Chapter 11
The Quantitative Effects of Mattress and Sleep Postures on Sleep Quality

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Abstract Mattress, as a sleep platform, its types and physical properties have important effects on sleep quality and rest efficiency. In this paper, by subjective evaluations, analysis of sleeping behaviors, the relationship between the sleep postures, change postures and sleep quality were studied. The results showed that: (1) the mattress properties had a remarkable effect on sleep behaviors and sleep quality; (2) Sleep behaviors had a close relationship with sleeping postures and sleep habits. The characteristics of sleep behaviors vary from person to person; (3) Chinese people had tended to prefer supine posture, and the number of turns during night was less in supine position than in the lateral position.

Keywords Mattress · Sleep movements · Sleep postures · Sleep quality

11.1 Introduction

Although the use of western-style mattress has been accepted by more and more Chinese people, there exist few intensive studies on mattress properties and Chinese demands. Compared with traditional beds, western-style mattresses seem to

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have brought more sleep disturbances and health problems. A survey of the US public concerning the quality of sleep has showed that 7 % of the subjects indicated that their sleeping problems were related to an uncomfortable mattress (Addison et al. 1986). Among them incorrect sleeping postures and insufficient support conditions, especially insufficient support of the low back was one of the most important factors causing low-back pain (Hildebrandt 1995). Park et al. have reported that the comfort of a bed was more heavily influenced by secondary properties, such as spinal curvature and distribution of body pressure in Human-Bed system than the primary properties of the material of mattress itself. However, these studies have not provided evidence that sleep quality differs according to mattress properties (Lee and Park 2006).

Lee and Park (2006) studied the effects of "comfortable" and "uncomfortable" mattress, although they did not find differences in sleep architecture, their experimental results showed that "comfortable" mattresses could help to reduce the movements in the stage of deep sleep (Lee and Park 2006). In fact, sleep is a complex phenomenon; sleep quality is affected by a combined action of physiological factors psychological factors and external environments.

The objective of this study was to investigate the Chinese people's demands on mattress and the relationship between the sleep postures, mattresses and sleep quality.

11.2 Methodology

Each subject was recorded at least 4 consecutive nights (starting on Monday night and ending on Friday morning) on each of the 18 mattresses. The subjects were blind to the bedding materials and structure of spring mattress. Two weeks prior (Jacobson et al. 2008) to the test all participants were asked to sleep in the sleep laboratory to adapt the laboratory conditions and maintain a constant life style without change in sleeping habits. The temperature and relative humidity in the sleep laboratory was controlled at 25 ± 1 °C and 50 ± 5 %, respectively. To minimize the seasonal influence on sleep quality (Kleitman 1939), the test took place from September to December.

(1) *Subjects*: The subjects, participating voluntarily in the study, had good health, simple life style, regular sleep habits, no history or symptoms of sleep disorders, and were not heavy snorers. The participants were required to sleep still on the experimental mattress during each testing cycle. No medicine, tea, coffee, and other stimulating beverages were allowed 3 h prior to the sleeping test. Volunteers were 11 female graduate students, age of 20–32 years. Average height, weight, and body mass index were 159.81 cm (± 9.88 cm), weight 51 kg (± 6.5 kg), and 20.2 (± 3.3), respectively.

(2) *Body movements during sleep*: Subject body movements were recorded in the dark using Ingra-red video cameras and meanwhile observed by the technicians outside of the sleeping room through monitors.

(3) *Sleep diaries and visual analogue Scales (VAS)*: A self-report of sleep was measured with a sleep diary that was filled out each morning immediately upon arising. The subjects needed to answer questions about any external disturbance during the night, the subjective quality of sleep, the level of fatigue and sleepiness, the location of the occurrence of discomfort or pain, perceived the number of awakenings, the degree of easily falling asleep, mattress stability. The subjects also needed to provide 7-level VAS scores each morning reflecting the comfort degree of different parts of human body.

(4) Selection of mattress: Eighteen mattresses were provided by Nanjing Kirin Co., Ltd. According to the CTBA standard, the compressive mechanical properties of the mattresses were obtained and the rigidity of mattresses was 76.5 ± 26.1 mm.

(5) *Analysis*: Prior research on sleep surfaces had suggested that a time frame of up to 4 nights or more may be required before a sleeper accommodates to a new sleeping surface in their home (Jacobson et al. 2008; Bader and Engdal 2000; Scharf et al. 1997). Therefore, data for VAS, sleep diary, sleep structure and movement parameters were analyzed from the fourth day to the seventh day of sleeping on one mattress, the first three night's record were not used. Correlations between variables were made with Spearman. To compare sleep quality between 18 different mattresses, the F-test for each pair of variables from all the recorded nights for the 18 mattresses conditions was used. Differences of $p < 0.05$ were considered significant for all statistical analyses.

11.3 Results

11.3.1 Sleep Postures

The amount of movements varied among the subjects, but the individual movement pattern had some reproducibility from night to night, providing that the activity and the stress during the day were moderate and that the subjects did not experience discomfort or pain during the night except sleeping on the mattress with poor stability or with top layers of too high hysteresis.

Table 11.1 gives mean values of the number of turns and adopted sleep postures and their standard deviations of 18 experimental mattresses tested by 11 subjects. For 11 subjects, the mean of the number of changing postures per night was 18.72. The average amount of time per night that spent in supine posture (53.02 %) was longer than that in lateral posture (45.88 %). The average amount of time per night that spent in the left side posture was slightly longer than that in the right side posture. The average amount of time per night that spent in prone posture was very short (1.09 %).

The number of turns presents negative correlation with the average amount of time per night that spent in supine posture and presents positive correlation with the average amount of time per night that spent in lateral posture and prone posture

Table 11.1 Mean values of the number of turns and adopted sleep postures during overnight experiments

The number of turns		Sleep postures				
		Supine (%)	Lateral on the left side (%)	Lateral on the right side (%)	Lateral (%)	Prone (%)
Mean	18.72	53.02	24.96	20.93	45.88	1.09
SD	7.74	16.95	13.96	13.04	16.76	3.56

Note The data in the table are the mean and the standard deviation for 18 mattresses and 11 subjects

Table 11.2 Correlation between the number of turns and sleep time in every posture

	The number of turns	The % time in supine position	The % time on the left side	The % time on the right side	The % time in lateral position	The % time in prone position
The number of turns	1	−0.329**	0.174**	0.203**	0.297**	0.295**
The % time in supine position		1	−0.615**	−0.533**	−0.974**	−0.128**
The % time on the left side			1	−0.244**	0.624**	−0.031
The % time on the right side				1	0.554**	−0.023
The % time in lateral position					1	−0.034
The % time in prone position						1

Note ** Mean data are significant correlation (2-tailed) at the 0.01

(Table 11.2). There was significant negative correlation between the average amount of time per night that spent in supine posture and lateral posture (Table 11.2). In other words, the longer the time that spent in supine posture was, the less the number of turns was.

11.3.2 Subjective Sleep Quality and its Factors

Sleep comfort presents positive correlation with adequate sense of sleep quantity, the degree of easily falling asleep, the degree of easily falling asleep after awake during sleep period time, satisfaction with mattress, body status in the next morning, stability feeling of mattress, and had negative correlation with dreaming quantity, perceived the number of awakening and fatigue in the next day, in which the correlation between sleep comfort, adequate sense of sleep quantity, body status in the next morning, satisfaction with mattress and stability feeling of mattress was stronger than others (Table 11.3).

There were significant correlations between the lumbar comfort, the buttock comfort, the upper leg comfort, the knee comfort and the lower leg comfort, especially the comfort of adjacent parts of human body shows closer relationship (Table 11.4).

11.3.3 The Correlations Between the Mattress Mechanical Characteristic and Sleep Quality

There were significant differences in the subjective sleep ratings scores (Fig. 11.1) among 18 tested mattresses. There was a mild trend showing that the subjective sleep quality increased as mattress firmness decreased, although most of the subjects felt a little too soft for some of the experimental mattresses in the adapted period (prior to the test).

11.4 Discussion

The influence of different postures (Dolan et al. 1988) is an important determinant of human body support. Optimizing body posture in both conscious and unconscious ways ensures continuous spine protection (Farfan and Gracovetsky 1984). But instead of creating perfect conditions to allow optimizing our body position in an unconscious way, the sleep system actually forces us into a certain position. Body position is therefore limited to an initial conscious selection and subsequent unconscious optimization. Furthermore, posture changes are necessary to avoid pressure overloading of soft tissues and to prevent muscle stiffness. During sleep a local ischemia—a deficiency of blood or oxygen supply—will arise in body zones that are in contact with the sleep system. This ischemia generates metabolic substances that stimulate the sensible nerve extremities, which will cause the person to change his or her posture before it gets painful (Dzvonik et al. 1986).

The main advantage of sleeping in a supine position is the fact that body weight is distributed over a large surface, resulting in pressure distribution and stability being optimized. The lumbar part of the vertebral column will mostly be positioned between a smoothed lordosis and a slight kyphosis, depending on (1) the kind of sleep system, (2) the natural curves of the spine, and (3) muscle tension while sleeping. When a mattress is too soft, places where body weight is concentrated (e.g., the hip zone) will sink deeply into the mattress. Some muscles may be well relaxed in this position, but the spine certainly will not; the pelvis will

Table 11.3 Correlation between the parameters of subjective sleep quality

	SC	ASSQ	DEFA	DQ	NA	DEFAA	SM	BSNM	FND	SFM
SC	1	0.625**	0.333**	−0.291**	−0.281**	0.303**	0.493**	0.616**	−0.454**	0.443**
ASSQ		1	0.315**	−0.113**	−0.138**	0.211**	0.376**	0.531**	−0.428**	0.376**
DEFA			1	0.065	−0.111**	0.249**	0.258**	0.299**	−0.207**	0.512**
DQ				1	0.240**	−0.035	−0.180**	−0.297**	0.221**	−0.382**
NA					1	−0.253**	−0.125**	−0.199**	0.176**	−0.561**
DEFAA						1	0.194**	0.258**	−0.327**	0.499**
SM							1	0.575**	−0.275**	0.458**
BSNM								1	−0.419**	0.298**
FND									1	0.266**
SFM										1

Note ** Mean data are significant correlation (2-tailed) at the 0.01

SC sleep comfort, *ASSQ* adequate sense of sleep quantity, *DEFA* the degree of easily falling asleep, *DQ* dreaming quantity, *NA* perceived the number of awakening, *EFAA* the degree of easily falling asleep after awake during sleep period time, *SM* satisfaction with mattress, *BSNM* body status in the next morning, *FND* fatigue in the next day, *SFM* stability feeling of mattress

Table 11.4 Correlation between parts comfort of human body in the next morning

	Neck comfort	Arm comfort	Shoulder comfort	Back comfort	Lumbar comfort	Buttock comfort	Upper leg comfort	Knee comfort	Lower leg comfort
Neck comfort	1	0.419**	0.459**	0.289**	0.166**	0.312**	0.338**	0.256**	0.319**
Arm comfort		1	0.494**	0.275**	0.129**	0.435**	0.427**	0.300**	0.301**
Shoulder comfort			1	0.301**	0.211**	0.310**	0.355**	0.271**	0.302**
Back comfort				1	0.413**	0.319**	0.241**	0.158**	0.184**
Lumbar comfort					1	0.312**	0.221**	0.165**	0.213**
Buttock comfort						1	0.656**	0.388**	0.495**
Upper leg comfort							1	0.647**	0.730**
Knee comfort								1	0.737**
Lower leg comfort									1

Note ** Mean data are significant correlation (2-tailed) at the 0.01

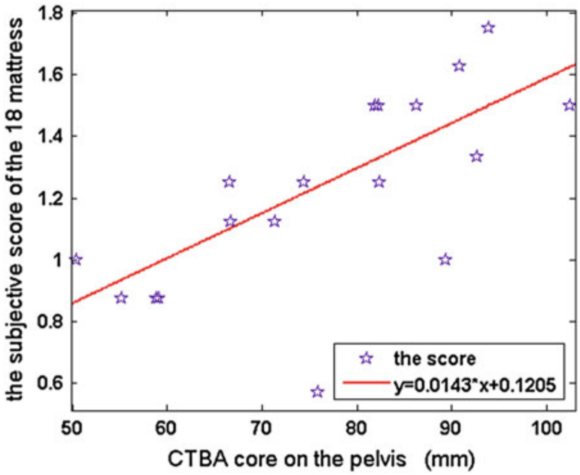

Fig. 11.1 Mean of the subjective rating scores given by participants in the sleep study (overall sleep quality)

cant backward resulting in a complete and unnatural lumbar kyphosis. When a sleep system is too firm, the lumbar part of the vertebral column will not smoothen immediately when lying down, and no contact will be made between the lumbar part of the back and the mattress. Upon muscle relaxation (which occurs after 10 to 15 min on average) the pelvis will cant backward slightly, which results in a slight smoothing of the lumbar part of the vertebral column. Some persons might however experience discomfort due to muscle tension that arises when the pelvis cants backward while the legs stay in a horizontal position (Haex 2005).

The lateral position is the most sleeping posture that European adopted, and it is able to support the human spine correctly when both the bed and pillow are well conceived: the spinal column is a straight line when projected in a frontal plane, while natural curves are maintained. Due to decreased contact surface and the center of gravity being more elevated, a lateral position is an unstable sleep position, which can be altered by the correct positioning of the extremities. Bending arms and legs enlarges the support area and thus improves stability.

According to our results it was found that the amount of time spent in each sleep posture to Chinese subjects was significant different from that of European subjects, Chinese people preferred to sleep in supine posture (53.02 % of the amount of time spent in supine posture), while European had a preferred side to sleep on and the amount of time spent in supine posture was less than 30 % (Verhaert 2011). From the point of view of ergonomics, the demand of the mechanical properties of mattresses should be different to the people with different preferences in sleep posture.

Our results also showed that sleep quality was different when subjects slept on spring mattresses with different characteristics of the bedding materials and structure, and the sleep movements and posture changes was relevant to the preferred sleeping posture. Sleep quality was related to sleep comfort, while sleep comfort was affected by the external factors such as the spirit state before sleeping (or the degree of easily falling asleep), adequate sense of sleep quantity and satisfaction with mattress use and so on. And sleep quality will influence badly the body status in the next day. To the unzoned mattress, the lack of effective support of waist and pelvic was an important factor effecting the use comfort of the mattress.

11.5 Conclusion

These results showed the difference of sleep quality when subjects slept on mattress with different properties. The sleep movements and change postures were related with the sleep postures. The number of change postures was less in supine posture than in lateral posture. The Chinese preferred the sleep posture in supine position. Further investigations are required with the factors of the mattress stability and instability patterns.

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