Appraisal of Bed Linen Performance with Respect to Sleep Quality

Tanima CHANDA[1], Meenakshi AHIRWAR[2], Bijoya Kumar BEHERA[2*]

[1]National Institute of Fashion Technology, Department of Master of Design, Bengaluru 560102, India
[2]Indian Institute of Technology Delhi, Department of Textile and Fiber Engineering, New Delhi 110016, India
*behera@textile.iitd.ac.in

ABSTRACT

Bed linen is the material laid above the mattress of a bed that serves various purposes - hygiene, warmth, protection of the mattress – and also has a decorative effect in the room. According to several studies, the type of bed linen used for our sleep has a direct effect on our health; in other words, sleep quality is the ultimate performance indicator of bed linen cloth. In this research work, a relationship between bed linen properties and sleep quality was established. Bed linens serve as a basic requirement for sleep, and assessing the right kind of sheet is an important aspect to look into. Analyzing the basic properties of bed linen is an important exercise to perform in order to provide the user with the best-quality sleep. This research focuses on deriving an equation that can be applied to calculate the objective measurement of sleep quality with respect to bed linen properties by developing a bed linen sleep quality index. Questionnaires were designed and subjective evaluation method was followed. A panel of experts was considered for a subjective rating of bed linen properties, their weightage, ranking and bed linen fabrics assessment. Coefficient of concordance was calculated to determine the agreement among the judges and a discriminant analysis was also carried out to determine the variation of the individual rating for a particular property. The results showed a high correlation between the subjective index and the objective index for the bed linen fabric samples. Thus, the objective sleep quality index could be estimated well.

KEYWORDS

Bed linen, bed linen sleep quality index, subjective evaluation, discriminant analysis

INTRODUCTION

Textile products are used in many sectors in various forms, one of which includes bed linen fabrics. Different sectors have different types of sheets in use, based on the area of use and purpose, such as hospitals, railways, hotels, homes, etc. Bed linen, also referred to as bed sheets, is a fabric placed immediately above the mattress of a bed to provide warmth, nice touch and a decorative effect. The major requirement for bed linen is to be comfortable, easy to take care of and durable. Softening is an essential step, required in the field of home textiles, including bed linens, to improve fabric properties making the fabric soft, smooth, and flexible [1].

The majority of bed linen is made from cotton and cotton/polyester blended yarns due to their comfort, level of hygiene, softness and water absorption capacity. Fabrics like cotton and its blends are considered

ideal for the household bed linen. Most of the people choose these fabrics as they are budget friendly and last long, as well. Depending on the end use, cost factor, durability of the textiles, comfort and aesthetic properties, the fiber choice is made between natural fiber, regenerated cellulosic fibers and synthetic fibers. Linen is also made of blends of other compatible natural and manmade fibers to achieve various structural and functional properties, and also to reduce costs. Linen fabrics produce excellent aesthetic and drape properties [2]. Thread count is essential while buying bed linen. The higher the thread count the better the wear-tear and softer the sheet. The GSM (g/m²) of the fabric, also referred to as the areal density of the fabric, also plays an important role i.e. higher GSM means that the bed sheet is plusher and more comfortable. Bed linens are mostly either dyed or printed, so the process must be chemical-free and good for the skin. The material and weave of the fabric determines its breathability i.e. whether it will remain cool or heat-up against our skin [3].

It was investigated that when people slept in comfortable beds their mean skin temperature was higher than when they slept in an uncomfortable bed and the skin temperature of the lower body, sleep efficiency as well as the percentage of deep sleep were also higher. The percentage of waking up after sleep onset was lower when people slept in a comfortable bed [4]. Comfort in bed is a complex phenomenon based on a subjective feeling as well as the physical properties of the interaction between the mattress and the human body [5, 6]. The comfort of the bed is evaluated by the quality of sleep [7].

Insufficient and poor sleep quality impairs cognitive performance in elderly people and impacts brain's reward processing, risk-taking, and cognitive function in adolescents. The normative imbalance between affective and cognitive control systems may be exaggerated by poor sleep [8, 9]. About one-third of a person's life is spent in sleep and lack of sleep time or sleep quality can affect human health. Sleep quality is affected by many factors, such as health conditions, emotional states, bedding condition and ambient environment. There have been limited researches about effects of bedding conditions on sleep quality and thermal comfort. Overall, bed linen is an integral part of bed micro-environment and its material and insulation level can affect the thermal comfort of sleep environment [10].

However, the exact elements that compose sleep quality, and their relative importance, may vary between individuals. Furthermore, because sleep quality is largely subjective, sleep laboratory measures may correlate with perceived sleep quality, but they cannot define it [8, 11]. As standards of living continue to improve, aesthetic characteristics of clothing become a primary consideration in determining serviceability and longevity of apparel fabrics. Apparel and household goods are often discarded for no other reason than that the fabrics lose the aesthetic appeal [12].

Sleep is essential for the body to recover from both physical and psychological fatigue suffered throughout the day and restore energy to maintain bodily functions [13]. The effects on sleep stages also differ depending on the use of bedding and/or clothing. The thermal environment is one of the most important factors that can affect human sleep [14, 15]. Apart from the bedroom environment, light in the room, temperature factor and color psychology, bed linen has direct contact with the human body at the time of sleep and it provides the foremost comfort/discomfort at the time. Our sleep positions, trapped body heat, sweat release and many more factors depend on the body-surface contact. The above-mentioned bed linen's properties must work hand-in-hand to provide the best restful night [16].

The market is flooded with a variety of bed linens of different designs, endless color options and superior properties. Therefore, it becomes difficult for an individual to make the right choice. There is no scientific formula or objective evaluation of performance index with respect to bed linen at this time that would enable us to engineer better quality bed linens. Different people of different age groups perceive the quality of bed linen in relation to good sleep quality differently, according to their level of interpretation [17].

Therefore, in this research, a subjective assessment of bed linen properties in relation to sleep quality was conducted to derive objective measure of sleep quality. In the first step of the survey, the judges provided different desirable bed linen attributes essential for good night sleep and in the second step bed linen attributes were ranked according to their priority and also evaluated for weightage according to a 100-dollar test. In the second survey, the bed linen fabrics were evaluated for the selected properties by the judges on the basis of intensity of the attributes/properties. The research required surveying the people who are aware of how the quality of bed linen affects sleep quality. This would help to understand the preference of people and further help in developing the right bed linen sleep quality index. Finally, both of those surveys were assessed, compared and the developed index equation was used to calculate the sleep quality index for the most preferred bed linen fabrics. The correlation was checked between the subjective rating of bed linen fabrics for sleep quality and the objective index obtained.

EXPERIMENT

Materials and Methods

Different bed linen fabrics evaluated through subjective assessment to develop bed linen sleep quality index BLSQI (Bed Linen Sleep Quality Index) included 100% cotton fiber, viscose-cotton (45:55), modal-cotton (70:30), 100% modal (regenerated viscose rayon fiber), poly-modal fiber (52:48), poly-modal-linen (52:48) and 100% excel (regenerated viscose rayon fiber) as given in Table 1.

Table 1. Properties of fabric samples

Composition	Weave	GSM (g/m²)	EPI * PPI
100% cotton	Plain	130	80*65
45% viscose / 55% cotton	2/1 Twill	110	82*70
70% modal / 30% cotton	Satin	125	192*62/2
100% modal	Satin	125	188*60/2
52% polyester / 48% modal	Plain	128	114*86
55% poly-modal (52:48) / 45% linen	Plain	138	120*80
100% excel	5 end satin	142	192*70*3

Where: EPI is number of yarn in warp direction, picks per inch; PPI is number of yarn in warp direction, picks per inch

Descriptive quantitative survey for determining bed linen properties affecting sleep quality

A subjective assessment was carried out to determine the relationship between bed linen properties and the sleep quality of an individual. The panel of 53 judges was constituted and these included academicians, experts from various sections of bed linen industry, research centers and consumers. A few number-based questionnaires were designed to record the exact scale value devoted to individual properties and included multiple choice questions to let the user select more than one option they prefer as shown in Figure 1. The survey was also carried out to determine the bed linen properties which affect sleep quality and also ranked the selected properties according to their priority as shown in Figure 2. The questions in the survey were more open ended, where users could share their level of awareness, views and ideas. The views of people were important to analyze the prototype preference material in the next stage of the subjective evaluation.

QUALITY BED-SHEET FOR A GOOD QUALITY SLEEP

This questionnaire intends to know your experience with bed linen/bed-sheet to get a good quality sleep.

Name-

Age-

Profession-

1. Do you think the quality of bed linen affects the quality of sleep?
   Yes/No
2. If you answered the previous question yes,
   Which of the following properties of the bed linen do you think affects the quality of our sleep?
   (☑necessary)

   ☐ Fiber (natural/manmade)
   ☐ Color
   ☐ Smell
   ☐ Feel (Smoothness/Roughness)
   ☐ Design/Patterns
   ☐ Print/Dye
   ☐ Compressibility
   ☐ Lustre
   ☐ Drape
   ☐ Stretchability
   ☐ Wrinkle/Crease

Figure 1. Questionnaire on the aspects of bed linen properties affecting sleep quality

Determination of weightage contribution of bed linen properties by the $100 test

The weightage contribution of the bed linen properties was determined by the subjective evaluation conducted by the panel constituting of 53 judges. The survey target population consisted of people of different age groups (>21) who may or may not be aware of quality of bed linen in relation to sleep quality. The sample chosen was a random population of individuals from India. The judges have to spend a total of $100 of virtual money among the different selected properties, which defines the weightage of the properties [18]. The weightage of each individual property contributing to sleep quality was determined and the questionnaire was designed as shown in Figure 2.

100 DOLLAR TEST

• Spend an imaginary $100 among the properties to rapidly assign relative value according to their level of importance.

(Note- the sum total spent on all the property must be exact $100.)

Divide $100 according to their level of importance

• Prioritize the properties with regards to its value of importance, according to you. (1 = most important…. so on)

e.g- 3 Fiber
      1 Color
      2 Smell etc.   **Weightage**
   ☐ Fiber (natural/manmade)   ....
   ☐ Color   ....
   ☐ Smell   ....
   ☐ Feel (Smoothness/Roughness)   ....
   ☐ Design/Patterns   ....
   ☐ Print/Dye   ....
   ☐ Compressibility   ....
   ☐ Lustre   ....
   ☐ Drape   ....
   ☐ Stretchability   ....
   ☐ Wrinkle/Crease   ....

Figure 2. Questionnaire on the ranking and weightage of bed linen properties

Subjective assessment of bed linen fabrics for selected quality properties

The second survey was to understand the fabric preference and consumers' desire for a good-quality bed linen. For this survey, a few specific fabrics were considered which were already in use for making bed linens as given in Table 1. The subjective assessment of the selected seven samples was conducted and the data was collected from a panel comprising of 41 adult participants. The samples were evaluated for the selected properties i.e. fiber, feel etc. on the scale 0-5 as shown in Figure 3. The judges also rated the fabrics for subjective bed linen sleep quality index on the basis of the overall quality of the fabrics in reference to sleep quality on the scale 0-5.

BED LINEN FABRIC ASSESSMENT

Rate the bed linen samples according to your preferred quality (0-5)
where 0 denotes poor property and 5 denotes excellent property

NAME:_____AGE:_____PROFESSION: _____

	Fiber	Feel	Color	Smell	Design	Wrinkle	Print	Stretch-ability	Compres sibility	Drape	Luster
100% Cotton											
Viscose-cotton											
Modal-cotton											
100% Modal											
Poly-Modal											
Poly-Modal-Linen											
100% Excel											

Figure 3. Questionnaire based on the selected properties of bed linen fabrics

Determination of agreement among the judges and discriminant analysis

The data received through the surveys had to be validated on its trueness. Some results may differ with the opinion on ranking. Therefore, to calculate the correctness of the survey data, a discriminant analysis was performed. And also to determine the agreement among the judges, the coefficient of concordance was found out [19]. The formula used to calculate the same has been derived by an expert group comprised of highly experienced weaving technologists in industry and senior fabric researchers from academic institutions and research centers as given in equation 1.

Coefficient of Concordance (W) = $\dfrac{12\Sigma(R_i-R)^2}{r^2 \cdot n \cdot (n^2-1)}$ (1)

where R_i = Average Rank Sum, R = Mean of the Data, r = Total Number of Judges, and n = Total Number of Grades

Development of bed linen sleep quality index: Basic approach

The sleep quality of an individual mainly depends on the health condition, emotional state, bedding condition and the ambient environment. Bed linen quality factors affecting sleep quality depending on the user's choice include fiber, feel, color, drape, smell, luster, stretch, compress, wrinkle, design, and print. The design,

pattern and luster of the fabric attribute to the texture of the fabric. The fiber properties along with drape and stretch attribute to the mechanical properties of the fabric. All these properties are directly linked to the aesthetic appearance of the fabric. Each of these quality parameters were quantified using subjective evaluation and integrated together to estimate a parameter called bed linen sleep quality index (BLSQI) as given in equation 2.

$$BLSQI: \sum_{i=1}^{n} A_i \cdot W_i \tag{2}$$

where *n* is the total number of properties, A_i is the grade of the ith property and W_i is the weightage of the ith property. In order to determine the weightage of each attribute, an expert panel was constituted and a survey was conducted to decide the contribution of each element to sleep quality of an individual.

The obtained bed linen sleep quality index was normalized to obtain the data to a specific smaller range, from 1 to 5. During normalization of the data the units of measurement for the data were eliminated, enabling easy comparison of the data of different units [20]. Therefore, to normalize the eleven characteristics by shrinking the data in the range between 1 and 5, every characteristic result must come within this range by using the equation 3. This will further help to compare the objective bed linen sleep quality index with the subjective bed linen sleep quality index. The maximum value was 5, which indicated the fabric had a higher bed linen sleep quality index and the minimum value was 1, which indicated lower bed linen sleep quality index.

$$Scaled\ characteristics = \frac{X_i - min_i}{max_i - min_i} \cdot (max\ range - min\ range) + min\ range \tag{3}$$

where i= the characteristics, X_i = characteristics value, Min_i = minimum value of the characteristics, Max_i = maximum value of the characteristics, Max range = maximum value is 5, Min range = minimum value is 1

RESULTS AND DISCUSSION

Determination of the relationship between bed linen quality and sleep quality

The survey was conducted to determine whether the sleep quality was affected by the bed linen quality or not. Majority of the population considered that the quality of bed linen fabrics directly affects their quality of sleep, which proves the hypothesis as shown in Figure 4.
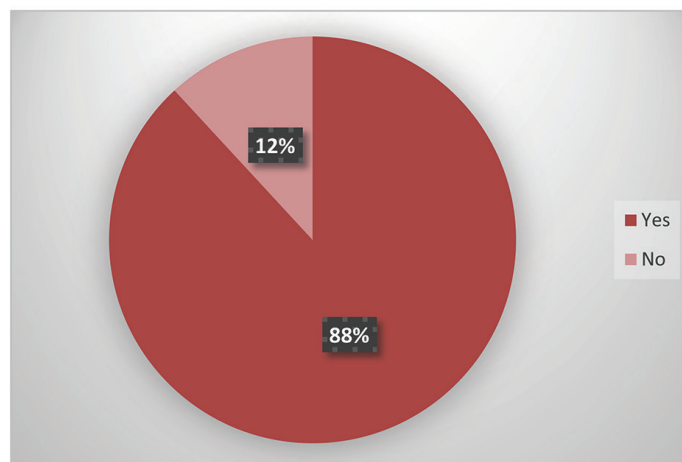

Figure 4. Bed linen properties affecting the quality of sleep

Determination of bed linen properties affecting sleep quality

The bed linen properties preferred by the consumers and judges included fiber type, feel, color, drape, smell, luster, stretch, compress, wrinkle, design and print. The preferred quality factors were also prioritized by the judges in the ascending order with 1 being the most preferred quality and 11 being the last as given in Table 2.

Table 2. Weight distribution and ranking of bed linen properties

Properties	Ranking	Weightage (W_i)
Fiber	1	42.8
Color	2	15.1
Smell	3	15.7
Feel	4	27.9
Design	5	10.2
Print	6	8.4
Compressibility	7	6.2
Luster	8	3.6
Drape	9	4.7
Stretchability	10	6.0
Wrinkle	11	8.6

Determination of the weightage and the ranking of bed linen properties

According to the $100 test, the judges have to spend a total of $100 of virtual money among different quality properties, which defines the weightage of the properties as given in Table 2. The weightage of each individual property contributing to sleep quality was determined. Though the feel factor was chosen as the most preferred factor for quality sleep, fiber factor received absolute majority in the 100$ test.

Subjective assessment of bed linen fabrics based on selected bed linen properties

This survey was conducted to rate the bed linen fabrics based on the properties obtained from Table 2.The fabrics were rated on the scale 0-5 with 0 being the poor quality and 5 being the excellent quality as given in Table 3. The rated value denotes Ai value in the equation 2. The fabrics were also rated for subjective sleep quality index as given in Table 4.

Table 3. Subjective evaluation of properties of bed linen fabrics

Properties (Ai) / Fabrics	Fiber	Feel	Color	Smell	Design	Wrinkle	Print	Stretch-ability	Compressi-bility	Drape	Luster
100% Cotton	3.7	3.5	3.8	2.7	3.9	4.3	3.4	2.6	2.7	3.8	3.9
Viscose-cotton	3.2	4.1	2.8	2.6	3.8	2.2	3.6	3.2	3.4	2.4	3.6
Modal-cotton	4.2	4.5	3.9	2.6	3.8	3.6	3.8	3.5	3.2	3.8	4.2
100% Modal	4.5	4.6	3.6	3.8	3.6	4.2	3.2	3.6	2.8	3.4	4.3
Poly-Modal	4.3	4.1	3.5	3.6	3.8	4.3	3.6	3.2	3.3	3.7	4.1
Poly-Modal-Linen	3.8	3.6	3.5	2.9	3.7	4.1	3.9	3.4	3.7	4.2	4.3
100% Excel	3.1	3.5	2.9	2.8	3.6	2.7	3.9	4.1	3.6	3.6	3.9

Table 4. Subjective bed linen sleep quality index

Fabric samples	Subjective BLSQI
100% Cotton	2.9
Viscose-cotton	1.8
Modal-cotton	4.6
100% Modal	4.5
Poly-Modal	4.0
Poly-Modal-Linen	3.5
100% Excel	2.0

Determination of agreement among the judges and discriminant analysis

The data received by the users must be validated on its trueness. The correctness of the survey data was calculated by performing a discriminant analysis. The discriminant analysis was carried out to determine the weight contribution of the individual bed linen attributes. The differences in subjective rating among the judges while ranking the fabrics for different bed linen attributes is shown in Figure 5. and the differences in subjective rating among judges while rating the subjective bed linen sleep quality index is shown in Figure 6. To determine the agreement among the participants, the coefficient of concordance was determined. The value 0.71 gives reasonably good agreement among the experts in the evaluation process of the survey data relating to selection and ranking of bed linen properties. The value of 0.61 indicates that there is relatively good agreement among the survey results relating to subjective bed linen sleep quality index of fabrics.
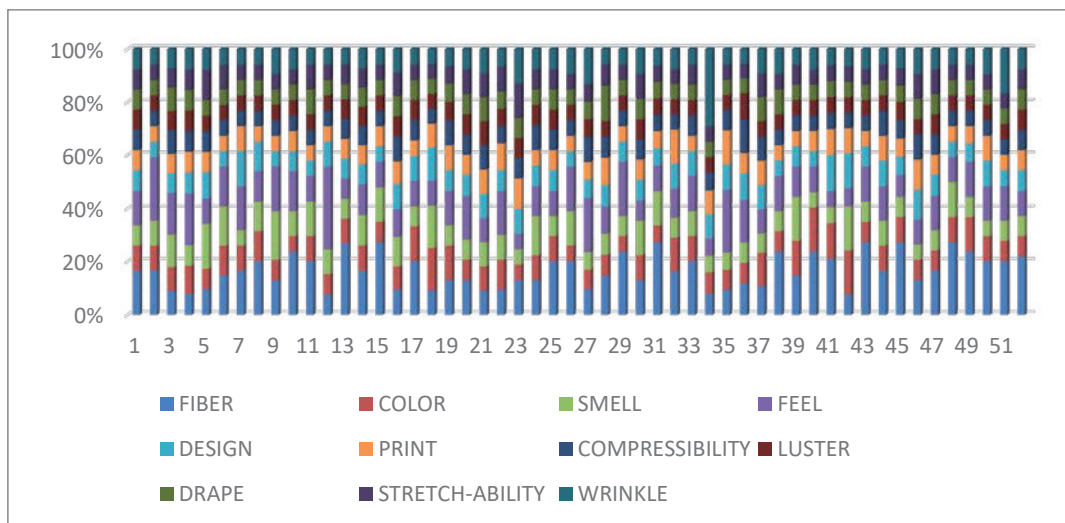

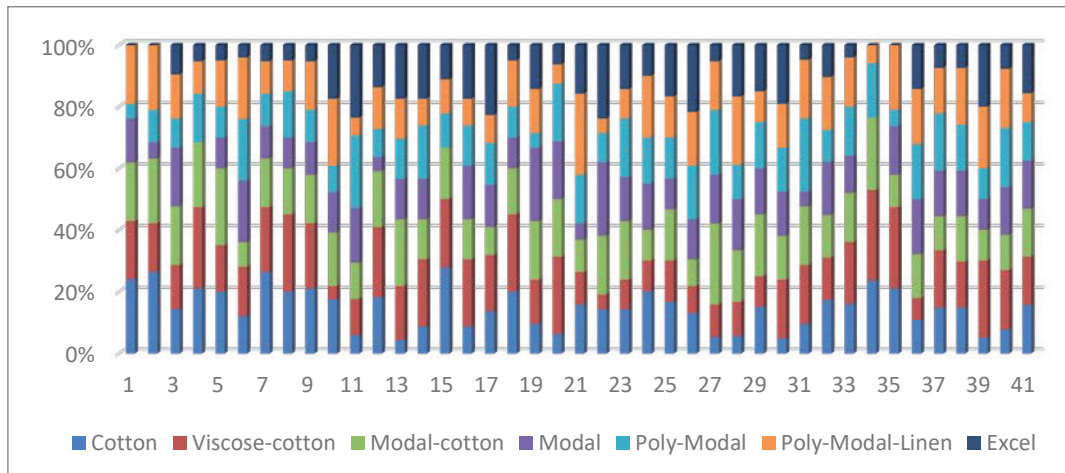Figure 5. Discriminant analysis of rating of bed linen properties for fabric samples

Figure 6. Discriminant analysis of subjective bed linen sleep quality index

Development of bed linen sleep quality index

The bed linen sleep quality index was evaluated by using the developed equation number 2. The W_i in the equation was the obtained weightage and A_i in the equation was the bed linen properties i.e. feel, color etc. with respect to the fabrics. An integrated index for sleep quality based on bed linen properties was determined using the equation 2 as given in Table 5. The values in Table 5 were normalized to obtain the data to a specific smaller range, from 1 to 5. To validate the above data, the values were normalized within a smaller range. The bed linen sleep quality index obtained after the normalization technique is given in Table 6.

Table 5. Bed linen sleep quality index without normalization

Fabric samples	BLSQI $= \sum_{i=1}^{11} Ai \cdot Wi$
100% Cotton	524.34
Viscose-cotton	486.89
Modal-cotton	580.48
100% Modal	605.10
Poly-Modal	585.59
Poly-Modal-Linen	545.78
100% Excel	488.66

Table 6. Bed linen sleep quality index with normalization

Fabric	BLSQI
100% Cotton	2.27
Viscose-cotton	1.00
Modal-cotton	4.17
100% Modal	5.00
Poly-Modal	4.33
Poly-Modal-Linen	2.99
100% Excel	1.11

Determination of correlation between subjective and objective bed linen sleep quality index

The subjective BLSQI was obtained by the experts by subjective evaluation, whereas the objective BLSQI was obtained by the developed equation 2. The correlation coefficient obtained for subjective and objective BLSQI was 0.95 as shown in Figure 7, which indicated a very good correlation between those two sets of values.
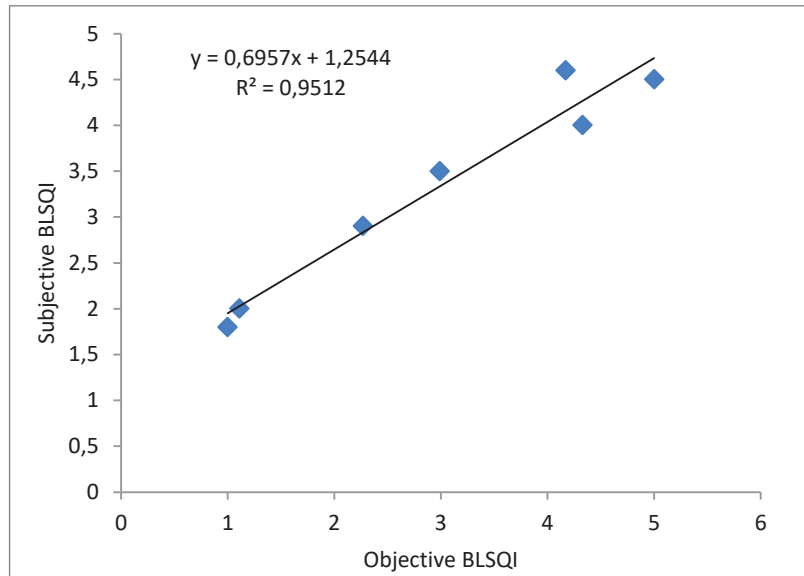

Figure 7. Correlation between the subjective and the objective BLSQI

CONCLUSION

The hypothesis that the sleep quality is directly proportional to bed linen quality was proved. While evaluating bed linen quality through subjective assessment, most people prioritized the fiber and the feel of the bed linen, rather than the color or other properties associated with aesthetics. Though the fiber factor was chosen as the most preferred factor for quality sleep, the feel factor received absolute majority in the 100$ test with 29% weightage among the total 11 considered bed-linen properties. The fiber factor received the highest weightage because the thermal and moisture properties, breathability etc. of the fabric are mainly dependent on fiber properties, and sweat release, body temperature and trapped body heat have an important role in good-quality sleep. The agreement among the judges was also good, 0.71 and 0.61, for rating the bed-linen properties of different fabric samples and the subjective BLSQI respectively. The development of bed linen sleep quality index provided the objective sleep index value for seven fabrics. The correlation coefficient for the subjective and objective BLSQI was 0.95, which indicated an excellent correlation. Thus, the objective sleep quality index could be estimated well following the developed procedure. This research can further help in calculating the performance of more introduced options in the wide sector of bed linens ahead in time so that consumers are able to get good-quality sleep.

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