying50s\sim60s)}}/IEMG_{\mathrm{i\,(standing50s\sim60s)}}\ (i = 1, 2, 3, \ldots, 20) \quad (1)$$

2.3.3 Psychological relaxation in HR

This study measured heart rate (HR) by installing a measurement equipment sensor on participant's index finger. This study extracted data of 60 seconds, respectively, when a participant stood and lied down on a mattress, and calculated by extracting the signals of last ten seconds (50~60 seconds) in order to obtain stable signals from the extracted data. This study calculated psychological relaxation through Equation (2).

$$Psychological\ Comfort_{\ i} = HR_{\mathrm{i\,(lying50s\sim60s)}}/HR_{\mathrm{i\,(standing50s\sim60s)}}\ (i = 1, 2, 3, \ldots, 20) \quad (2)$$

2.3.4 Whole body relaxation in SaO2

This study measured oxygen saturations (SaO2) by installing the measurement sensor on participant's index finger. This study extracted the data of 60 seconds, respectively, when a participant stood and lied down on a mattress. This study calculated by extracting the signals of the last 10 seconds (50~60 seconds) to obtain stable signals from the extracted data. This study calculated whole body relaxation through Equation (3).

$$Cardiac\ Efficiency_{\ i} = SaO_{\mathrm{i\,(lying50s\sim60s)}}/SaO_{\mathrm{i\,(standing50s\sim60s)}}\ (i = 1, 2, 3, \ldots, 20) \quad (3)$$

2.3.5 Pressure concentration in PBP

This study measured peak body pressure (PBP) of the participants by installing a PBP gauge on a mattress. This study calculated peak pressure concentration through Equation (4) by finding human body parts (head, back and hip), where peak body pressure is generated.

$$Dermal\ Comfort_{\ i} = (P_{1stmaxi}+P_{2ndmaxi}+P_{3rdmaxi})/P_{total\ average}\ (i = 1, 2, 3, \ldots, 20) \quad (4)$$

2.4 Equipment

This study selected five types of mattresses with different spring shapes produced by S company in Korea. The size of the mattresses was queen size, and the five types of mattresses were the same in dimensions: 1,700mm in width, 2,075mm in length and 250mm in height. However, the hardness of springs the inside was different. To find out whether hardness differences existed between the mattresses, each mattress' hardness value was measured, according to each mattress' pressed depth (0~80mm) using S company-manufactured static load experimenting device. For measurement method, this study complied with ASTM F1566-14. Consequently, the hardness of mattresses was significantly different (p<.01), and the post hoc test results revealed all mattresses were significantly different in the mattress hardness (p<.01) (Table 4).

Table 4. Results of ANOVA on mattresses with different strength

Source	Type III sum of squares	df	Mean square	F	*p*-value
Mattress	15463.161	4	3865.790	221.268	.000

This study also compared the strength of each mattress, which revealed statistically significant difference as such. As a result, mattress three was revealed as the strongest mattress, followed by mattresses one, two, four and 5 in the order. This classification was re-classified with a, b, c, d and e in the order of the mattress' strength. As shown in Figure 2, the lowest value of the first grade mattress was 14.33, and it was classified into the most comfortable bed. The third grade mattress' average value was 31.44, which was classified into the hardest bed.

Mattress	Max. value
Mattress 1	14.33
Mattress 5	25.35
Mattress 2	27.68
Mattress 4	21.64
Mattress 3	31.44

Mattress Grade as per strength	Max. value	Level
A mattress	31.44	5
B mattress	27.68	4
C mattress	25.35	3
D mattress	21.64	2
E mattress	14.33	1

Hardness

Softness

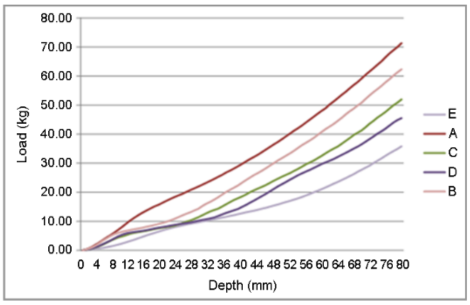

Figure 2. Mattress grades as per strength

To measure the participants' psychophysiological signals, this study used EMG, PBP distribution plate and HR (oxygen saturations) equipment (Table 5).

Table 5. Equipment applied

Name	Model	Made	Picture
EMG	ME-6000T	Mega electronic (Finland)	
Body pressure distribution plate	SPDP	Sigma system (Korea)	

Table 5. Equipment applied (Continued)

Name	Model	Made	Picture
Physiological signals	Pulse oximeter	Nihon kohden (Japan)	

2.5 Experiment process

This study measured anthropometric data of the participants, and a private property survey on mattress using habit and preference was conducted before the experiment was carried out. This study also explained the experiment process to the participants, attached each bio signal measurement equipment to each participant, and checked stable signals.

To improve data collection reliability, the onsite experimental conditions were defined as follows: The experiment was conducted covering each mattress' brand to remove prejudice against mattress. The participants could not talk, during the experiment, and they were instructed to participate in the experiment wearing the prepared pajamas, namely, the most comfortable outfit. The experiment was undertaken at pleasant indoor temperature of 26℃ so that sleep could not be disturbed with too hot or too cold temperature (Lee et al., 2000). In addition, the mood of night was created by turning off all the lights and pulling the curtain. If a participant was judged to become sufficiently stable, after the person lied down on the mattress with medium level of strength for about ten minutes, this study measured EMG, HR and oxygen saturations signals for one minute, when a participant stood. The same method was used, when a participant lied down on the mattress to measure for one minute. In this experiment, PBP distribution was measured, when a participant stood on the mattress to measure. After the measurement, Also, PBP distribution was measured, when a participant lied down on the mattress to measure. After the measurement was finished, each participant lied down on five different mattresses, and recorded subjective satisfaction with each mattress.

2.6 Analysis of body fitness assessment

To express private properties recorded with grade information per mattress, subjective satisfaction assessment results and the quantitative information measured from psychological bio signals and PBP as unified mathematical result values, they were converted to grade information. To decide physical relaxation and the suitability of mattress strength, this study applied the following bio-mechanical principle. As shown in Figure 3, it is difficult to maintain spinal arch curve, because X and Y are formed less, if the elasticity of a mattress is not enough in general. Therefore, ideal lumbar vertebral curvature angle can be maintained by elasticity, as a mattress is harder. For this reason, it is good to recommend a hard mattress to a person without a problem in physical relaxation required for sleep. However, a bit softer mattress is recommended to a person with relatively insufficient back muscle or physical relaxation in order to complement demerits that may be caused by a hard mattress.

This study also verified the normalization of grade-information data through one-sample kolmogorov-smirnov test as shown in Table 6.

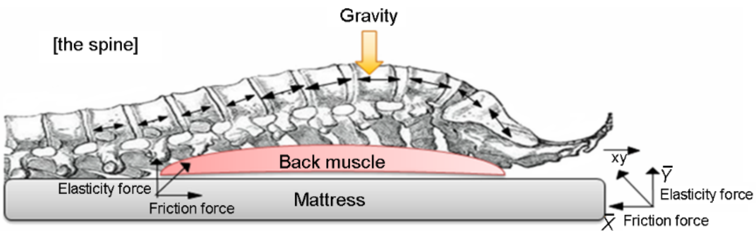

Figure 3. Bio-mechanical principle for selecting a right mattress

Table 6. One-sample kolmogorov-smirnov normal distribution verification

	Back muscle relaxation	Psychological comfort	Dermal comfort	Personal habit	Cardiac efficiency
N	20	20	20	20	20
Kolmogorov-Smirnov's Z	0.422	0.722	0.694	0.909	1.790
Approximate significance probability (two-sided)	0.994	0.674	0.722	0.381	0.003
Normal distribution (Yes/No)	Yes	Yes	Yes	Yes	No

This study carried out normalization review on the variables revealing physical relaxation (peak body pressure concentration, psychological relaxation, back muscle relaxation and whole body relaxation) and private property. If data does not follow normal distribution, it is to minimize bias by grade that is caused, when grade is classified with a regular gap. As a result, oxygen saturations values did not conform to normal distribution, and therefore, the values were excluded from the final psychophysiological variables.

3. Result

3.1 Results of personal habit survey

In the personal habit survey, maximum value 3.40 and minimum value 2.00 were revealed, and Figure 4 shows the comparative result with mattress grades. Fifth grade was shown between 3.40~3.12, fourth grade between 3.12~2.84, third grade between 2.84~2.56, second grade between 2.56~2.28, and first grade between 2.28~2.00.

3.2 Result of back muscle relaxation in EMG

Judging that low EMG value means the use of a hard mattress can sufficiently relax back muscle, a logic that a hard mattress favorable to spinal support can be used was used in this study. On the contrary, this study decided grade by mattress grade corresponding to the judgement that a slightly soft mattress that can relax back muscle's tension is necessary, because high EMG value means tensed back muscle under any circumstances. The measured values were maximum 1.64 to minimum 0.23, and a comparison was made with mattress grades. The result was shown in Figure 4, and the fifth grade was between 0.23~0.51, fourth grade between 0.51~0.79, third grade between 0.79~1.08, second grade between 1.08~1.36, and first grade between 1.36~1.64.

3.3 Result of psychological relaxation in HR

Low psychological relaxation means it's the difference is huge between the standing posture and lying posture, and thus physiological relaxation is regarded as good. A mattress with high strength has higher grade. On the contrary, psychological relaxation is regarded as no good, if the difference is small between the standing posture and lying posture. A mattress low strength has higher grade. The measured values were maximum 0.95 to minimum 0.68, and this study compared with the mattress grades. Figure 4 shows the result, and the fifth grade was between 0.68~0.73, fourth grade between 0.73~0.79, third grade between 0.79~0.84, second grade between 0.84~0.89, and first grade between 0.89~0.95.

3.4 Result of dermal comfort in PBP

Low peak body pressure concentration means peak body pressure is evenly distributed, and the specific part of a mattress is not hard on specific body part. Therefore, a mattress with high strength has higher grade. On the contrary, if peak body pressure concentration is high, a specific part of a mattress is hard on specific body part. Therefore, a mattress with low strength has higher grade. Measured values were maximum 6.07 to minimum 3.15, and this study compared with mattress grades. The result was shown in Figure 4, and the fifth grade was between 3.15~3.74, fourth grade between 3.74~4.32, third grade between 4.32~4.90, second grade between 4.90~5.49 and first grade between 5.49~6.07.

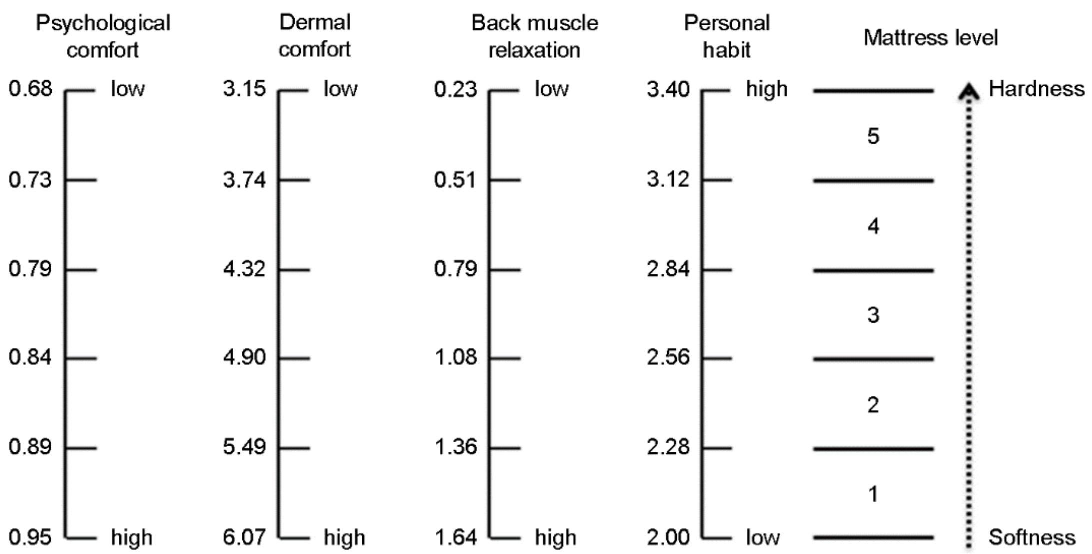

Figure 4. Psycho-physiological variables and mattress grades

3.5 Result of subjective satisfaction survey

As a result of each participant's subjective survey, 11 participants preferred medium strength mattress. Through this result, it is estimated that rather too hard or soft mattress can be felt uncomfortable to the participants, since healthy people without back disease participated in the experiment.

3.6 How to use relaxation index

This study built indices recommending mattress strength suitable for users using EMG, PBP, personal habit and HR. According to the experiment method presented above, EMG, PBP, personal habit and HR are measured, when a user stands and also lies down. When a user's HR is 0.81, PBP is 4.02, back muscle relaxation is 0.99, and personal habit is 2.98, the final mattress strength level is calculated by calculating the average of the indices (Figure 5).

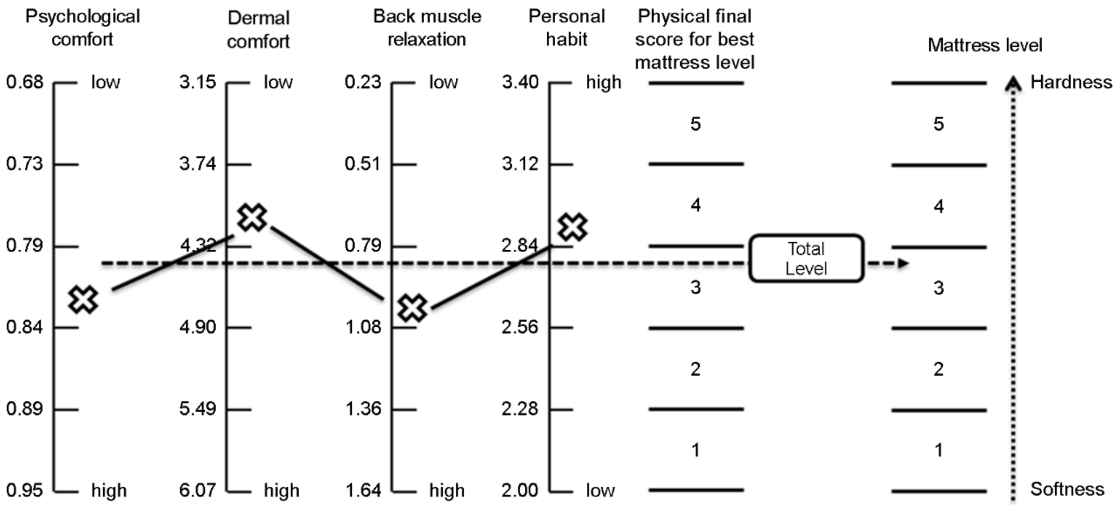

Figure 5. Comparison between physical relaxation and mattress level (example)

3.7 Comparison of relaxation index and subjective satisfaction

This study compared subjective satisfaction results, as a result of mattress strength recommendation index. Consequently, ten

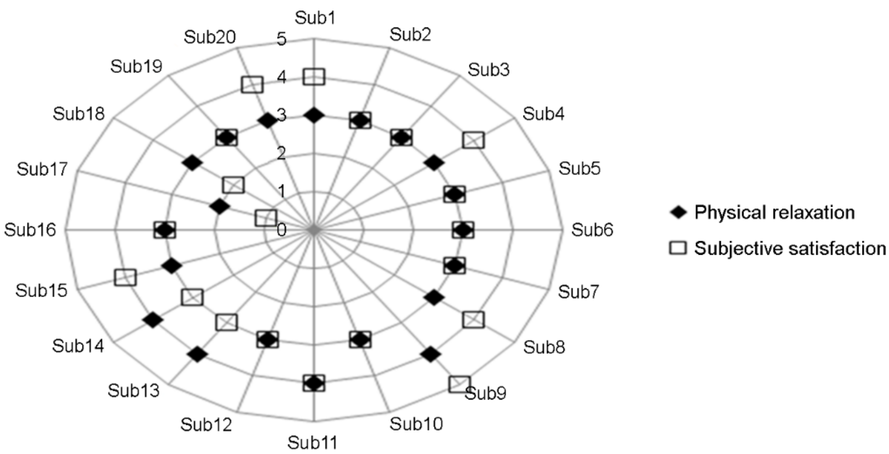

Figure 6. Comparison between physical relaxation and subjective satisfaction level

participants matched among 20 participants, and the remaining ten participants showed the result deviating just one level (Figure 6).

3.8 Mathematical prediction

The measurement equation calculated above is complicated to use. Because, measurement equipment is attached to skin to measure back muscle relaxation, users may feel resistance, or some women may reject the measurement. In this regard, this study explored mathematical prediction equations that can measure back muscle relaxation.

3.8.1 Correlation between back muscle relaxation and psychophysiological variables

To identify correlation between back muscle relaxation and each psychophysiological variable, this study calculated Spearman's Rank Correlation Coefficient using the SPSS15. Consequently, back muscle relaxation and peak body pressure concentration (rs=.581), psychological comfort and personal habit (rs=.520) had relatively higher correlation as shown in Table 7.

Table 7. Correlation analysis with each variable. N: subject number, ( ): significant

	N	Dermal comfort	Psychological comfort	Cardiac efficiency	Personal habit	Back muscle relaxation
Dermal comfort	20	- (-)	.653 (.061)	0.170 (.408)	.260 (.483)	.581 (.063)
Psychological comfort	20	.653 (.061)	- (-)	.110 (.574)	.349 (.475)	.580 (.051)
Cardiac efficiency	20	.170 (.408)	.110 (.574)	- (-)	.377 (.687)	.454 (.689)
Personal habit	20	.260 (.483)	.349 (.475)	0.377 (.687)	- (-)	.520 (.061)
Back muscle relaxation	20	.581 (.063)	.580 (.051)	.454 (.689)	.520 (.061)	- (-)

3.8.2 Regression process in multiple regression analysis

This study conducted a multiple regression analysis to analyze the relationship between back muscle relaxation, a dependent variable, and three independent variables, namely, psychological comfort, peak body pressure concentration and personal habit. To elevate discrimination of the regression equation, each independent variable's grade value was squared from one to four in order to increase R^2 value, the coefficient of determination indicating what percentage of deviation of the dependent variable is explained by the independent variables. This study calculated the regression equation with the highest R^2 (Table 8).

Table 8. Process to increase R^2 values (example)

Square			Back muscle relaxation		
Dermal comfort	Psychological comfort	Personal habit	R^2	Adjusted R^2	Standard error of estimates
1	2	1	.389	0.237	1.236
2	2	1	.384	0.230	1.241
3	2	1	.377	0.222	1.248

Table 8. Process to increase R^2 values (example) (Continued)

Square			Back muscle relaxation		
Dermal comfort	Psychological comfort	Personal habit	R^2	Adjusted R^2	Standard error of estimates
4	2	1	.372	0.215	1.253
1	**4**	**1**	**.512**	**0.262**	**0.806**
2	4	1	.401	0.251	1.224
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
1	1	4	.345	0.181	1.28
2	1	4	.342	0.177	1.283
3	4	4	.363	0.204	1.262
4	4	4	.353	0.191	1.272

Looking at the model summary in Table 9, R^2, the result of three inputted independent variables, namely, peak body pressure concentration, psychological comfort and personal habit, was 0.512. It explains the deviation of the dependent variable, back muscle relaxation, as 51.2%.

Table 9. Result for R^2 value

R^2	Adjusted R^2	Standard error of estimates
0.512	0.262	0.806

The multi regression equation on back muscle relaxation's coefficient of determination, R^2=.512, was calculated as shown in Equation (5) (Table 10).

Table 10. Result for coefficients

	Unstandardized coefficients		Standardized coefficients	t	*p*-value
	B	SE			
Constant	**2.077**	1.172		1.772	0.1
Dermal comfort	**0.504**	0.184	0.560	2.741	0.017
Psychological comfort	**-0.003**	0.002	-0.335	-1.649	0.023
Personal habit	**0.178**	0.373	0.098	0.478	0.062

$$Y\ (\text{Back Muscle Relaxation}) = 2.077 + 0.504x_{1(\text{Dermal Comfort})} - 0.003x_{2(\text{Psychological Comfort})} + 0.178x_{3(\text{Persona lHabit})} \quad (5)$$

3.8.3 Comparison of the prediction estimation results and subjective satisfaction

This study calculated back muscle relaxation estimated through the regression equation. Figure 7 compares mattress grades through estimated back muscle relaxation and subjective satisfaction level. As a result, the back muscle relaxation and subjective satisfaction results of ten participants among 20 participants matched, and those of eight participants showed just one level difference. Those of two participants showed difference within two levels.

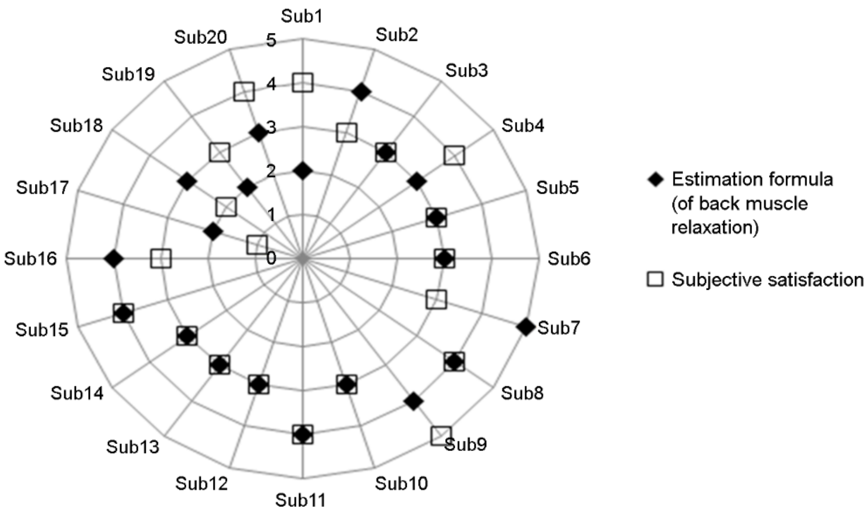

Figure 7. Estimate results using the estimation formula (of back muscle relaxation) and subjective satisfaction level compared

4. Discussion

This study identified correlation among psychophysiological signals that are generated, when a person lies down, and analyzed whether variables can be used as a quantitative tool in selecting an optimum mattress. Main characteristics of the correlation analysis on each psychophysiological variable regarding the measurement variables used for developing logical methodology and mathematical prediction equation are summarized below:

The correlation coefficient of back muscle relaxation and peak body pressure concentration was rs=0.581, which is similar to the result of Kovacs et al. (2003); Vanderwee et al. (2005) Kovacs et al. (2003) insisting that comfort increases, and subjective satisfaction increases, as no specific mattress part is hard on one's specific body part, when one lies down on a mattress.

The correlation coefficient between back muscle relaxation and psychological comfort was rs=0.580, and heart rate (HR) fell, when one laid down on a mattress with good psychological relaxation. The result is similar to the result of the study of Bader (2000) saying that HR falls, when one lies down on a comfortable mattress. Like the result of the study of Vanderwee et al. (2005) asserting that HR falls, if stress is small, it is judged that back muscle relaxation affects stress.

Lee and Hong (2001) conducted a questionnaire survey on the cushion property of a mattress and pressure sensation on the buttocks targeting people in their teens to 70s in a fact-finding survey on various phenomena upon using a bed. They presented a mathematical prediction equation (R^2=0.580) on total comfort. As a result, they reported the degree of supporting spine by the mattress has an impact on comfort. In this study, the similar result was drawn by conducting comparative verification with subjective satisfaction, according to comparing back muscle relaxation estimated through the regression equation and subjective satisfaction level. Although, the quality of sleep is judged by using polysomnography (Lee and Park, 2006; Tsai and Liu, 2008), peak body pressure (Nicol and Rusteberg, 1985; Peter and Avaliono, 1998), magnetoencephalography (Higashi et al., 2003), psychological signals (Kim et al., 2011; Kim et al., 1997) and heart rate (Kim et al., 1999), according to mattress strength, these methods are not easy to be used by industrial businesses. In addition, studies to present a model for industrial businesses to easily use are inadequate. This study proposed a mathematical model equation using bio signals, and this model equation has meaning in that it can discern wrong selection of a mattress unsuitable for oneself. However, Defloor (2000) said discomfort becomes different, according to sleeping posture, and Bader (2000) said the strength of a mattress affects the quality of sleep. Kawabata and Tokura (1995) asserted the effects on the ratio of deep sleep are different, according to bed type in a sleep experiment using a water bed and a spring bed. Addison et al. (1986) insisted mattress surface functions as a cause of insomnia. Likewise, many external factors affect the selection of a mattress. In this regard, various variables need to be considered to enhance the accuracy of mathematical prediction equation in the future.

5. Conclusion

This study proposed the methodology to select a suitable mattress through physical relaxation or a regression equation. The psychophysiological variables and suitability selection process used in this study seem to be used for selecting and assessing ergonomic products mechanically or emotionally. These variables are considered to be used as objective variables to mechanically and emotionally assess mattresses or relevant ergonomic products.

References

Addison, R.G. and Thorpy, M.J.T., A survey of the United States public concerning the quality of sleep, *Sleep Research*. 16, 244, 1986.

Bader, G.G. and Engdal, S., The influence of bed firmness on sleep quality, *Applied Ergonomics*, 31(5), 487-497, 2000.

Cooper, R., Osselton, J.W. and Shaw, J.C., *EEG Technology. butterworths 1*, 1980.

Defloor, T., The effect of position and mattress on interface pressure, *Applied Nursing Research*, 13(1), 2-11, 2000.

Donaldson, E. and Kennaway, D.J., Effects of temazepam on sleep, performance, and rhythmic 6-sulphatoxymelatonin and cortisol excretion after transmeridian travel, *Aviation, Space, and Environmental Medicine*, 62(7), 654-660, 1991.

Eden, M. and Carrington, R., The Philosophy of the bed, *New York: Putnam's*, 1961.

Higashi, Y., Yuji, T., Oikawa, D., Akihiro, M., Koudabashi, A., Fujimoto, T. and Tamura, T., Evaluation for mattress comfort by using MEG.In Neural Engineering, 2003. Conference Proceedings, *First International IEEE EMBS Conference on*, 63-66, 2003.

Kanz, E. and Gertis, W., Schlagtiefemessungenanverschiedenenpolsterwaren, *Bekleidungsmedizin* Vol.4, 6-14, 1964.

Kawabata, A. and Tokura, H., Effects of two different kinds of bed on thermophysiologicalreponses and heart rate during night sleep. *J. Home Econ, JPN*, 46(3), 235-240, 1995.

Kim, J.Y., Park, J.S., Yu, S.W., Lee, S.J. and Ko, T.S., Ergonomic Evaluation of "Air-Ball" Mattress by using Skin Pressure and Temperature Changes, *Paper presented at the Fall Conference of the Ergonomics Society of Korea*, 2007.

Kim, J.Y., Min, S.N., Lee, M.H., Jeong, J.H., An, J.H. and Shin, Y.S., Measurement of User Experience to Select a Comfortable Mattress.In Design, User Experience, and Usability, Theory, Methods, Tools and Practice, *Springer Berlin Heidelberg*, 449-458, 2011.

Kim, M.J. and Choi, J.H., A Study on the Bed Climate and the Physiological Responses in Sleep, *Journal of the Korean Society of Clothing and Textiles*, 15(2) 77-87, 1991.

Kim, W.S., Park, S.J. and Kim, K.H., Analysis of Sleep physiological signal for the Comfortable bed the development, *Conference of the Ergonomics Society of Korea*, 190-195, 1997.

Kim, W.S., Park, S.J., Kim, J,S., Hwang, J.H. and Kim, K.H., Study of Sleep stage classification using heart rate variation, *Conference of the Ergonomics Society of Korea*, 321-324, 1999.

Kovacs, F.M., Abraira, V., Peña, A., Martín-Rodríguez, J.G., Sánchez-Vera, M., Ferrer, E., et al. Effect of firmness of mattress on chronic non-specific low-back pain: randomised, double-blind, controlled, multicentre trial, *The Lancet*, 362(9396), 1599-1604, 2003.

Lahm, R. and Iaizzo, P.A., Physiologic responses during rest on a sleep system at varied degrees of firmness in a normal population, *Ergonomics*, 45(11), 798-815, 2002.

Lee, H.J. and Hong, K.H., Survey on the Use of Bed for Comfortable Sleeping, *Korean Journal of Human Ecology*, 10(4), 349-355, 2001.

Lee, H. and Park, S., Quantitative effects of mattress types (comfortable vs. uncomfortable) on sleep quality through polysomnography and skin temperature, *International journal of industrial ergonomics*, 36(11), 943-949, 2006.

Lee, N.B., Lim, J.J., Geum, J.S., Lee, G.H. and Choi, H.S., Evaluation of Sleep Comfort for Indoor Thermal Environment based on the Physiological Signal Analysis, *Korean Journal of the Science of Emotion & Sensibility*, 3(2), 75-84, 2000.

Michael, B., Good Night: the sleep doctor's 4-week program to better sleep and better health, *Penguin USA*, 2007.

Na, Y.J., Analysis of the Sleep Environment, *Seoul National University*, Master's Thesis, 1989.

Nicol, K. and Rusteberg, D., Pressure distribution on mattress, *Biomechanics*, 26, 1479-1486, 1985.

Park, S.J., Lee, H.J. and Hong, K.H., Selection of Bed Mattress for Good Sleeping, *KSCT/ITAA Joint World Conference*, Seoul, 2001.

Park, S.J., Whang, M.C. and Kim, C.B., Measure and analysis of pressure distribution on a bed, *Proceeding of the 39th Human Factors and Ergonomics Society Annual Meeting*, SanDiego, 297-300, 1995.

Parsons, H.M., The bedroom, Human Factors, *The Journal of the Human Factors and Ergonomics Society*, 14(5), 421-450, 1972.

Peter, B. and Avaliono, F., Mattress evaluation-assessment of contact pressure, comfort and discomfort, *Applied Ergonomics*, 29(1), 35-39, 1998.

Shin, S.M., A Study on the Use of Bedclothes, *Journal of the Korean Home Economics Association*, 39(10), 29-37, 1983.

Suckling, E., Koenig, E., Hoffman, B. and Brooks, C., The physiological effects of sleeping on hard or soft beds, *Human Biology*, 29(3), 274, 1957.

Tsai, L.L. and Liu, H.M., Effects of bedding systems selected by manual muscle testing on sleep and sleep-related respiratory disturbances, *Applied ergonomics*, 39(2), 261-270, 2008.

Vanderwee, K., Grypdonck, M.H. and Defloor, T., Effectiveness of an alternating pressure air mattress for the prevention of pressure ulcers, *Age and Ageing*, 34(3), 261-267, 2005.

Yang, C.K., Normal sleep physiology, *Society of Otorhinolaryngology*, 12(1), 3-14, 2001.

Yu, S.W., Kim, J.Y., Min, S.N. and Sung, S.H., Analysis of Suitability for Mattresses by Using Psycho-Physiological Measures, *Spring Conference of Korean Journal of the Science of Emotion & Sensibility*, 2009(5), 63-66, 2009.

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