Effect of napping on a bean bag chair on sleep stage, muscle activity, and heart rate variability

Masaki Nishida (✉ nishida@waseda.jp)

Waseda University

Atsushi Ichinose

Waseda University

Yusuke Murata

Waseda University

Kohei Shioda

Waseda University

Research Article

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Abstract

Although ample evidence has demonstrated that daytime napping is beneficial for health and cognitive performance, bedding for napping has not yet been scientifically investigated. In this study, we assessed the effect of a bean bag chair (BC), which would automatically adjust according to body shape and size, on daytime napping and physiological parameters related to sleep, such as electroencephalogram (EEG), electromyogram (EMG), and heart rate variability (HRV). Fourteen healthy participants were enrolled within the context of a randomized, single-blind, crossover study to evaluate the effects of a BC in comparison with those of a urethane chair manufactured to have a similar shape (UR). EEG analyses revealed no significant differences in sleep architecture or frequency components; however, a significant decrease was found in EMG recordings in the trapezius muscle, which represents the neck region ($p = 0.024$). Additionally, a significant main effect of bedding in the LF/RF ratio ($F [1, 20] = 4.314, p = 0.037$) was revealed. These results suggest that napping with a BC may provide a comfortable napping environment involving muscle relaxation and proper regulation of autonomic nervous function.

Introduction

The importance of napping during the day has been demonstrated in recent years. Previous research demonstrated a positive association between an appropriate nap and the prevention of cardiovascular disease [1], type-2 diabetes [2], and global health as reflected in human longevity [3]. Napping also helps mitigate homeostatic sleep drive, consequently improving subsequent extensive performance, such as memory [4], emotion [5], and physical performance [6]. For shift workers, scheduling naps is a critical issue from a labor management perspective [7, 8]. It has been commonly accepted that daytime napping is useful for human health and performance, as well as counteracting excessive daytime sleepiness.

Several studies have demonstrated that the overall beneficial effects of napping can be obtained even after a short nap of under 30 minutes. Naps exceeding 30 minutes during the daytime facilitate deep sleep in the form of slow-wave sleep [9], thereby prolonging sleep onset latency in subsequent nighttime sleep [10]. Moreover, waking up from slow-wave sleep causes sleep inertia, reflecting temporary sleepiness, decreased alertness, and impaired performance upon awakening [11]. There is a general agreement that short midday napping offers a variety of benefits, encompassing cognitive and executive performance.

Sleep, including daytime napping, is sensitive to the environment, including the bedding and mattress used. An inappropriate sleep environment results in difficulty falling asleep and affects nap quality and recovery from fatigue, and subsequent sleepiness [7, 12]. Several studies have scientifically assessed the effect of bedding on nocturnal sleep and physiological variables during sleep [13–15]: a few studies have demonstrated the relationship between suitable napping and associated environmental factors. Zhao et al. showed that napping in a chair with the trunk tilted forward 45 degrees and the head resting on a special pillow was not significantly different from a nap in a bed in terms of objective sleep variables; however, compared with those with no nap, subjective sleepiness and fatigue improved in both the chair and bed [16]. Roach et al. demonstrated that the quantity and quality of sleep obtained in a reclined position were similar to those obtained when resting in a flat seat; unlike the upright posture, reclined positions diminish psychological arousal through autonomic nerve regulation [17]. Previous studies on bedding for napping have focused on the chair angle, without sufficient consideration of materials.

A bean bag chair (BC) consists of a polystyrene bead filling inside a bag; it is transformed into a supportive chair thanks to an expert ergonomic design. In light of previous studies that have shown that reclining chairs provide an advisable napping environment [16, 17], BCs are likely to provide appropriate napping conditions with a comfortable reclining posture, enabling the proper regulation of the sympathetic nervous system to ensure the beneficial effects of napping.

In this study, we assessed the effects of a BC on nap propensity, as reflected by physiological indices, and compared the findings with those for a traditional sofa-type chair manufactured with urethane (UR chair). The experiment was carried out according to a randomized single-blind crossover design. The assessments of napping on each chair were based on sleep polysomnography (PSG), alongside continuous electroencephalograms (EEG), electrooculograms (EOG), and electromyograms (EMG). Between-napping assessments of subjective sleepiness (Karolinska sleepiness scale [KSS]) and sleep quality (questionnaires and visual analog scale [VAS] for the sleep status) were administered. We evaluated surface muscle activities during naps attached to the cervical and lateral abdominal region. In addition, heart rate variability (HRV) was calculated both before and during napping to evaluate autonomic nervous function. We hypothesized that (1) a BC subjectively improves the quality of napping, (2) preferentially regulates nap propensities as measured by EEG, (3) relieves the tension level of surface muscles activity, and (4) helps modulate autonomic nervous function to provide proper cognitive and physical recovery.

Results

Sleep and related parameters: EEG analysis

Sleep variables from assessments the night prior demonstrated no statistical difference between two bedding opportunities, showing similar results in each condition of the study (Table 1). The EEG data of one participant were unamenable to analyses because of poor recording as a result of unstable electrode placement. Table 2 presents sleep variables during napping, alongside nap-related parameters. With regard to sleep architecture, no significant differences were found between the two bedding conditions. Seven and six participants demonstrated N3 stage sleep in the BC and

UR conditions, respectively. Three participants demonstrated rapid eye movement (REM) sleep in both conditions. A spectral EEG analysis during each sleep stage showed no significant differences in any frequency band between the two bedding conditions. In addition, a critical flicker–fusion frequency (CFF) revealed no significant difference between the two bedding conditions (Supplementary Table S1).

EMG analysis during napping

Figure 1 shows the difference in surface EMG activity during sleep in each designated muscle alongside the grand average of two muscles. The EMG data of three participants were excluded from the study owing to poor EMG recording. The trapezius muscle demonstrated significantly lower EMG activity in the BC condition than in the UR condition ($t = -2.276$, $df = 10$, $p = 0.046$). The external oblique muscle did not yield a significant difference in EMG activity between the BC and UR conditions ($t = -1.493$, $df = 10$, $p = 0.166$). The grand average EMG activity in the BC condition was lower than that in the UR condition, although the difference was not statistically significant ($t = -2.807$, $df = 10$, $p = 0.063$).

HRV analysis during napping and pre-nap wakefulness

Table 3 shows the HRV variables for each bedding condition between pre-nap wakefulness and non-rapid eye movement (NREM) sleep during the nap experiment. Similar to the EMG recordings, the HRV data of three participants were excluded from the study owing to poor recording. The panels of Figure 2 (one panel for each HRV variable) demonstrate the average values for each bedding condition recorded in pre-nap wakefulness and NREM sleep during napping. For all variables, there were no significant interactions between bedding condition and level of awareness. We found a significant main effect of alertness for LF/HF ($F[1, 20] = 4.314$, $p = 0.037$, $\eta^2 = 0.375$), representing a lower LF/HF value in the BC condition than in the UR condition. There were no significant main effects in other HRV-related variables associated with the level of alertness.

Discussion

In this study, we evaluated whether a BC would improve physiological indices during napping, relative to those observed during napping in UR bedding. Although sleep architecture and spectral analysis variables showed no significant difference between the two bedding conditions, significantly mitigated muscle activity, especially in the trapezius muscle, was observed in the BC condition relative to that in the UR condition. In addition, the LF/HF ratio during sleep in the BC condition was decreased relative to that during sleep in the UR condition; this indicates that a BC helps reduce the sympathetic tone of the autonomic nervous function during napping.

One of the most notable results linked to a BC was a remarkable decreased activity of the trapezius muscle, which is a large triangular muscle extending from the cervical region to the width of the shoulders. The trapezius is supposed to stabilize the shoulder blades and facilitate shoulder and neck movements [18]. Previous reports have demonstrated that the middle trapezius muscle demonstrates the greatest activation when an individual is laying on their side with a pillow of the least comfortable height [19]. Moreover, the use of uncomfortable pillows with increased neck tension results in regular waking and poor sleep quality [20]. In contrast, a less significant decrease in muscle activity in the abdominal oblique muscle governs ipsilateral side-bending and contralateral rotation of the lower trunk. As such, a BC has the potential to provide a napping posture that reduces the muscular load on the neck, possibly preventing neck pain, poor neck mobility, and stiff shoulder, a measure of overall autonomic activity levels.

Among HRV variables, a significant main effect of bedding was observed for LF/HF ratio in the BC compared with that in UR bedding conditions, thereby indicating that napping in a BC is associated with a decreased LF/HF ratio. Previous studies have demonstrated that sympathetic activity decreases during NREM sleep, especially deep sleep classified as N3 stage [21–23]. In contrast, we detected no significant main effect of alertness; however, our results elucidated that the BC condition has the potential to provide suitable napping conditions for recovery, modulating the LF/HF ratio, which is thought to reflect the magnitude of psychosomatic stress [24, 25]. It remains controversial but commonly known that the LF/HF ratio reflects sympathovagal balance, whereby increases in LF/HF are assumed to reflect a shift in “sympathetic dominance,” while decreases in this index correspond to a “parasympathetic dominance.” A significant decrease in sympathetic balance with BC use may be attributed to a reduction in the cervical muscle load, adjusting an automatically suitable posture during napping by means of elasticity. Inappropriate cervical tension appears to lead to increased autonomic nervous activity as reflected in the LF/HF ratio [26, 27], suggesting that the diminished muscle tone, especially in the neck region, owing to BC bedding is beneficial for proper regulation of autonomic function for napping.

In contrast to the decrease in EMG activity and HRV changes, effects of a BC on sleep stages were not detected. As this study was limited to a short nap experiment not encompassing a whole night’s sleep, significant differences in sleep architecture were difficult to obtain for each bedding condition. Even previous studies exploring the effect of high resistance bedding on all-night sleep revealed no statistical differences in sleep architecture, only an increase in delta power in the first cycle of non-REM sleep [15]. Moreover, admitting that napping is a style of incomplete sleep, represented by the fact that most participants showed no signs of slow-wave sleep or REM sleep, the lack of significant differences in the quantitative frequency analysis is quite consistent with sleep propensities.

This study has several limitations. First, the number of enrolled participants was relatively small; larger numbers are required to detect more significant sleep effects. Additionally, sex differences are not evenly distributed, raising the question of potentially uncontrolled for alterations in sympathovagal activity due to hormonal imbalances associated with the menstrual cycle [28]. Second, sleep scoring was performed based on a single EEG derivation instead of conventional polysomnography. Nevertheless, the same EEG expert completed the final confirmation visually, ensuring the validity of the sleep structure and quantitative EEG analysis. Third, the study was designed as single-blind; even if experimental participants did not notice the bedding chair they were using, they may have been able to identify whether the chair was a BC or UR. Furthermore, the study investigated the acute effect of the chair on napping opportunity. Studies are needed to evaluate the changes in physiological indices with the continuous use of BCs. Regardless of these limitations, our results point to the possibility that different types of bedding have a considerable effect on napping and its associated physiology. Further research is warranted considering the physiological and ergonomic aspects of a comfortable nap.

In conclusion, although the BC did not alter sleep propensities or frequency components, it may reduce muscle activity in the cervical region in association with the LF/HF ratio, reflective of sympathovagal activity in healthy adults. These alterations were reported to be effective in providing a comfortable napping situation for nappers in terms of psychosomatic aspects. Therefore, napping in a BC, which appears to improve autonomic parameters, is beneficial for a wide range of applications and strategies, encompassing psychosomatic relaxation, improving afternoon performance, and effective recovery for athletes.

Methods

Ethics statement

The research protocols were approved by the Academic Research Ethical Review Committee of Waseda University (IRB #2019 – 106) and the work was performed in accordance with the 1964 Declaration of Helsinki. Informed consent was obtained from all participants before participating in experiments.

Materials

Figure 3 shows the bedding and lying posture used in this study. For the BC condition, a BC filled with soft micro-beads was used (Yogibo Max®, Webshark inc., Osaka, Japan). For the UR condition, a urethane-based, polyethylene-surfaced cushion chair (LOWYA® Long seat chair, Vega Co., Fukuoka, Japan) was used. The chair sizes were quite similar (BC: 170 cm × 48 cm × 70 cm, UR: 172 cm × 56 cm × 75 cm), and the BC was 16% lighter than the UR (BC: 8.0 kg, UR: 11.5 kg). The chairs were installed in a quiet and dark shield room in the sleep laboratory of Waseda University, where the temperature was set at approximately 25.0°C and the light intensity level was adjusted to approximately 200 lux, as measured with a light meter.

Participants and setting

Fourteen healthy participants (22.4 ± 1.5 [SD] years old; male, $n = 12$) with normal sleep habits were enrolled. Participants were recruited through poster advertisements, social media, and emails to students of Waseda University. Participants were selected based on the absence of any prior diagnosis of pathological sleep disorders and their not having taken any medication and alcohol at the time of the experiments. Participants were asked to maintain regular bedtimes between 6 and 8 for 1 week before the laboratory experiment.

All participants were assessed using the Pittsburgh Sleep Quality Index (PSQI) for regular sleep quality and Morning-Eveningness Questionnaire (MEQ) for individual circadian chronotype. Subjective bedding preferences (SBP) were also assessed using VAS (higher scores = softer bedding preference). The mean values for the participants were BMI, 22.5 ± 1.8 , SBP, 4.7 ± 1.9 , PSQI, 5.9 ± 2.9 , and MEQ 43.3 ± 9.9 , respectively.

Study design

A randomized, single-blind crossover design was used to evaluate the effects of BC and UR at at least 1-week intervals. Participants entered the laboratory and were asked to rate their level of sleepiness based on the KSS before and after the nap. Participants reported subjective evaluation of sleep in VAS scores after taking a nap.

Participants were placed on the experimental equipment and requested to sit on the experimental chair for napping after the lights were switched off at 13:00. Participants were woken up as lights were turned back on at 14:00 by the examiner.

Actigraphy

To monitor sleep in the night preceding the experiment, participants were requested to wear an MTN-220 (Acos Co., Ltd., Nagano, Japan) on the front side of the trunk by clipping it to their waist belt or the edge of their trousers/pants. Recording started at 6 pm the preceding night and stopped at 8 am on the day of the experiment. The sensitivity and specificity of the MTN-220 were equivalent to those determined for conventional actigraphy [29] and polysomnography [30].

EEG and sleep stage scoring

EEG recordings were obtained during the nap using a portable recording system (Brainwave Sensor, ZA-X®, Proassist, Ltd., Osaka, Japan). This system consisted of a wireless transmitter and receiver, using a pair of bipolar EEG and EOG electrode leads connected to the transmitter. The signals were recorded at a sampling rate of 128 Hz with filters of 0.5–40 Hz for EEG and 0.5–10 Hz for EOG. To validate this system, previous studies reported that this portable device was considerably consistent with polysomnography (PSG) at each sleep stage [31].

Sleep stages were scored every 20 seconds by a clinical professional technologist according to the American Academy of Sleep Medicine (AASM) manual scoring rules [32].

EEG recordings during sleep were classified into 30-second intervals and brain waves were categorized as follows: delta (1.0–4.0 Hz), theta (4.0–8.0 Hz), alpha (8.0–12.0 Hz), and beta (16.0–35.0 Hz). Fast Fourier Transformation was performed to provide the mean spectral density on extracted intervals to assess the component of each frequency band.

Electromyography

Continuous EMG recording of body muscles during nap was carried out, minimizing the number of muscles attached to the channel to avoid disturbing sleep. Muscle activity of the bilateral trapezius muscle and the bilateral abdominal oblique external muscle were measured. Two EMG probes were positioned 2 cm apart on the bilateral external oblique muscle with Ag/AgCl electrodes. Both electrodes were placed around the center of a line drawn between the inferior borders of the 10th rib and pubis and on the muscle belly under the 10th rib. For the trapezius muscle, probes were placed 2 cm apart on the upper fibers of the trapezius, approximately 2 cm to the lateral inferior direction of the vertebra prominens (C7). Additionally, referenced probes were also placed at the left upper shoulder.

For the measurement of EMG signals, a multi-telemeter system (Polymate mini A108, Miyuki Giken, Co. Ltd., Tokyo) was employed. Raw EMG signals were sampled at 500 Hz, with a time constant of 0.01 s, and notch-filtered to erase the 50 Hz frequency interference. For the EMG amplification, the high cutoff filter was set to 300 Hz and the low cutoff filter to 30 Hz to exclude frequency relevant to respiratory and any heart- or motion-associated activity [33, 34].

To assess the activity of surface muscles in the EMG signal in the time domain, an integrated EMG (iEMG) was calculated. The integrated EMG is the mathematical integration of a rectified EMS signal, representing a method for numerical integration and numerical approximation of definite integrals [35]. Specifically, it is the following approximation:

$$Y = \int_a^b f(x) dx \approx \frac{b-a}{6} \left[f(a) + 4f\left(\frac{a+b}{2}\right) + f(b) \right]$$

In this formula, a and b are the unit spacing. F(a) and f(b) are the amplitudes of the EMG signal at a and b. Actually, the iEMG was computed as an approximation of the cumulative integral of the whole EMG signal amplitude during a 20-second period.

HRV

HRV was analyzed from continuous electrocardiogram recordings obtained at the Actiheart 5 monitors (Cambridge Neurotechnology, Cambridge, UK) used to record motility as well as heart interbeat interval data. These are flat and lightweight (10.5 g) wearable devices for which high levels of intra- and inter-instrument reliability, as well as good validity of measures, have been reported [36].

Participants were requested to attach the Actiheart monitor on the chest with a fastened belt during their nap. A 15-minute period of properly collected data during the sleep period were extracted for analysis by visually screening the raw data. Artifacts expressed as invalid data were also excluded from analysis according to the manufacturer's instruction manual.

In terms of frequency analysis, the integrated spectral power of the periodic components was calculated to quantify the total spectral power (TP; ≤ 0.4 Hz; ms^2) and the power in the low-frequency (LF; 0.04–0.15 Hz; ms^2) and high-frequency (HF; 0.15–0.4 Hz; ms^2) bands. However, the HF normalized units ($\text{HFnu} = \text{HF}/(\text{HF} + \text{LF}) \times 100$) and the LF/HF ratio were computed as an index thought to represent the sympathovagal balance. Furthermore, for the time domain analysis, the root mean square of successive differences (RMSSD) between adjacent R-R intervals was also calculated. We applied HFnu and RMSSD as indices for parasympathetic tone and LF/HF as indices for sympathovagal balance.

The evaluation of HRV variables was carried out to apply artifact-free windows of a 3-minute consecutive undisturbed duration. The HRV during sleep was extracted based on the sleep stages obtained on EEG recording. Sleep stages to be extracted were N1 and N2 only; N3 stage sleep was excluded because only some participants showed signs of N3 stage sleep. Additionally, a 3-min pre-nap window was analyzed as the wakefulness period (W). Epochs of N1 and wake after sleep onset were excluded from the analysis due to difficulty in isolating the recording as a result of instability.

Fatigue assessment

To assess the effects of napping on recovery from fatigue, a flicker test was conducted after napping. The flicker test was established to measure the flicker perception threshold, which changes as a result of the level of arousal due to fatigue. We evaluated CFF, reflective of fatigue and mental workload [37]. To avoid sleep inertia, the flicker test was conducted at least 30 minutes after awakening from the napping experiment.

Statistical analysis

For demographic variables, we calculated the mean values and standard deviations. The normality of the distributions was confirmed using the Shapiro–Wilk test. Variables from the preceding night, EEG and EMG during napping were normally distributed. Thus, the results (between BC and UR) of EEG and EMG were analyzed with a paired t-test. To assess HRV between wakefulness and sleep, a two-way analysis of variance (Napping condition [BC or UR] × Sleep status [Wakefulness or Sleep]) with repeated measures was performed for each variable. All calculations were performed using SPSS statistics version 27 (IBM, Armonk, NY, USA).

Declarations

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

M.N. and K.S. designed the research plan. M.N. controlled the research project. A.I. and Y.M. performed the experiment and collected data. M.N., A.I., Y.M., and K.S. analyzed the data. M.N. wrote the manuscript and prepared all figures and tables. All authors reviewed the manuscript.

Competing interests

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Tables

Table 1. Sleep parameters from the preceding night and subjective scale scores for each bedding condition

Variable measured	BC	UR
Bed time (hh:min)	00:43 (01:53)	00:50 (01:20)
Out of bed time (hh:min)	07:35 (01:36)	07:47 (01:14)
Total time in bed (min)	356 (125)	324 (113)
Total sleep time (min)	279 (111)	276 (104)
Sleep onset latency (min)	10 (11)	9 (7)
Sleep efficiency (%)	79.3 (15.0)	85.0 (11.8)
Wake after sleep onset (min)	50 (52)	34 (26)

Abbreviations: BC, bean bag chair; UR, urethane chair

Values are shown as mean (standard deviation) unless specified.

Table 2. Comparisons of nap-related parameters between bean bag and urethane chairs

	KSS (pre-nap)	KSS (post-nap)	KSS change (%)	VAS	Flicker (Hz)
BC	4.3 (1.6)	4.1 (1.4)	112.7 (70.7)	5.6 (1.3)	36.20 (2.33)
UR	4.4 (1.4)	4.5 (2.1)	122.0 (64.5)	4.4 (2.1)	36.23 (2.31)
p-value	0.723	0.925	0.775	0.131	0.956

	TIB	SPT	TST	SL	SE (TST/SPT)	WASO
BC	71.10 (6.26)	49.62 (7.50)	46.90 (8.26)	16.44 (7.35)	94.28 (5.68)	2.72 (2.66)
UR	71.83 (7.37)	49.98 (9.82)	46.71 (10.26)	16.99 (6.33)	93.66 (8.74)	3.26 (4.47)
p-value	0.442	0.293	0.545	0.584	0.721	0.608

	%N1	%N2	%N3	%REM
BC	21.65 (9.92)	47.74 (19.18)	17.58 (22.37)	7.31 (12.69)
UR	23.45 (15.75)	44.99 (18.23)	20.87 (27.58)	4.35 (10.43)
p-value	0.926	0.701	0.537	0.476

Abbreviations: BC, bean bag chair; UR, urethane chair; KSS, Karolinska sleepiness scale; VAS, visual analog scale (subjective sleep satisfaction); TIB, total time in bed; SPT, sleep period time; TST, total time of sleep; SL, sleep latency; SE, sleep efficiency; WASO, wake after sleep onset; N2, non-REM sleep stage 2; N3, non-REM sleep stage 3; REM, rapid eye movement

Values are shown as mean (standard deviation) unless specified.

Table 3. HRV variables during pre-nap wakefulness and naps in each bedding chair

Abbreviations: HRV, heart rate variability; BC, bean bag chair; UR, urethane chair; CI, confidence interval; RMSSD, root mean square of successive differences; LF, low frequency; HF, high frequency; TP, total power; HFnu, normalized HF unit

Values are shown as mean (standard error of the mean) unless specified.

Statistical significance was evaluated by 2-way analysis of variance.

Figures

BC			UR		Main effect						Interaction		
					Type			Alertness			Type x Alertness		
	pre-nap wakefulness	NREM sleep	pre-nap wakefulness	NREM sleep	<i>F(df)</i>	<i>p</i>	η^2	<i>F(df)</i>	<i>p</i>	η^2	<i>F(df)</i>	<i>p</i>	η^2
RMSSD	90.4 (17.9)	60.4 (6.4)	68.6 (10.5)	76.5 (8.2)	0.015 (1, 20)	0.904	0.001	0.709 (1, 20)	0.410	0.034	1.969 (1, 20)	0.176	0.090
95% CI	55.2 - 125.6	47.7 - 73.0	48.1 - 89.2	48.1 - 89.2									
LF (ms ²)	1876.4 (548.6)	1313.3 (264.3)	1594.3 (488.7)	2186.5 (475.7)	1.868 (1, 20)	0.187	0.085	0.014 (1, 20)	0.906	0.001	1.086 (1, 20)	0.310	0.052
95% CI	801.1 – 2951.7	795.3 - 1831.3	636.4 – 2552.2	1254.1 - 3188.9									
HF (ms ²)	1790.7 (756.5)	811.5 (115.1)	1212.3 (292.0)	1288.8 (200.1)	0.007 (1, 20)	0.934	0.001	0.703 (1, 20)	0.412	0.034	1.006 (1, 20)	0.328	0.048
95% CI	308.0 – 3273.4	585.9 - 1037.1	640.0 – 1784.6	896.6 - 1681.0									
LF/HF	1.49 (0.20)	2.29 (0.43)	1.75 (0.33)	2.85 (0.92)	4.314 (1, 20)	0.037	0.375	1.043 (1, 20)	0.327	0.080	1.567 (1, 20)	0.235	0.115
95% CI	1.10 – 1.88	1.45 - 3.13	1.10 – 2.40	1.05 - 4.65									
TP (ms ²)	12300.2 (4395.9)	4775.5 (845.5)	5817.1 (1225.4)	7890.1 (2210.9)	0.801 (1, 20)	0.381	0.039	2.445 (1, 20)	0.491	0.024	0.493 (1, 20)	0.491	0.024
95% CI	3684.2 – 20916.2	3118.0 - 6432.4	3415.3 - 8218.9	3556.7 - 12223.5									
HFnu	0.44 (0.04)	0.39 (0.04)	0.43 (0.03)	0.40 (0.05)	0.301 (1, 20)	0.589	0.015	3.314 (1, 20)	0.084	0.142	0.000 (1, 20)	0.991	0.000
95% CI	0.36- 0.52	0.31 - 0.47	0.37 - 0.49	0.30 - 0.50

Figure 1

Surface muscle activity of the trapezius muscle, abdominal oblique muscle, and grand average of the activity of both muscles. The trapezius muscle demonstrates significantly lower EMG activity in the BC condition than in the UR condition ($p = 0.046$). Moreover, the grand average EMG activity in the BC condition is lower than that in the UR condition, although the difference is not statistically significant ($p = 0.063$). * $p < 0.05$ by paired t-test. Abbreviations: EMG, electromyogram; BC, bean bag chair; UR, urethane chair.

Figure 2

Change in HRV variables across alertness for each bedding environment. Values in the panel indicate main effect of bedding. Abbreviations: HRV, heart rate variability; RMSSD, root mean square of successive differences; LF, low frequency; HF, high-frequency; TP, total power; HFnu, normalized HF unit; BC, bean bag chair; UR, urethane chair. The error bar indicates the standard error of the mean.

Figure 3

Actual photo of a bean bag chair (A) and schematic view of napping posture from the side in both napping environments (B) BC, bean bag chair; UC, urethane chair

Supplementary Files

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- [SupplementaryTable.docx](#)