How Do Tilt Angles Affect Users' Comfort Level While Using Bed Tables?

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Abstract. Bed tables become more and more popular among many young people and office workers, with the angle-tilted structure which allows users more working posture choices. Otherwise, whether working in front of bed tables of which the desktop's angle can be tilted meet ergonomics rules and do not lead to users' discomfort is still unknown. Therefore, the goal of this research is to test whether the tilt angle will affect users' comfort while working in front of a bed table. To achieve this goal, an experiment with 12 participants was designed, in which a questionnaire was used to collect the participants' subjective feelings of comfort and the spinal angles were recorded to analyze objective comfort level of participants. According to the SPSS analysis of data, the result showed that a 30°desktop tilt angle of bed table might improve both physical comfort level and subjective physical feeling. The result of this research may provide some references for the future design of bed tables and give users some suggestions of choosing different working furniture.

Keywords: ergonomics; bed table; working posture; comfort; industrial design

1 Introduction

The ergonomics of working stations and postures have been an old topic among researchers in medical, human factor and industrial design fields, as nowadays most people sit in front of a computer and keep the same posture for a long time during their daily works. And according to some researchers [1-2], an incorrect working posture and working stations which are not set based on ergonomics knowledge may make people feel uncomfortable while working and if workers keep working in incorrect postures or inappropriate working stations for a long time, they may even get neck, spinal or back diseases. So, it is necessary to assure the working stations and working postures for office workers are ergonomically appropriate for long time working.

A great number of researches exploring the correct working postures and appropriate working station settings have been done among researchers all around the world. Most of these researches talked about the correct sitting postures and the most appropriate height and size of working desks and chairs, as most office workers sit in front of a desk while working. And the researchers did make great progress in the area of ergonomics of sitting postures and working station

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settings. For example, Claus et al. compared different sitting postures through describing the spinal form by geometric graphics in their research [3]. And Vergara and Page also evaluated different sitting postures through geometric methods [1]. Sánchez et al. used a video-based method to quantify posture of the head and trunk in sitting [4].

As for the researches of working stations, Le and Marras evaluated three different office workstations through biomechanics [5]. In their research, besides workstation that allows users to sit, there were 2 other workstations which allow users to stand and perch while working. This was a new area of ergonomics while working, which talked about some new working postures. And in the article of Alinia et al., the lying posture was evaluated through sensors [6]. Based on these researches, ergonomics rules for different working postures and workstations have been added.

However, although the present researches for working postures and workstations have already been in-depth, there is seldom research about ergonomics of working in front of a bed table. And the research about bed table ergonomics is necessary, as this kind of special table is becoming more and more popular with office workers and students, especially young people and people who have limited spaces at home. The bed tables allow users to work in bed with different angle and height choices. Unlike normal tables, bed tables allow people to work in more variable postures, for example, people do not have to sit so straight as sitting in front of a normal table, instead, they may sit in their beds in front of the bed table with a comfortable pillow behind their backs; or people may even work in the lying posture. With these new working postures allowed and the small spaces required, bed tables' sales became larger among young people. As university students have limited spaces in their dormitories, most of them would like to have a bed table. Also, due to Covid-19, working from home became a new trend in most of the offices [7-10]. Under this background, many young office workers who rent houses or share flats with some roommates, which allows them limited personal working spaces, started to use this kind of bed table while working from home.

Otherwise, although bed tables became more popular, there were also some people arguing that the working postures in front of the bed tables might cause discomfort. Whether this was true or not still remained unknown. Whether bed tables meet ergonomic requirements or whether bed tables do cause users' discomfort still needed to be test.

Therefore, this research was aimed to solve this problem. The goal of this research was set as testing how tilt angle of desktops of bed tables affects users' feeling of comfort while working with bed tables.

2 Method

A simulation experiment was designed to test how tilt angles affect users' comfort. The experiment simulated users' working scenarios with a bed table to test participants' feelings of comfort about working in front of a bed table.

2.1 Participants

12 participants aged between 18 to 24 (height 157cm-180cm, including 5 females and 7 males) were invited to this experiment. All participants were university students, who are expected to

be exposed to sitting in front of a computer and working for a large proportion of daily life, and are the main users of bed tables. All of the subjects provided informed consent and had no reports of previous or current low back pain in the past 6 months.

2.2 Experimental design

2.2.1 Independent variable

As is shown in Fig.1, the independent variable in this experiment was the tilt angle of desktop of the bed table. The bed table from brand SaiJing was chosen, the desktop angle of which can be switched to 15°and 30° and 3 tilt angles were test in this experiment. They were 0°, 15 ° and 30 °, respectively. 3 different bed table working conditions, of which participants would evaluate the comfort level, were formed, according to the 3 tilt angles. The conditions were named condition 1, condition 2 and condition 3, which indicated angle 0°, angle 15° and angle 30°, respectively. See Fig.2 for the 3 conditions.

2.2.2 Dependent variable

According to the goal of this research, the dependent variable of this experiment was user's feeling of comfort while working in front of a bed table, which was quantified through both subjective factor and objective factor.

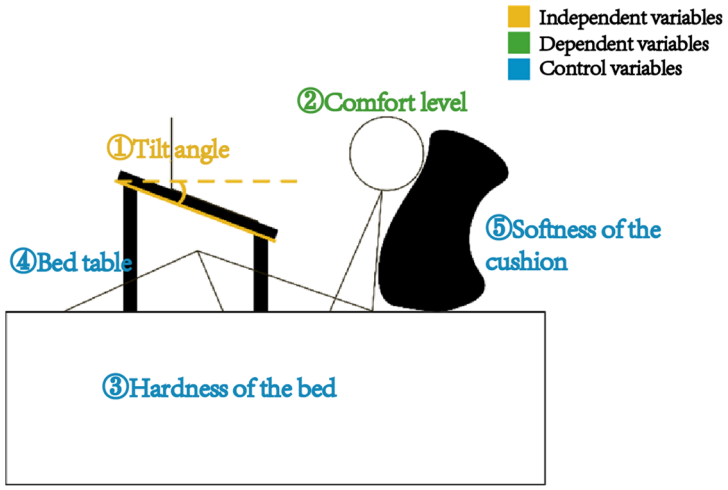


Fig. 1. Summary of experiment variables

2.2.2.1 Subjective factor

The subjective factor indicated participants' personal feelings of the comfort while working with a bed table. To quantify participants' subjective feelings, a questionnaire was designed, in which the participants were asked to rate the comfort level of conditions described in 1) Independent variable. The comfort level of participants' bodies was divided into 4 parts, neck part, upper back part, waist part and buttock part to make the questions more detailed. The

participants can score the comfort level from 1 to 9 for the 4 body parts. Scores over 5 represented feeling 'comfortable' and scores under 5 indicated feeling 'uncomfortable'. 9 indicated the highest comfort and 1 meant the lowest comfort level.

2.2.2.2 Objective factor

As for the objective factor, spinal angle was chosen to show participants' objective comfort level while working in different bed table conditions.

According to Chen et al.'s research [11], the angles of joint parts on human bodies can indicate the force joint parts got, that is, the larger the angles were, the larger forces joint parts got, which might cause more discomforts of bodies. Based on this theory, the angles of participants' spins were measured to represent the objective comfort level of participants. Taking reference from the research of Claus et al. [3], the author identified 5 points named T1, T5, T10, L3 and S2, respectively. 5 markers were sticked on participants' bodies to mark the 5 points, as is shown in Fig.3 (a). And as is shown in Fig.3 (b), 3 angles were formed through connecting these 5 points, which were named angle1: Thoracic angle, angle2: Thoraco-lumbar angle and angle3: Lumbar angle, respectively, according to Claus et al. [3]. To make sure these angles were recorded accurately, all participants were required to wear straitjackets during the experiment. Besides, participants with long hair were required to coil up their hair or wear a hat to avoid the neck part being obscured.

2.2.3 Control variables

As is shown in Fig.1, the bed table, the hardness of the bed and the softness of the cushion were kept same in all the 3 conditions in this experiment to reduce deviations of the results caused by environment factors. And the distance from bed table's desktop to user's body was kept as 10cm. In this experiment, all the 12 participants finished some type-writing tasks in a same room, which assured that all the other factors except independent variable were same.

2.3 Procedure

Before the experiment, all the participants were given 10 minutes to get used to the SaiJing bed table. After finishing the hardware test, the experiment began. All the participants were asked to do both a 6-minute type-writing task in each condition. Between 2 adjacent type-writing tasks, participants were given a 3-minute rest to answer a questionnaire to evaluate the comfort level of the previous condition, recover from the fatigue of the previous task and get ready for the next task. Participants needed to finish the same type-writing task in all the 3 conditions. See Fig.4 for the flow chart of the experiment procedure. The condition order for each participant was random.

Fig. 2. Summary of the 6 conditions

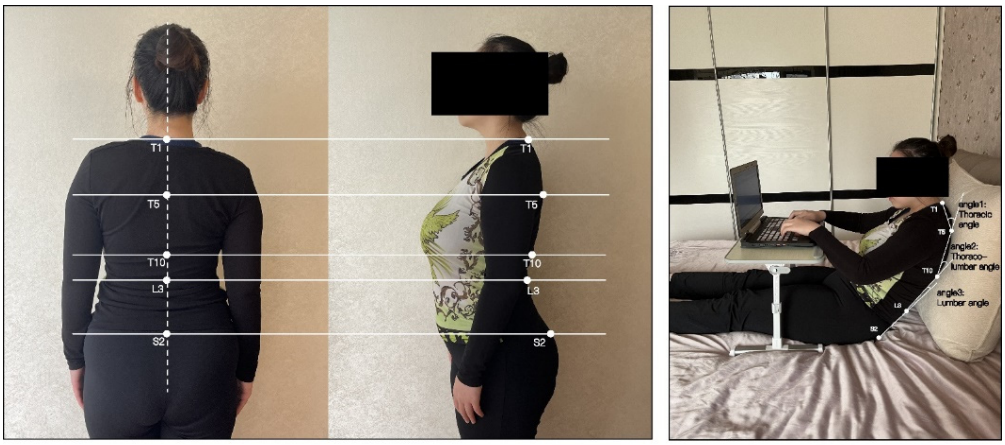


Fig. 3. 5 points identified on participant's body (a) and the 3 angles to be measured (b)

Fig. 4. Experiment Procedure

2.4 Data analysis

SPSS was used to analyze the data collected through the experiment process. Firstly, to select an appropriate analysis method, the normality of the data was test. As the sample size of this experiment was small, Quantile-quantile plot was used and according to Quantile-quantile plot, the data was confirmed to have normality. Then, analyses of different parameters were described in detail below, respectively.

2.4.1 Subjective score

To examine how tilt angles affected subjective comfort feeling, a One-way ANOVA analysis was operated. The analysis among condition 1, condition 2 and condition 3 was aimed to show how tilt angles affected comfort level.

2.4.2 Spinal angle

As is described in 1) Subjective score, in this section, One-way ANOVA was selected to analyze how spinal angles' sizes changed under different conditions, which would reflect the changes of comfort level with different tilt angles of desktop.

3 Results

The summary of statistically significant differences for the various measurements introduced in previous sections were shown in TABLE 1 ($\alpha = 0.05$). For subjective comfort feeling, tilt angles showed significance for scores of upper back part and waist part.

As for objective comfort level, the tilt angles showed significance for all the 3 spinal angles.

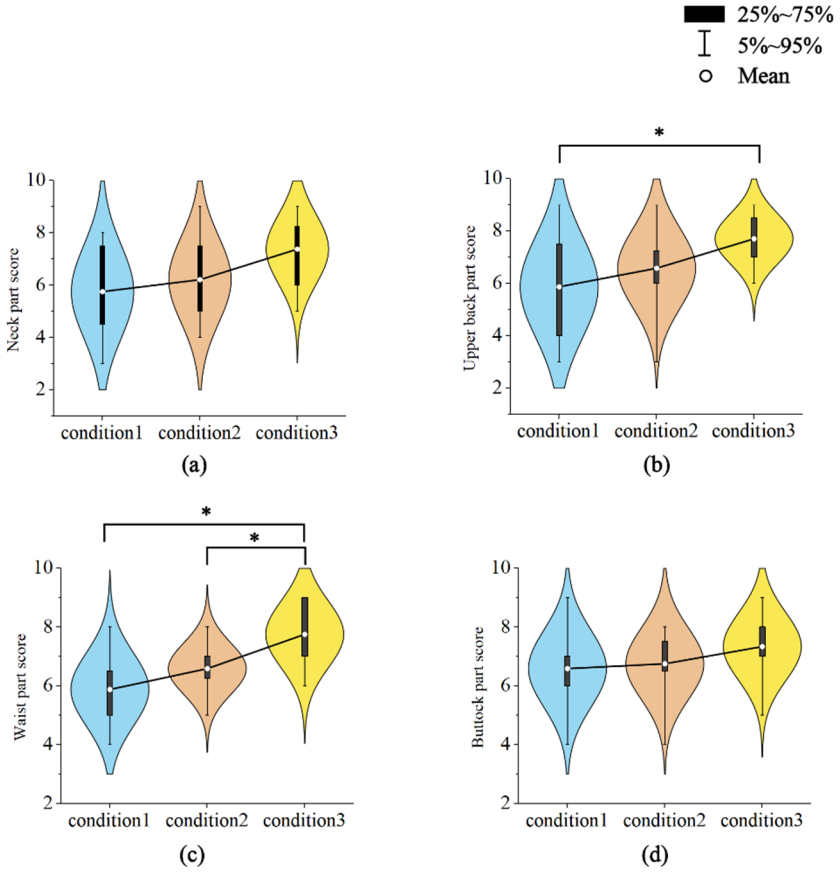
3.1 Subjective score

Tilt angles showed significance for upper back score and waist score. For upper back score, significance ($p < 0.05$) remained between the 0°group and the 30°group, and for waist score, significance ($p < 0.05$) remained between both the 0°group & the 30°group and the 15°group & the 30°group, according to in-group comparison results shown in TABLE 2.

According to Fig.5, scores went higher with larger tilt angles, which indicated that tilt angles had some influences on users' subjective comfort feelings and a larger tilt angle might provide users with more comfortable feelings.

3.2 Spinal angle

Tilt angles showed significance for all the 3 spinal angles. significance ($p < 0.05$) remained among 0°tilt angle, 15°tilt angle and 30°tilt angle for angle1: Thoracic angle. According to in-group comparison analysis, significance ($p < 0.05$) remained between 0°tilt angle and 30°tilt angle for angle2: Thoraco-lumbar angle and remained between 0°tilt angle & 30°tilt angle and 15°tilt angle & 30°tilt angle for angle3: Lumbar angle. See TABLE 3 for the results of in-group comparison. See Fig.6 for statistic figures of analysis for spinal angles.



* *p value* < 0.05

Fig. 5. Neck part scores (a), Upper back part scores (b), Waist part scores (c), Buttock scores (d)

Table 1. Summary of the statistically significant effects for the dependent measures

Dependent variables	Dependent measures	Tilt angle
Subjective comfort feeling	Subjective neck scores	
	Subjective upper back scores	*
	Subjective waist scores	*
	Subjective buttock scores	
Objective comfort level	Angle1: Thoracic angle	*
	Angle2: Thoraco-lumbar angle	*
	Angle3: Lumbar angle	*

*p＜0.05

Table 2. Summary of the results of in-group comparison for subjective scores among condition1, condition2 and condition3

Subjective scores	I	J	p
Neck part score	Condition1	Condition2	1.000
		Condition3	0.052
	Condition2	Condition1	1.000
		Condition3	0.245
	Condition3	Condition1	0.052
		Condition2	0.245
Upper back part score	Condition1	Condition2	0.790
		Condition3	0.018
	Condition2	Condition1	0.790
		Condition3	0.239
	Condition3	Condition1	0.018
		Condition2	0.239
Waist part score	Condition1	Condition2	0.370
		Condition3	0.001
	Condition2	Condition1	0.370
		Condition3	0.041
	Condition3	Condition1	0.001
		Condition2	0.041
Buttock part score	Condition1	Condition2	1.000
		Condition3	0.433
	Condition2	Condition1	1.000
		Condition3	0.760
	Condition3	Condition1	0.433
		Condition2	0.760

Table 3. Summary of the results of in-group comparison for spinal angles among condition1, condition2 and condition3

Spinal angles	I	J	p
	Condition1	Condition2	0.000
		Condition3	0.000
	Condition2	Condition1	0.000

Angle1: Thoracic angle		Condition3	0.000
	Condition3	Condition1	0.000
		Condition2	0.000
Angle2: Thoraco-lumbar angle	Condition1	Condition2	0.068
		Condition3	0.033
	Condition2	Condition1	0.068
		Condition3	0.737
	Condition3	Condition1	0.033
		Condition2	0.737
Angle3: Lumbar angle	Condition1	Condition2	0.283
		Condition3	0.000
	Condition2	Condition1	0.283
		Condition3	0.000
	Condition3	Condition1	0.000
		Condition2	0.000

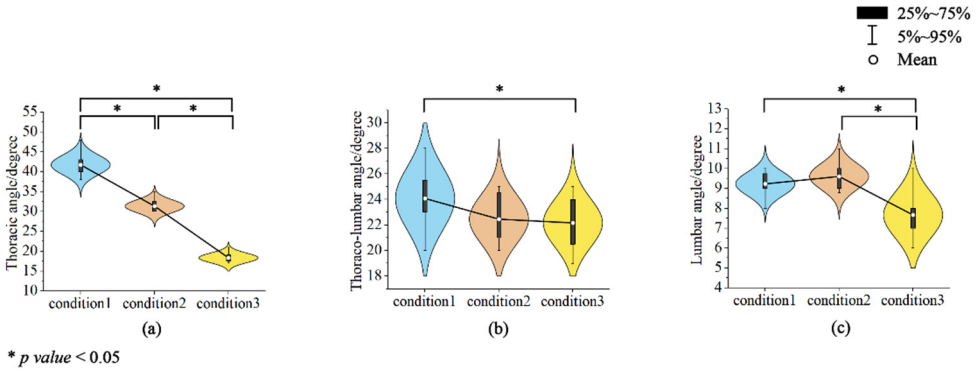


Fig. 6. Thoracic angle (a), Thoraco-lumbar angle (b), Lumbar angle (c)

4 Limitation

There were still some factors in this experiment that might cause deviation of the result.

Firstly, in this experiment, participants were asked to do type-writing tasks according to the content of a novel. However, the experimenter did not stipulate where to put the book, which led to the result that some participants put the novel on their legs and bowed their heads to read the content of the novel from time to time. As a result, these participants who put the book on

their legs might possibly feel more neck discomforts than other participants and these neck discomforts were not caused by the tilt angles of the bed desk.

Secondly, after the experiment, some participants reported that besides the 4 body parts concerned in the questionnaire, their forearms also felt tired, which might also be a comfort criteria of bed tables. However, in this research, forearm comfort level was not concerned. In the future research, forearm comfort level might be added and it will possibly be considered during the further bed table design process.

Finally, in this study, only 3 tilt angles were test and it was found that the 30°tilt angle can provide users with the highest comfort level among the three. However, it cannot be concluded that 30°was the best tilt angle for desktop of bed tables. In further studies, more tilt angles needed to be test to find out the best tilt angle while working with bed tables and applied these findings into future design processes of bed tables.

5 Conclusion

According to the results of the experiment, 30°tilt angle had greatest level for both physical comfort and subjective comfort feelings among the 3 tilt angles. Synthesizing both physical and subjective results, the 30°tilt angle was found to have obvious influence on comfort level. Among the 4 body parts listed for subjective scores, upper back part and waist part were more likely to be influenced by changes of tilt angles, while buttock got almost same scores with different tilt angles, which was understandable as buttock parts seldom moved while working with bed desks. And tilt angle also showed no significance for neck part, which may because some participants bowed their heads to read the contents of the type-writing tasks and provided low neck part scores due to the discomfort resulted by bowing heads frequently, as is mentioned in the previous section. In the future experiments, the experimenter should stipulate where to put the book for type-writing tasks. And the 30°tilt angle had significant comfort influences for all the 3 spinal angles, while the 15°tilt angle only showed significance for spinal angle1: Thoracic angle, among all the 3 objective spinal angles and the 4 subjective body part scores.

Therefore, this result indicated that a 30°tilt angle can improve comfort feelings to some extent, while working with a bed table.

These conclusions might provide some tilt angle selecting suggestions for users while working with bed tables. Also, these results can provide designers with some references for the design of bed tables.

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