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Relationship between mattress technological features and sleep quality: an actigraphic study of healthy participants

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The introduction of new mattresses with innovative technology has led to a significant improvement in objective sleep quality. We aimed to explore whether this improvement in sleep quality was merely due to the introduction of a new mattress regardless of the innovative level of its technological features. Twenty-eight healthy volunteers tested a standard technology mattress (traditional spring mattress) and a new technology mattress in expanded polyurethane and visco-elastic (Myform[®]). Sleep quality was assessed before and after introducing the new mattresses, objectively (through actigraphy) and subjectively (through the Mini Sleep Questionnaire). Myform[®] led to a significant improvement in actigraphic sleep parameters of sleep onset latency and sleep efficiency. Therefore it is not enough to introduce a new mattress with any technology in order to determine a significant objective sleep quality improvement; the innovative technological features of the mattress seem to be fundamental.

Keywords: actigraphy; mattress; sleep quality; technological features; healthy participants

Introduction

Over the years the bedding industry has developed different technological solutions in mattress manufacture. The first mattresses were produced with cotton, silk and wool. Afterwards springs became the main component of mattresses. Recently independent springs and foams of latex, polyurethane and visco-elastic have been introduced in the mattress production process. The introduction of new component materials such as independent springs, latex, polyurethane and visco-elastic has led to an increase in mattress cost, but at the present moment it is not known whether these materials can improve sleep quality.

In spite of the importance of sleep for quality of life (Kyle et al. 2010), and the fact that we spend about one-third of our lives sleeping on a mattress, few studies have explored the effect of mattress on sleep quality in normal sleepers. As regards healthy participants, some studies have highlighted that the mattress is not able to modulate sleep quality (Suckling et al. 1957; Rosekind et al. 1976; Okamoto et al. 1997; Scharf et al. 1997; Okamoto et al. 1998; Bader and Engdal 2000). On the contrary, other papers have shown that certain mattresses could lead to a better sleep

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quality in healthy people (Jacobson et al. 2006; Lee and Park 2006; Jacobson et al. 2008; Jacobson et al. 2009; Tonetti et al. forthcoming). The results of these studies are hardly comparable because different types of mattress were examined and different tools were used in order to determine the effect of the mattress on sleep quality: polysomnography (PSG) (Suckling et al. 1957; Rosekind et al. 1976; Okamoto et al. 1997; Scharf et al. 1997; Okamoto et al. 1998; Bader and Engdal 2000; Lee and Park 2006), actigraphy (Tonetti et al. forthcoming) and questionnaires (Jacobson et al. 2006, 2008, 2009).

A recent study (Tonetti et al. forthcoming) has shown that both new latex and independent spring mattresses with innovative technological features led to an objective sleep quality improvement in healthy participants, but left open the following question: was sleep quality improvement merely due to the introduction of a new mattress regardless of the innovative level of its technological features? So, the present study aimed to address the following question: with the aim of improving sleep quality, is a high investment in a mattress with new technology necessary or is it enough to purchase a standard technology mattress at a lower cost? To this end, effects on sleep quality of new mattresses with different technological characteristics were assessed in the same group of healthy participants: a traditional spring mattress (standard technology) and a mattress in expanded polyurethane and visco-elastic (Myform[®]) (new technology).

Methods

Participants

The participants were 28 healthy volunteers (14 males and 14 females) (mean age \pm SD, 41.75 \pm 10.23; age range: 30–71 years). Each participant involved in the research project provided informed consent. At the end of the research, the volunteers were given their preferred mattress from those that they had tested in return for their participation. None worked flexi-time or night shifts. Exclusion criteria included sleep disorders, serious or acute illness, use of psychopharmaceutical drugs, disabilities which would interfere or restrict mobility and high intake of any stimulating beverages, as caffeine, theine and nicotine.

To this end, volunteers were interviewed by a trained researcher in order to assess whether or not they met the exclusion criteria stated above. Moreover, during the interview they filled out the Sleep Disorders Questionnaire (Violani et al. 2004). During the research, all participants slept alone and were asked to keep their usual sleep-wake rhythms.

Actigraphs

We used the Basic Mini-Motionlogger[®] (MML) actigraphs (Ambulatory Monitoring, Inc., Adrsley, NY), whose sleep measure in healthy participants is naturalistic and similar to that of PSG (Tonetti et al. 2008). The hardware of the actigraph consists of a piezoelectric accelerometer with a sensitivity of ≥ 0.01 . The sampling frequency is 10 Hz and filters are set to 2–3 Hz. The actigraphs were initialised for zero crossing with a one-minute epoch sampling. MML data files were analysed by Action W-2[®] version 3.23 software (Ambulatory Monitoring, Inc., Adrsley, NY).

Action W-2[®] version 3.23 software identified each epoch as sleep or wake using the mathematical model validated by Cole and Kripke (1988) and Cole et al. (1992).

This algorithm computed a weighted sum of the activity in the current epoch, the preceding four epochs, and the following two epochs as follows: $S = 0.0033(1.06a_n4 + 0.54a_n3 + 0.58a_n2 + 0.76a_n1 + 2.3a_0 + 0.74a_1 + 0.67a_2)$; where from a_n4 to a_n1 were the activity counts from the preceding 4 min, and a_1 and a_2 referred to the following two min. The current minute was scored as sleep when $S < 1$. Actigraphs had a mark-event button that participants were requested to push to signal bedtime and get-up time.

Actigraphic measures

Sleep was assessed using the following sleep measures. Time in bed (TIB) was the interval, in minutes, between bedtime and get-up time. Sleep onset latency (SOL) was the interval, in minutes, between bedtime and sleep start. Total sleep time (TST) was the sum, in minutes, of all sleep epochs between sleep onset and sleep end. The nighttime awakenings lasting more than five min ($NA > 5$) were calculated too. Nocturnal mean motor activity (MA) was the mean number of nocturnal movements in a one-min epoch. Sleep efficiency (SE, %) was the ratio of the total sleep time to time in bed multiplied by 100. Wake after sleep onset (WASO) was the sum (in minutes) of all wake epochs between sleep onset and sleep end.

Subjective measures

Participants were asked to complete the Mini Sleep Questionnaire (MSQ) (Zomer et al. 1985; Fabbri et al. 2006) to subjectively evaluate sleep quality. This questionnaire is composed of 10 items on a 7-point Likert scale (1 means always, 7 means never), referring to the past week. MSQ measures the quality of sleep and also the quality of wake, comprising two main factors: sleep and wake. For example, an item included in the sleep factor was “Did you experience any nighttime awakenings?”, while one question belonging to the wake factor was “After morning awakening, did you experience a headache?”. Higher scores on these two factors correspond to a higher quality of sleep and wake.

Participants filled out the Hassles Scale (HS) (DeLongis et al. 1982; Farnè et al. 1990) to evaluate the severity of some stressful events occurring during the recording weeks. This tool includes 53 items on a 3-point Likert scale (1 corresponds to mild, 3 corresponds to severe), with reference to the past week. For example, one item of the HS was the following: “Parking problems”. Higher scores mean higher perceived stress. This questionnaire was used to check that sleep effects were due only to the new mattresses tested and not to daily stressful events. During the recording periods, participants were requested to fill out a sleep log everyday within 30 minutes of the last morning awakenings.

Mattresses and bed base

Two new mattresses with different technological features were tested: a traditional spring mattress (standard technology) and a mattress in polyurethane and visco-elastic (Myform[®]) (new technology). Both types of mattress were firm. With regard to the traditional spring mattress, its height was 23 cm and had a box system with 400 springs, while Myform[®] had a height of 22 cm and was composed of a foam of polyurethane and visco-elastic. The traditional spring mattress had a weight of 10 kg/m², while

Myform[®] had a weight of 12 kg/m². Myform[®] had seven differential lift zones, while the traditional spring mattress had none. The size of the new mattress was the same as that of the mattress that each participant had slept on originally. Moreover, to ensure that participants could sleep in similar conditions, a new wooden slatted bed base was introduced, which had 28 compressed slats in beechwood.

Procedure

Each individual was requested to participate for six consecutive weeks. All participants took part in three weeks of actigraphic and subjective recordings (baseline and two experimental weeks) at their home. Each recording period was preceded by an adaptation week to the new wooden slatted bed base (first adaptation week) and to the new mattresses (second and third adaptation weeks) (Figure 1). Participants tested both of the new mattresses in a balanced order: one half tested the traditional spring mattress first and the other half started with the Myform[®] mattress. During the adaptation weeks no actigraphic or subjective recordings were taken. In each recording week, participants wore MML actigraph on their non-dominant wrist and at the end of these weeks, they filled out the questionnaires described above.

Using event-marker points, an experienced scorer correctly set the time spent in bed (the interval between light-off and light-on). If participants forgot to push the event-marker button, the scorer referred to the sleep log information. If both kinds of

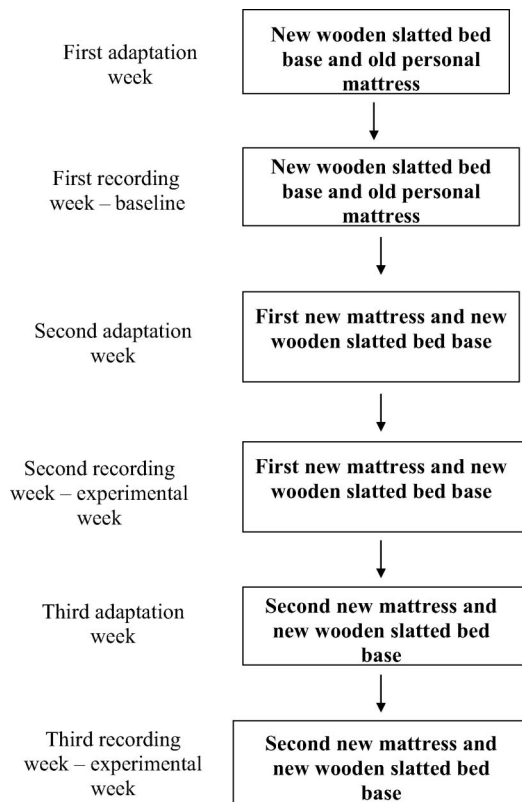


Figure 1. Graphical representation of the experimental procedure.

information were lacking, therefore the night was not counted; this situation happened only twice. Participants were not aware of the goal of our research and thus they did not know that the mattresses they were testing had technological characteristics of different innovation and also that they were extremely different in cost.

Data analysis

Aiming to detect the possible order effect, we have performed an ANOVA with repeated measures comparing the mean values of the first (baseline) with those of the second and third recording weeks regardless of the mattress types used. Moreover we carried out a repeated measures ANOVA, with a within factor at three levels: old mattress, traditional spring mattress and Myform[®] mattress. If ANOVA gave significant results, Scheffè post-hoc test was performed. The significant level was set at $p < 0.05$.

Results

Actigraphic data

Testing the possible order effect, for each actigraphic sleep parameter no significant differences have been observed between the first (baseline) and the second and third recording weeks regardless of the mattress types used. Data referring to the comparison between old, traditional spring and Myform[®] mattresses are described below. As shown in Table 1, with regard to TST and $NA > 5$, the new mattresses and the old one were not significantly different. As regards TIB, the three mattresses differed significantly ($F_{2,54} = 4.34$; $p < 0.05$). At post-hoc, Myform[®]-TIB resulted lower than traditional spring mattress-TIB ($p < 0.05$).

Regarding to SOL, repeated measures ANOVA showed significant differences between the old mattress and the new ones ($F_{2,54} = 9.39$; $p < 0.001$). Performing post-hoc comparisons, Myform[®]-SOL resulted significantly lower than old mattress-SOL ($p < 0.05$) and traditional spring mattress-SOL ($p < 0.0005$).

Table 1. Actigraphic and subjective measures (means and SD) for old mattress, traditional spring mattress and Myform[®] mattress.

Actigraphic and subjective measures	Old mattress	Traditional spring	Myform [®]
TIB*	476.32 ± 45.58	482.41 ± 40.23	457.24 ± 52.47
SOL****	7.13 ± 2.07	7.85 ± 2.50	5.52 ± 2.70↑
TST	438.43 ± 49.62	440.79 ± 39.39	429.11 ± 52.11
NA > 5	3.53 ± 2.70	3.88 ± 4.04	3.40 ± 5.33
MA***	11.89 ± 5.46	12.86 ± 6.39	9.63 ± 5.47
SE (%)***	92.00 ± 4.54	91.45 ± 4.86	93.91 ± 4.59↑
WASO**	30.77 ± 21.79	33.78 ± 25.35	22.61 ± 22.44
MSQ sleep factor	33.79 ± 6.79	33.49 ± 5.76	34.69 ± 4.41
MSQ wake factor*	23.26 ± 4.27	21.93 ± 4.75	23.56 ± 4.12
HS	27.96 ± 21.70	28.82 ± 21.27	25.32 ± 15.74

TIB refers to time in bed (min); SOL, sleep onset latency (min); TST, total sleep time (min); $NA > 5$, mean number of nighttime awakenings lasting more than 5 min; MA, mean number of nocturnal movements in 1-min epoch; SE, sleep efficiency (%); WASO, wake after sleep onset (min). MSQ refers to Mini Sleep Questionnaire; HS, Hassles Scale. * $P < 0.05$; ** $P < 0.005$; *** $P < 0.01$; **** $P < 0.001$; † indicates an improvement of the actigraphic measure in comparison to old mattress.

With regard to MA, the three mattresses differed significantly ($F_{2,54} = 6.00$; $p < 0.01$). At post-hoc, Myform[®]-MA was significantly lower than traditional spring mattress-MA ($p < 0.01$).

Regarding SE, ANOVA gave a significant result ($F_{2,54} = 7.17$; $p < 0.01$). Performing post-hoc comparisons, Myform[®]-SE resulted significantly higher than old mattress-SE ($p < 0.05$) and traditional spring mattress-SE ($p < 0.005$). As regards WASO, ANOVA showed significant differences between three mattresses ($F_{2,54} = 6.10$; $p < 0.005$). At post-hoc, Myform[®]-WASO resulted significantly lower than traditional spring mattress-WASO ($p < 0.01$) and tended to differ from old mattress-WASO ($p = 0.06$).

Subjective data

Controlling for the possible effect of sequence of mattresses, the MSQ and HS data were not significantly different between the first (baseline), second and third recording weeks (regardless of the types of mattresses tested). The MSQ sleep factor scores were not significantly different between the old and new mattresses, contrary to the MSQ wake factor scores ($F_{2,54} = 3.30$; $p < 0.05$) (Table 1). Performing post-hoc comparisons, Myform[®]-MSQ wake factor tended to differ from traditional spring mattress-MSQ wake factor ($p = 0.06$). HS scores did not differ significantly between personal and new mattresses (Table 1).

Discussion

Only the introduction of Myform[®] resulted in an improvement of objective sleep quality compared to the old mattress. Specifically, a decrease was observed in the sleep onset latency leading to an increase in sleep efficiency with Myform[®] compared to the old mattress. On the contrary, no significant differences in actigraphic sleep measures were detected between the personal and new traditional spring mattresses. The sleep quantity (total sleep time) did not change significantly during the three recording weeks and for this reason we are able to conclude that the objective sleep quality (sleep onset latency and sleep efficiency) improved with the new technology mattress – Myform[®].

Participants spent less time in bed with Myform[®] in comparison to the traditional spring mattress. However they capitalised at best this time to sleep, since Myform[®]-sleep efficiency is higher than that of the traditional spring mattress. These data may be interpreted as a further support to the improving of sleep quality with the Myform[®] mattress. As far as perceived sleep quality was concerned, no significant differences were detected between the old and each of the new mattresses in MSQ sleep factor. The quality of wake with Myform[®] tended to be higher than that of the traditional spring mattress, but no improvement has been observed in comparison to the old mattress. These data are partially in agreement with those of a previous study (Tonetti et al. forthcoming) that did not show any significant change in MSQ sleep and wake factor scores between personal and new mattresses of new technology. The lack of significant improvement in subjective sleep quality could be due to a possible ceiling effect. In fact we selected good sleepers, and the baseline mean values of sleep and wake factors of our healthy participants were higher than those of an Italian sample of similar age (mean sleep factor score: 27.39 ± 5.08 ; mean wake factor score: 20.89 ± 4.23) (Fabbri et al. 2006). Another possible

explanation is that perceived sleep quality improvement needs a longer time to emerge than objective sleep quality. It could be interesting to test the effect of a new technology mattress on sleep quality in poor sleepers, aiming to detect if their sleep quality improves also from a subjective point of view.

Considering that during the three weeks of recording the perceived severity of stressful events did not change significantly (as assessed by HS), it is therefore possible that sleep changes could really be due to the new mattress Myform[®], because this was the only variable introduced during the study. The present results, and those previously published (Tonetti et al. forthcoming), provide an answer to the fundamental question of this study regarding the relationship between new mattress technology and sleep quality improvement. It is not enough to introduce a new mattress of any technology; a new mattress with innovative technological features is necessary in order to achieve a significant improvement in sleep quality. This argument is strengthened since we were able to show that the sequence of mattresses tested was without effect. The results are particularly relevant because an objective sleep quality improvement was detected in healthy participants who had already shown a good sleep quality in the baseline session (Natale et al. 2009).

The main reasons underlying the significant differences in results between standard and new technology mattresses could be related to their component materials. Specifically visco-elastic is thermo-variable and thus it is able to adjust itself to the human body. This feature could contribute towards an increase in the ergonomic level of Myform[®]. On the contrary, traditional springs do not interact with the human body. Moreover the use of Myform[®] could have led to a decrease in body movements since visco-elastic reacts to body heat and models itself on the basis of human features. In contrast, traditional springs tend not to absorb body movements, rather, movements are increased, and thus traditional spring mattresses are not able to decrease mean nocturnal motor activity.

A limitation of the present study is that we did not take into account the anthropometric features of participants (for example, body mass index). The sleeping system comprises not only the mattress, bed base and pillow, but also includes these human features that can determine a better or worse adjustment to the new mattress. Thus future studies should also test the influence of these characteristics. Since the mattress seems able to influence sleep quality and represents one element of the sleeping system, further investigations are required relating to other parts of that system and, more in general, to other components of the bedroom that may affect sleep.

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