The Influence of Density of the Materials and Body Mass Index on the Elderly's Sleep Efficiency

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Abstract

Insomnia is a common problem among the elders and it directly affects their health. The mattress is one factors influencing sleeping efficiency. The developed pressure at the sleeping surface during sleeping will to cause body discomfort, leading to sleep problem. The developed pressure depends on the density of bedding materials and body mass. The present research aims to study the effects of the mattress density and body mass on the elderly sleep efficiency. The sleep data was collected from 6 volunteers: 3 male and 3 female at the age group of 60 – 79 years. The experiment was done on mattresses with densities of 24.6 and 60 kg/m^3 and 4-inch thickness. The volunteers randomly slept on each mattress for three nights. Sleep data was recorded by sleep tracker (Jawbone up24), calibrated with Polysomnography. The study revealed that sleep efficiency on the 60 kg/m^3 density mattress was more than 90 percent while those on the 24.6 kg/m^3 density mattress were in the range of 78-84 percent. Moreover, sleep efficiency of the volunteers with the body mass index of 22.22 - 23.74 kg/cm^2 was significantly different from those of volunteers with the body mass index of 24.61-24.92 kg/cm^2 when they slept on the 24.6 kg/m^3 density mattress. Additionally, the pressure test revealed that a pressure at shoulder may affect sleep efficiency.

Keywords: pressure, sleep efficiency, elderly, body mass index

1. Introduction

Undeniably, individuals' hygiene and health is related to a balance between relaxation and daytime activities. Most of us spend one-third of our life in sleeping [1-2]. One factor that effects on our health is sleep quality, which can be indicated by sleep efficiency: a ratio of total sleep time to total time in bed. There are many factors affecting sleep efficiency such as physical, mental, emotional, and environmental factors [3]. It is found that 7 percent of American people, especially elders, have sleep problems, resulted by their mattresses [4]. The reason why elders have the sleep problem is deterioration and malfunction of cells and organs, like backbone [5]. The inappropriate sleep postures, pressure on sleeping surface and body mass of obese elder apparently cause shorter sleep time, leading to low sleep efficiency. Conversely, those with normal body mass index would have higher sleep efficiency and slow wave sleep (SWS) than those of the obese ones [6-7]. In addition, pressure on sleeping surface, depending on mattress density, is believed to be related to low back discomfort, pain, or stiffness and shoulder pain [8]. According to the previous study, pressure between the sleeping surface and skin of 30 mmHg is suggested to be the acceptable upper limit to assure that capillary blood perfusion to soft tissue can be maintained [9-10].

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However, there is no in-depth study on the relationships between the pressure on the sleeping surface and sleep efficiency. The pressure on the sleeping surface depends on the mattress density and body mass laid on the mattresss.

According to the previous studies, a medium-firm mattress in which the layers of material had been laid is recommended to obtain good sleep quality [11-14]. However, the medium-firm mattress is not clearly defined. It depends on types of material and individual physical *characteristics*. This work, therefore, aims to study the effects of the mattress density and body mass on the sleep efficiency, and relate these factors to the pressure on the sleeping surface.

2. Methods

The equipments used in this work were pressure mapping FSA version 4.0, Vista Medical company and sleep tracker (Jawbone up 24). The pressure mapping is used to measure pressure on the sleeping surface during sleeping. The Jawbone up 24 is used to measure sleep data such as sound sleep time, light sleeping time, time in bed (TIB), number of awakenings and total sleep time (TST). The data obtains from the Jawbone up 24 is compared with those obtained from polysomnography(PSG) using sample size of 5 and the relationship between these data is shown by linear regression as shown in figure 1.

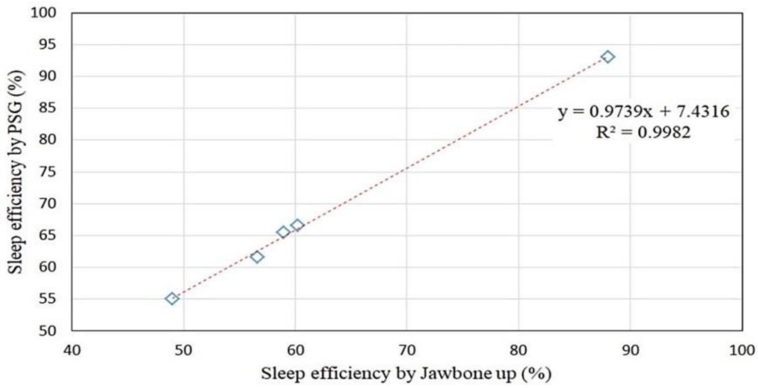

Fig. 1 Relationship between sleep efficiency obatined from Jawbone up and PSG

Fig 1 shows the sleep efficiency obtained from Jawbowe up 24 compared with that obtained from PSG. This figure shows excellent linear relationship between these value. The regression equation shows that sleep efficiency measured by Jawbone up is about 6.0 percent lower than that obtained from PSG.

The mattresses used in this work are 24.6 kg/m^3 density polyurethane foam and the 60 kg/m^3 density reborn foam. The sizes of both mattresses are 90 x 200 square centimeter and 4-inch thickness. Six elderly volunteers who have no sleep problems and have normal body mass are chosen in this test. To conduct the sleep test, the mattresses would be covered with thin fabric before conducting the test. All volunteers would randomly sleep in their houses with different mattresses for 3 nights each. Prior to experiments, each volunteer will be asked about his/her sleep behavior. On the test day, volunteers must avoid any caffeine, alcoholic drinks and perfumes. The time to sleep is scheduled as the same as their normal sleep time. The volunteers are requested to take a bath and to wear casual comfort dresses as their pleasure. The data collected are sleep onset latency, time in bed, number of awakenings and total sleep time. The sleep efficiency is calculated from the following equation:

$$Sleep\,efficiency = \frac{Total\;Sleep\,Time \times 100}{Time\,in\,Bed} \tag{1}$$

For pressure measurement, the pressure is measured three times for each material. All volunteers will lie on two mattresses with a pressure mapping in between for both supine and lateral positions. The highest pressure at the shoulders and hip has been chosen to find their relationships with sleep efficiency.

3. Results

3.1. Effects of mattress density on sleep efficiency

Fig 2 demonstrated the sleep efficiency of six volunteers sleeping on two mattresses with different density.

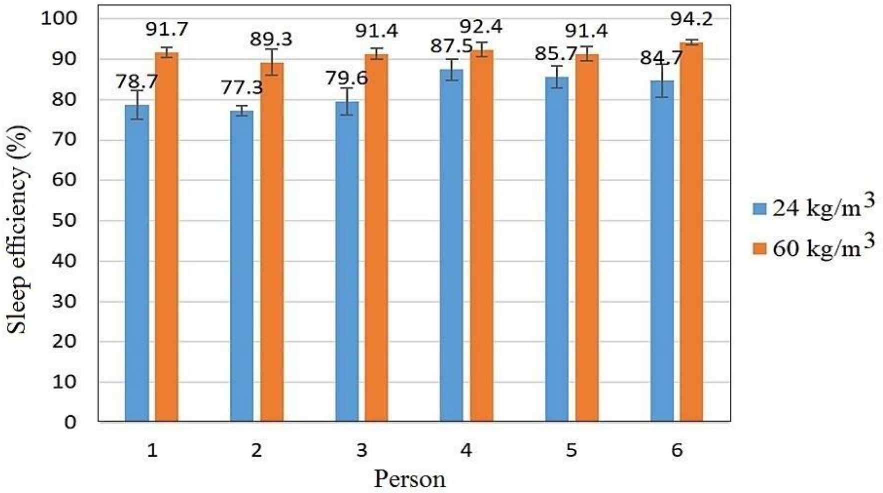

Fig. 2 Sleep efficiency measured by Jawbone up 24

From the figure, the sleep efficiencies on the 60 kg/m^3 density mattress are higher than those on the 24.6 kg/m^3 density mattress. Using the pair t-test, the sleep efficiency on 60 kg/m^3 mattress is higher than that on 24.6 kg/m^3 mattress significantly with significant level of 0.05. The higher sleep efficiency on the higher density mattress may be explained by the fact that the higher density mattress cause less body sink, which results in less spine bending. The spine bending causes back muscle tautness and an increase of lumbar spine pressure. These phenomena leads to back pain and resulting in low total sleep time. As indicated by Gabriel et.al, sleeping on the soft sleeping surface is proven to cause low back pain [15].

It should be pointed out that sleep efficiencies on the 60 kg/m^3 mattress are about 90 percent or higher. As mention earlier, sleep efficiency measured by Jawbone up is about 6 percent less than that measured by PSG; therefore, the sleep efficiency on 60 kg/m^3 density mattress is about 96-97 percent if measured by PSG. This value is very high. Therefore, the 60 kg/m^3 density mattress would be recommended for elders to gain good sleep efficiency during sleeping.

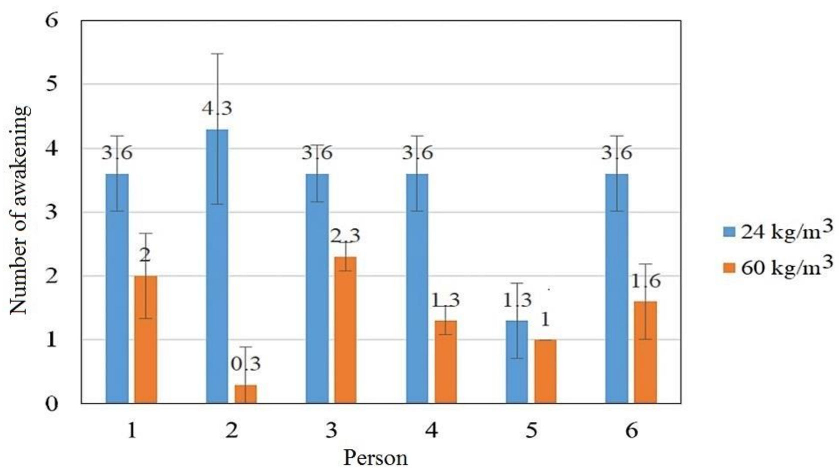

Fig. 3 Number of awakening of volunteers on different mattresses

Fig. 3 shows number of awakening of 6 volunteers who had slept on the 24.6 and 60 kg/m^3 density mattresses. Form the figure, they have woken up 3 to 5 times per night when they sleep on the 24.6 kg/m^3 density mattress and range of 0 to 3 times per night when they sleep on the 60 kg/m^3 density mattress. The result confirms that sleeping on the 24.6 kg/m^3 density mattress causes more discomfort than sleeping on the 60 kg/m^3 density mattress.

3.2. Effects of pressure on the sleeping surface on sleep efficiency

To study the relationship between sleep efficiency and pressure, the pressure mapping is used to measure pressure between the sleeping surface and skin in both supine and lateral positions. An example of pressure profile during sleeping in lateral position is shown in fig 4. The profile shows both number and color code to indicate the magnitude of pressure on the sleeping surface during sleeping. The pressure, used to relate with sleep efficiency, is the maximum pressure measured with their individual preferred position.

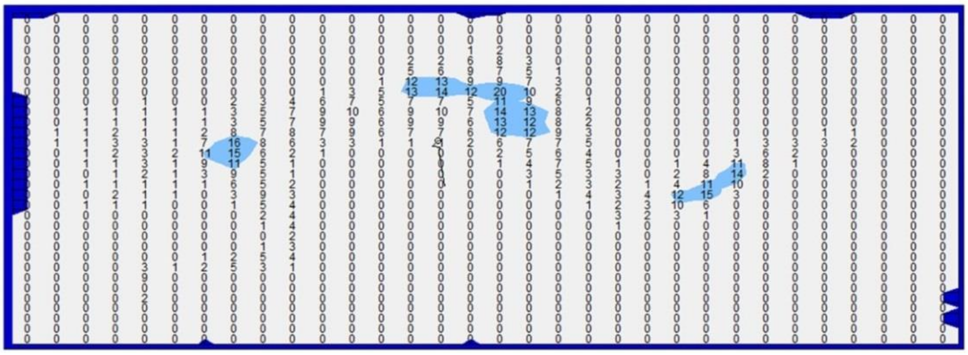

Fig. 4 Pressure profile measured during sleeping with lateral positioning.

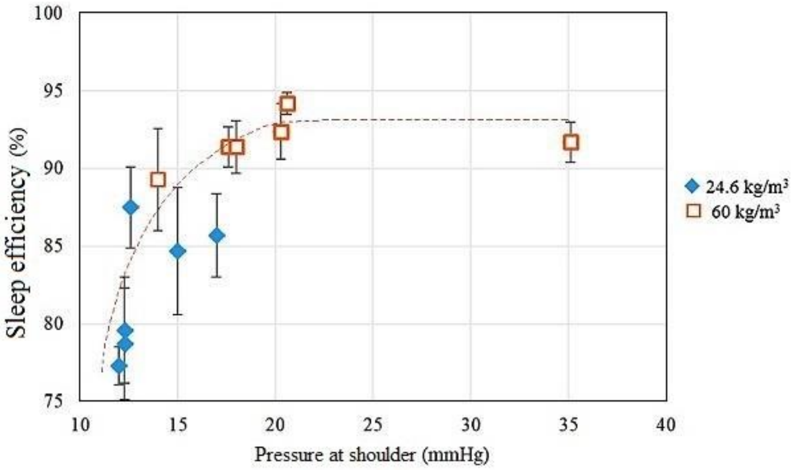

Fig. 5 Pressure at shoulder and sleep efficiency of volunteers sleeping on the 24.6 kg/m^3 and 60 kg/m^3 density mattresses

According to Fig. 5, the pressure at shoulder might be related to sleep efficiency. Apparently, the sleep efficiency is 90 percent or higher when pressure at shoulder is at least 17.6 mmHg. Compared with the previous suggestion, which states that the pressure of approximately 30 mmHg is the upper pressure limit that blood could normally flow and nourish organs and tissues of cells, Fig. 5 indicates that pressure at shoulder, can increase up to 35 mmHg, which is more than the suggested upper pressure limit.

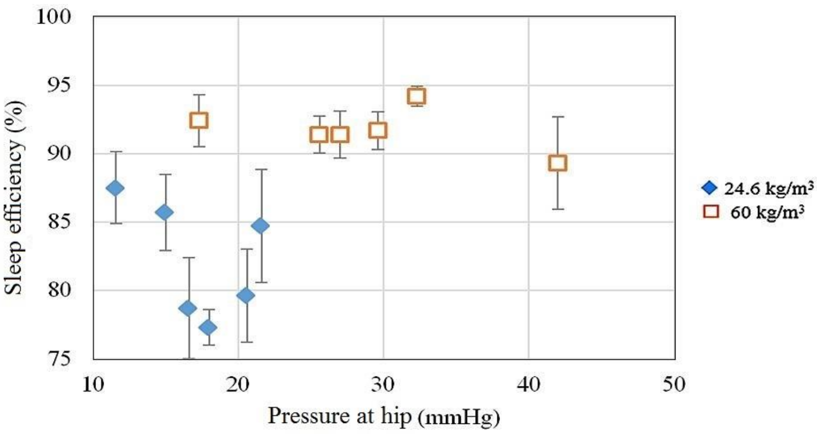

Fig. 6 Pressure at hip and sleep efficiency of volunteer sleeping on the 24.6 kg/m^3 and 60 kg/m^3 density mattress

In addition, the result shows that for pressure at shoulder of lower than 17.6 mmHg, the lower the pressure, and the lower is the sleep efficiency. It should be noted that pressure at shoulder of lower than 17.6 mmHg only occurs when volunteers sleep on the 24.6 kg/m^3 density mattress. It can be concluded that pressure at shoulder on the low density mattress is low and resulting in low sleep efficiency. This means that pressure at shoulder may effected on human discomfort during sleeping. In contrast to Fig. 5, pressure at hip does not show any relationship with sleep efficiency as shown in Fig. 6.

3.3. Effect of body mass index on sleep efficiency

The sleep efficiency might be effected by other factors such as age, weight and height, [10]. Therefore, the relationships among body mass index (BMI), mattress density and the sleep efficiency was studied. For this reason, the volunteers is classified into two groups: those of the BMI of 22.22-23.74 kg/cm^2 and of 24.61-24.92 kg/cm^2, respectively. The relationship among body mass index, mattress density and sleep efficiency occuring on the 24.6 and the 60 kg/m^3 density mattress is shown in fig 7.

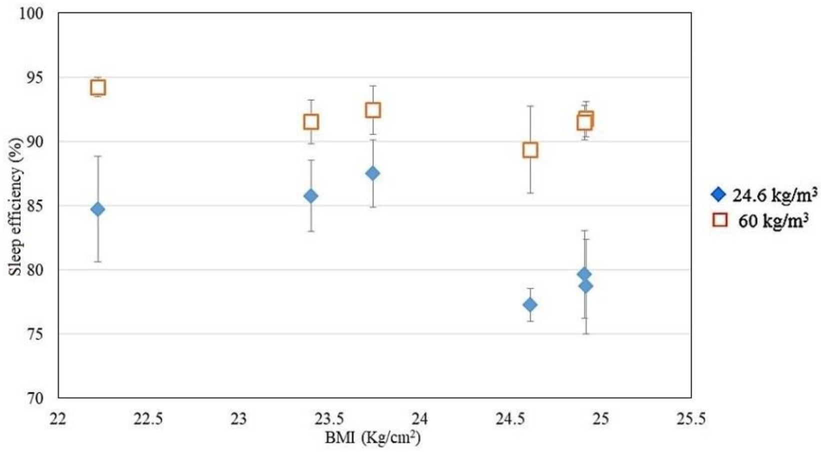

Fig. 7 BMI and sleep efficiency of volunteer sleeping on the 24.6 kg/m^3 and 60 kg/m^3 density mattresses

The independent t-test shows that BMI related to sleep efficiency when sleeping on the 24.6 kg/m^3 density mattress but not on the 60 kg/m^3 density mattress with significance level of 0.05. The statement means that BMI is less related to sleep effciency when sleeping on the high density mattress. According to definition of BMI, it represents the ratio of mass to square of height. It is used to define body fatness. For the low density mattress, a small increase of body mass index or body fatness causes more body sink into the mattress. As a result, body spine bends and potenially lead to back pain and discomfort. The figure also shows that for low density matteress, the higher the BMI of volunteer, the lower is the sleep efficiency. The result is in an agreement with the study by Vorona et. al. [16], who indicates that the total sleep time of one who has high body mass index is lower than the one whose body mass index is normal.

4. Conclusions

The present study demonstrated that mattress density and body mass index effected on sleep efficiency. Sleeping on the 60 kg/m^3 density mattress provided higher sleep efficiency than on the 24.6 kg/m^3 density mattress for all volunteers. The body mass index was found to affect sleep efficiency only when volunteers slept on the 24.6 kg/m^3 mattress. The study also showed that pressure at shoulder may affect sleep efficiency when volunteers slept on low density mattress but on high density mattress.

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