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RESEARCH ARTICLE

A weighted blanket increases pre-sleep salivary concentrations of melatonin in young, healthy adults

Elisa M. S. Meth[1] | Luiz Eduardo Mateus Brandão[2] | Lieve T. van Egmond[1,3] | Pei Xue[1] | Anastasia Grip[1] | Jiafei Wu[1] | Ayaat Adan[1] | Filip Andersson[4] | André P. Pacheco[1] | Kerstin Uvnäs-Moberg[5] | Jonathan Cedernaes[2,6] | Christian Benedict[1]

[1]Department of Pharmaceutical Biosciences, Uppsala University, Uppsala, Sweden

[2]Department of Medical Sciences, Uppsala University, Uppsala, Sweden

[3]Department of Surgical Sciences, Uppsala University, Uppsala, Sweden

[4]Cura of Sweden AB, Sundsvall, Sweden

[5]Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Uppsala, Sweden

[6]Department of Medical Cell Biology, Uppsala University, Uppsala, Sweden

Correspondence
Christian Benedict, Visiting address: BMC, Husargatan 3, 751 24 Uppsala, Sweden.
Email: christian.benedict@farmbio.uu.se

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Summary

Weighted blankets have emerged as a potential non-pharmacological intervention to ease conditions such as insomnia and anxiety. Despite a lack of experimental evidence, these alleged effects are frequently attributed to a reduced activity of the endogenous stress systems and an increased release of hormones such as oxytocin and melatonin. Thus, the aim of the present in-laboratory crossover study (26 young and healthy participants, including 15 men and 11 women) was to investigate if using a weighted blanket (~12% of body weight) at bedtime resulted in higher salivary concentrations of melatonin and oxytocin compared with a light blanket (~2.4% of body weight). We also examined possible differences in salivary concentrations of the stress hormone cortisol, salivary alpha-amylase activity (as an indicative metric of sympathetic nervous system activity), subjective sleepiness, and sleep duration. When using a weighted blanket, the 1 hour increase of salivary melatonin from baseline (i.e., 22:00) to lights off (i.e., 23:00) was about 32% higher ($p = 0.011$). No other significant differences were found between the blanket conditions, including subjective sleepiness and total sleep duration. Our study is the first to suggest that using a weighted blanket may result in a more significant release of melatonin at bedtime. Future studies should investigate whether the stimulatory effect on melatonin secretion is observed on a nightly basis when frequently using a weighted blanket over weeks to months. It remains to be determined whether the observed increase in melatonin may be therapeutically relevant for the previously described effects of the weighted blanket on insomnia and anxiety.

KEYWORDS
alpha-amylase, cortisol, melatonin, oxytocin, sleep, weighted blanket

1 | INTRODUCTION

Weighted blankets have emerged as a method within the scope of occupational therapy practice to ease conditions such as insomnia and anxiety (Eron et al., 2020; Gee, Peterson, Buck, & Lloyd, 2016). For example, a study involving 120 psychiatric patients found that the use of a weighted blanket during bedtime for over 1 month eased the severity of insomnia more than among patients using a light blanket during sleep (Ekholm, Spulber, & Adler, 2020). In addition, depression and anxiety symptoms decreased significantly in participants using the weighted blanket (Ekholm et al., 2020). However, the potential mechanisms underlying the sleep-improving and anxiolytic effects of the weighted blankets remain unclear. One hypothesis is that weighted blankets may have a calming effect through deep pressure stimulation (Eron et al., 2020). In support of this hypothesis, using a weighted blanket in a supine wake position has been shown to lower electrodermal activity (Mullen, Champagne, Krishnamurty, Dickson, & Gao, 2008), a proxy of sympathetic nervous system (SNS) activity (Miller et al., 1999). Additional mechanisms potentially accounting for the calming effects of deep pressure stimulation may be activation of the oxytocinergic system and reduced physiological and behavioural reactivity to stressors as seen after stimulation of the cutaneous sensory nerves, e.g., unmyelinated C-tactile afferents in the skin (Case et al., 2021; Löken, Wessberg, Morrison, McGlone, & Olausson, 2009; Marshall, Sharma, Marley, Olausson, & McGlone, 2019; Olausson et al., 2002, 2008; Portnova, Proskurnina, Sokolova, Skorokhodov, & Varlamov, 2020; Walker, Trotter, Swaney, Marshall, & Mcglone, 2017).

Oxytocin is produced by the hypothalamic neurons and released into the circulation through the neurohypophyseal system (Uvnäs-Moberg, 1997a). It has several biological effects, e.g., the promotion of labour and breastfeeding, decreasing fear, pain, and stress, and increasing levels of wellbeing and calm (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Moberg, Handlin, & Petersson, 2020; Uvnäs Moberg, Handlin, Kendall-Tackett, & Petersson, 2019; Uvnäs-Moberg, Handlin, & Petersson, 2015). However, whether weighted blankets increase the release of oxytocin is unknown.

Melatonin is produced by the pineal gland and plays an essential role in sleep timing (Dawson & Encel, 1993). In addition to ambient light (Brzezinski, 1997), non-photic cues such as physical activity, meal patterns, and social activities can impact the release of melatonin in humans (Mistlberger & Skene, 2005). However, whether weighted blankets alter melatonin release has not been investigated experimentally.

Thus, the primary aim of the present in-laboratory crossover study was to investigate if using a weighted blanket at bedtime results in higher salivary concentrations of melatonin and oxytocin compared with when using a light blanket. In addition, we also examined possible differences in salivary concentrations of the stress hormone cortisol, alpha-amylase activity (a measure of SNS activity [Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004]), subjective sleepiness, and sleep duration.

2 | METHODS

2.1 | Participants

Twenty-six normal-weight young, non-smoking men and women participated in the study (Table 1 for sample characteristics). All of the included women ($n = 11$) were on hormonal monophasic contraceptives to account for the potential confound of the menstrual cycle (Baker & Lee, 2018). A screening interview ensured that the participants reported good general health status. For example, those indicating that they suffered from an acute or chronic disease, including somatic and psychiatric conditions, were not considered to be eligible for study inclusion. A history of weighted blanket use before the study, as well as confirmative answers to either of the following questions, led to exclusion from the study: "Do you sleep uncovered?", "Did or do you have difficulties falling and staying asleep?", "Did or do you suffer from heavy snoring or other sleep-related breathing disturbances?", "Did a medical examination reveal any other sleep disorders?", "Do you habitually sleep less than 7 hours?", "Do you habitually go to bed before 22:00 or later than 24:00 on working days?", "Do you regularly use medications, drugs, or nicotine?", "Do you consume more than five standard units of alcohol or caffeine beverages per day?", and "Did you travel across time zones in the last months, or do you have plans to travel across time zones in the next weeks?". We also excluded subjects in the case of extreme chronotype, as measured by a score of ≤ 30 or ≥ 70 in the Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976).

As the study was partially performed amid the COVID-19 pandemic, the participants were only invited for onsite experimental sessions when they were free of any COVID-19-related symptoms. The regional Ethics Committee approved the study protocol (Dnr 2019–04541), which has been preregistered (https://osf.io/b3qxk). Furthermore, all the participants provided informed consent in written and oral form before partaking in the study.

2.2 | Experimental procedure

All participants underwent two experimental sessions in a randomised and counterbalanced order in our laboratory, as outlined in Figure 1. The day before the first testing session, the participants visited the laboratory for an adaptation night. The adaptation night served to adjust the participants to the experimental setting. In addition, before each experimental night, the participants were asked to habituate to both the light and the weighted blanket, either for three nights at home before the adaptation night or for four nights at home before the second experimental session. On the testing days, the subjects were provided a standardised dinner upon arrival at the sleep laboratory (19:00). Between 19:00 and 21:00, the subjects sat in front of two light-emitting diode boxes (0.4 m distance; each box emitted 300 lux; Wake-up light Philips HF3531, UK) to minimise inter-individual differences in the timing of the dim-light melatonin onset. Between 21:00 and 23:00, the room lights were dimmed to 5 lux. In

TABLE 1 Sample characteristics

Characteristic	Overall	Weighted blanket	Light blanket	*p*-value
Number of men	15	--	--	--
Number of women	11	--	--	--
BMI, kg/m^2[a]	22.3 ± 0.5	--	--	--
Age, years[a]	24.4 ± 0.6	--	--	--
Habitual nighttime sleep duration, hours[a]	8.1 ± 0.9	--	--	--
Baseline values at 22:00				
Salivary alpha-amylase levels, U/mL	--	74.9 ± 13.8	84.5 ± 17.1	0.751[b]
Salivary melatonin levels, pg/mL	--	8.9 ± 1.5	9.4 ± 1.6	0.347[b]
Salivary cortisol levels, mmol/L	--	1.1 ± 0.1	1.1 ± 0.1	0.964[c]
Salivary oxytocin levels, pg/mL	--	1298 ± 184	1487 ± 200	0.230[b]
Karolinska Sleepiness Scale, points	--	5.1 ± 0.3	5.7 ± 0.3	0.096[b]

Data are shown as mean ± SE, unless otherwise stated.
BMI, body mass index.
[a]Assessed/surveyed during the screening session.
[b]Wilcoxon signed-rank test.
[c]Paired Student's *t*-test.

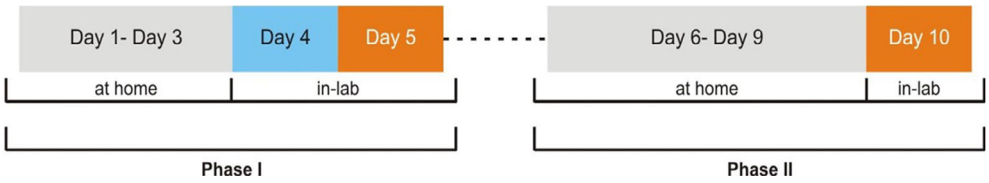

FIGURE 1 Overview of the randomised, counterbalanced within-subjects design. Boxes highlighted in grey illustrate the two at-home adaptation phases (i.e., day 1 to 3 and day 6 to 9); in blue, the sole adaptation night (day 4); and in orange, the two experimental days (days 5 and 10)

one session, the subjects used a weighted blanket (Cura of Sweden, Sundsvall, Sweden) covering the extremities, abdomen, and chest, in a supine position 1 h before and during 8 h of sleep opportunity (scheduled between 23:00 and 07:00). The filling of the weighted blanket consisted of honed glass pearls combined with polyester wadding, corresponding to 12.2% of the participants' body weight. In the other experimental session, the subjects used a light blanket, which weighed 2.4% of their body weight.

To assess the effects of the blankets on melatonin, alpha-amylase, cortisol, and oxytocin, saliva was collected every 20 min between 22:00 and 23:00. Additionally, the participants' subjective sleepiness was assessed every 20 min using the Karolinska Sleepiness Scale (KSS; Gillberg, Kecklund, & Akerstedt, 1994) during the hour before lights off (i.e., 22:00–23:00), and the next morning (i.e., at 07:00 and 08:00, respectively). Sleep duration in each experimental night was recorded with the ŌURA ring (Ōura Health, Oulu, Finland). The ŌURA ring is a commercial multi-sensor wearable that measures multiple physiological variables and shows acceptable accordance with polysomnography-assessed sleep duration (de Zambotti, Rosas, Colrain, & Baker, 2019). For the present study, we focused on total sleep duration as an outcome.

2.3 | Saliva assays

Saliva was collected by passive drool using a Saliva Collection Aid (Salimetrics, State College, PA, USA), stored immediately on ice until 23:00, and then kept at −80°C until analysis. Melatonin saliva tubes were wrapped with aluminium foil to avoid photodegradation (Andrisano, Bertucci, Battaglia, & Cavrini, 2000). Saliva melatonin concentrations were determined by a commercially available immunoassay with luminescence detection (LIA, IBL-International, Hamburg, Germany). Salivary free cortisol was measured using a chemiluminescence immunoassay (CLIA; IBL International, Hamburg, Germany). For alpha-amylase analysis, we applied a quantitative enzyme-kinetic method (Rohleder & Nater, 2009). Finally, salivary oxytocin was measured using an Oxytocin ELISA kit (Enzo Life Sciences, New York, USA).

2.4 | Statistical analysis

Data were analysed using IBM SPSS Statistics 26 (SPSS Inc. Chicago, IL, USA). To account for intra- and inter-individual differences in

baseline salivary concentrations of melatonin, cortisol, oxytocin, as well as alpha-amylase activity, we calculated the difference between the baseline (i.e., 22:00) and post-baseline time points (i.e., 22:20, 22:40, and 23:00). We also baseline-adjusted the subjective sleepiness scores by subtracting the 22:00 KSS score from those measured at 22:20, 22:40, and 23:00. Data distribution was tested using the Kolmogorov–Smirnov test, and comparisons of baseline values between the blanket conditions relied on a paired Student's *t*-test for normally distributed variables and a Wilcoxon signed-rank test for skewed variables.

We applied generalised linear mixed models (GLMMs; assuming a normal distribution with an identity link function) to determine the effects of the following fixed factors on the outcomes: within-subjects factors BLANKET (i.e., weighted vs. light blanket) and TIME. We also investigated possible interactions between BLANKET and TIME. Unless otherwise specified, data are reported as mean ± standard error (SE). Due to sample size restrictions, we did not investigate possible interactions between BLANKET and biological sex.

Ratings of perceived heaviness of the weighted blanket measured on a 100 mm visual analogue scale were assessed after the end of the second experiment. Using Spearman's correlational analysis, we investigated whether the perceived heaviness of the weighted blanket correlated with the change in salivary concentrations of melatonin, oxytocin, cortisol, and alpha-amylase in the weighted blanket condition. Overall, $p < 0.05$ was considered significant.

3 | RESULTS

3.1 | Effects of the weighted blanket on salivary melatonin, cortisol, alpha-amylase, and oxytocin

No baseline differences in any of the salivary factors were found between the blanket conditions ($p \geq 0.230$ as derived from either a Wilcoxon signed-rank test or paired Student's *t*-test; Table 1). The salivary melatonin concentrations rose on average by about 5.8 pg/mL between 22:00 and 23:00 ($p < 0.001$ for TIME). The average increase in salivary melatonin concentrations between 22:00 and 23:00 was greater in the weighted blanket condition (weighted vs. light blanket: 6.6 ± 0.7 vs. 5.0 ± 0.5 pg/mL; $p = 0.011$ for BLANKET; Figure 2a); however, no interaction between BLANKET and TIME was found ($p = 0.855$).

Salivary cortisol concentrations dropped on average by about 0.2 mmol/L between 22:00 and 23:00; however, no significant main effects of TIME ($p = 0.052$) or BLANKET were observed (weighted vs. light blanket: −0.2 ± 0.03 vs. −0.2 ± 0.04 pg/mL from baseline; $p = 0.992$ for BLANKET; $p = 0.950$ for BLANKET*TIME; Figure 2b).

Compared with its activity measured at 22:00, the activity of salivary alpha-amylase was descriptively but not statistically reduced by about 12 U/mL at 22:20, 17 U/mL at 22:40, and 25 U/mL at 23:00 ($p = 0.213$ for TIME). The change in alpha-amylase activity from baseline did not differ between the two blanket conditions (weighted vs. light blanket: −16.5 ± 4.2 vs. −19.5 ± 5.3 U/mL from baseline; $p = 0.665$ for BLANKET); and no interaction was observed ($p = 0.891$ for BLANKET*TIME; Figure 2c).

Compared with the salivary levels measured at 22:00, oxytocin rose by about 315 pg/mL at 22:20; 112 pg/mL at 22:40, and 84 pg/mL at 23:00; however, no significant main effect of TIME was found ($p = 0.453$ for TIME). The change in the salivary oxytocin concentrations from baseline observed until 23:00 was highly variable within and between subjects and did not reach significance between the weighted and light blanket conditions (251 ± 135 vs. 91 ± 104 pg/mL from baseline; $p = 0.384$ for BLANKET; $p = 0.363$ for BLANKET*TIME; Figure 2d).

3.2 | Effects of the weighted versus light blanket on subjective sleepiness before and after sleep

At 22:00, the participants exhibited a lower KSS score during the weighted blanket condition; however, the difference in sleepiness between the blanket conditions did not reach significance ($p = 0.096$ as derived from a Wilcoxon signed-rank test; Table 1). Irrespective of the blanket condition, compared with the baseline, the KSS score was 0.4 ± 0.1 points higher at 22:20, 0.8 ± 0.1 points higher at 22:40, and 1.0 ± 0.2 points higher at 23:00 ($p = 0.004$ for TIME). The KSS score was about 0.2 ± 0.2 points higher during the weighted than the light blanket condition; however, this difference did not reach significance ($p = 0.215$ for BLANKET). Finally, the change in KSS scores from baseline did not vary by TIME between the blanket conditions ($p = 0.498$ for BLANKET*Time; Figure 2e).

The following morning, i.e., after the participants had slept either with a weighted or a light blanket, no differences in the KSS scores were found between the blanket conditions (weighted vs. light blanket: 4.2 ± 0.2 vs. 4.2 ± 0.2 points; $p = 0.936$ for BLANKET; 07:00: 4.8 ± 0.2; 08:00: 3.5 ± 0.2; $p < 0.001$ for TIME; $p = 0.256$ for BLANKET*TIME).

3.3 | Effects of the weighted versus light blanket on total sleep duration

Due to technical problems connecting the ŌURA ring with the mobile application, on 13 of the 52 experimental nights (25% of the experimental nights), total sleep duration estimates were unavailable for the analysis. No significant differences were found when comparing total sleep duration between the blanket conditions (6.83 ± 0.13 vs. 6.84 ± 0.14 h; $p = 0.986$ for BLANKET).

3.4 | Correlation between perceived blanket heaviness and hormone secretion

As suggested by Spearman correlational analysis, the perceived heaviness of the weighted blanket on a visual analogue scale was inversely associated with the change in salivary melatonin concentrations in the

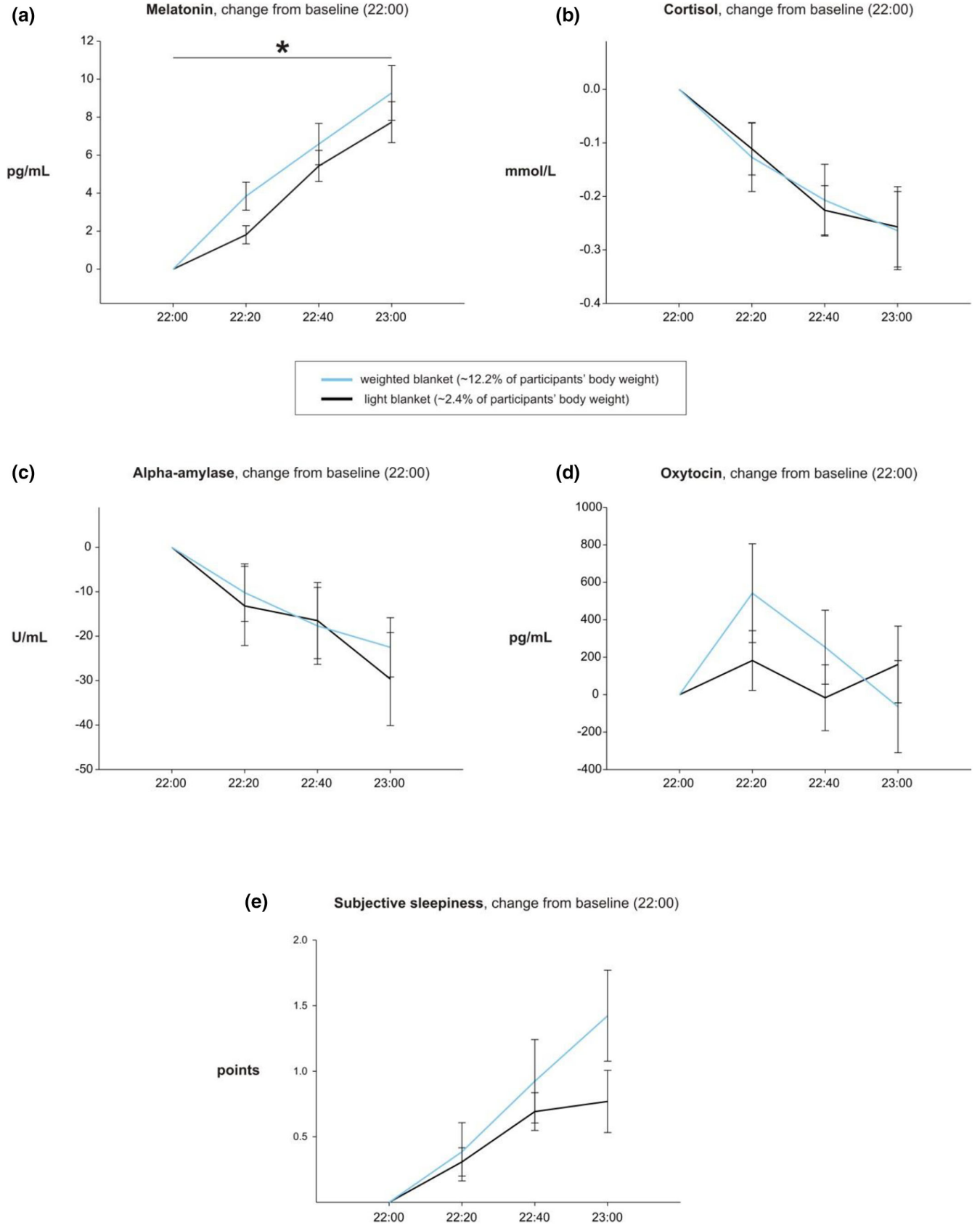

FIGURE 2 Effects of the weighted versus light blanket on salivary (a) melatonin, (b) cortisol, (c) alpha-amylase activity, (d) oxytocin, and (e) subjective sleepiness ratings. $N = 26$ (11 women). For oxytocin, no data from one female subject were available for analysis. *$p < 0.05$ for a main effect of blanket (derived from a generalised linear mixed model using the within-subjects factors blanket and time as fixed factors)

weighted blanket condition (Spearman's rho = −0.384); however, the correlation did not reach significance ($p = 0.064$). No other correlations with perceived heaviness were observed (Spearman's rho; cortisol: −0.190, $p = 0.385$; alpha-amylase: −0.189, $p = 0.388$; and oxytocin: 0.130, $p = 0.565$).

4 | DISCUSSION

In the present experimental study, involving 26 healthy young men and women, we found that using a weighted blanket in bed was associated with a higher increase of salivary melatonin in the hour before sleep than using a light blanket. Some studies suggest that melatonin possesses sleep-promoting and anxiolytic properties (Brzezinski et al., 2005; Madsen, Zetner, Møller, & Rosenberg, 2020; Scheer & Czeisler, 2005). However, whether the observed rise in melatonin accounts for the sleep-promoting and anxiolytic effects of weighted blankets reported previously (Ekholm et al., 2020; Eron et al., 2020; Gee et al., 2016) is unclear.

Our study cannot identify the underlying mechanism for the observed stimulatory effects of the weighted blanket on melatonin. However, one explanation could be that the pressure exerted by weighted blankets activates cutaneous sensory afferents, carrying sensory information via the spinal cord to the nucleus tractus solitarius. This brainstem region has projections to the paraventricular nucleus of the hypothalamus (Saper, Loewy, Swanson, & Cowan, 1976), a brain area hosting parvocellular oxytocinergic neurons. Through their impact on other brain networks, parvocellular oxytocinergic neurons can promote calm and well-being and decrease fear, stress, and pain (Uvnäs-Moberg et al., 2019; Uvnäs-Moberg, 1997b; Eliava et al., 2016). In addition, they also connect to the pineal gland to influence the release of melatonin (Møller, 2021), which could explain the more significant rise in salivary melatonin in the weighted blanket condition. Noteworthy, spinal cord injuries resulting in a total loss of afferent sensory signalling are associated with a complete absence of evening melatonin increase (Verheggen et al., 2012), suggesting a critical role of the peripheral sensory nervous system in regulating the central nervous release of melatonin.

We noticed an initial and transient rise in the circulating oxytocin levels in the weighted blanket condition; however, this effect did not reach statistical significance. Two factors affect the interpretation of these findings. The first concerns the use of commercially available assays for the measurement of plasma oxytocin (including the one used herein), as the presence of multiple immunoreactive products in addition to oxytocin may result in an overestimation of oxytocin (Szeto et al., 2011). Furthermore, oxytocin levels are increased by the oestrogen component of oral contraceptives (McCarthy, 1995), which was used by the women participating in the study and may have affected our ability to detect differences in oxytocin between the blanket conditions.

A previous study found that the one-time use of a weighted blanket resulted in reduced SNS activity (Chen, Yang, Chi, & Chen, 2012). However, in our research, salivary concentrations of the stress hormone cortisol (which dropped before sleep irrespective of the blanket condition) and the mainly sympathetically regulated alpha-amylase (Rohleder et al., 2004) did not differ between the blanket conditions. Hence, our study does not provide compelling evidence that dampening the activity of endogenous stress systems accounts for the sleep-promoting and anxiolytic effects of weighted compared with light blankets. However, we cannot rule out that the activity of endogenous stress systems may have differed between the blanket conditions if saliva had been collected over a more extended period.

While sleepiness increased during the hour before scheduled lights off, we did not find significant differences in subjective sleepiness between the weighted and light blanket conditions before or after one night of sleep. Additionally, the total sleep duration remained unaffected by using a weighted blanket. At first glance, these results may contradict a previous study in which using a weighted metal chain blanket during bedtime over an extended period reduced insomnia severity among patients with psychiatric diagnoses (Ekholm et al., 2020). However, our study involved a highly selected population of healthy young adults without any history of chronic somatic or psychiatric co-morbidities or sleep disorders. Additionally, we investigated the effects of a weighted blanket on sleep only for one night, and sleep was measured with a consumer sleep wearable. Thus, we cannot rule out that weighted blankets may aid sleep in healthy young adults when used over more extended periods or that the effects may have become visible with methods to assess sleep other than the one used in the present study (e.g., polysomnography). In this context, it is also essential to discriminate between the subjective and objective effects of weighted blankets. For example, one study found that children with autism spectrum disorder favoured using weighted blankets, despite a lack of objective changes in their sleep (Gringras et al., 2014).

Several methodological limitations apply to our findings. First, it is unclear whether using different weights of the weighted blanket would have produced similar results. In this context, the perceived heaviness of a weighted blanket, which can vary considerably between subjects with different levels of interoceptive and sensory awareness, could impact the extent to which the blanket affects the salivary secretion of factors such as melatonin. It is also unclear whether similar results would be seen in other populations, e.g., elderly subjects and patients with sleep and neuropsychiatric disorders. Finally, our findings must be confirmed in more extensive studies.

5 | CONCLUSIONS

Our study is the first to suggest that using a weighted blanket may result in a greater release of melatonin at bedtime. However, future studies should investigate whether the stimulatory effect on melatonin secretion remains when using a weighted blanket over more extended periods. It is also unclear whether the observed increase in melatonin is therapeutically relevant.

AUTHOR CONTRIBUTIONS

E.M.S.M., L.T.E., F.A., K.U.V., J.C., and C.B. conceived the study. E.M.S.M., P.X., A.G., J.W., A.A., and A.P.P. contributed to data collection. E.M.S.M., L.E.M.B., A.G., A.A., A.P.P., and C.B. analysed the data. E.M.S.M., A.P.P., K.U.M., J.C., and C.B. interpreted the data. E.M.S.M., A.P.P., and C.B. drafted the paper. L.E.M.B., L.T.E., P.X., A.G., J.W., A.A., F.A., K.U.M., and J.C. provided critical feedback on the draft, and approved it in its final version.

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CONFLICT OF INTEREST

The author F.A. is an employee of Cura of Sweden. None of the remaining authors declare any commercial or financial relationships that could be construed as a potential conflict of interest, nor were they paid by Cura of Sweden for conducting the present experiment.

DATA AVAILABILITY STATEMENT

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ethical restrictions.

ORCID

Luiz Eduardo Mateus Brandão https://orcid.org/0000-0002-8672-7870

Lieve T. van Egmond https://orcid.org/0000-0002-3271-8530

Kerstin Uvnäs-Moberg https://orcid.org/0000-0003-4902-839X

Jonathan Cedernaes https://orcid.org/0000-0002-9052-8372

Christian Benedict https://orcid.org/0000-0002-8911-4068

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