

The impact of a brief gratitude intervention on subjective well-being, biology and sleep

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Abstract

This randomised controlled experiment tested whether a brief subjective well-being intervention would have favourable effects on cardiovascular and neuroendocrine function and on sleep. We compared 2 weeks of a gratitude intervention with an active control (everyday events reporting) and no treatment conditions in 119 young women. The treatment elicited increases in hedonic well-being, optimism and sleep quality along with decreases in diastolic blood pressure. Improvements in subjective well-being were correlated with increased sleep quality and reductions in blood pressure, but there were no relationships with cortisol. This brief intervention suggests that subjective well-being may contribute towards lower morbidity and mortality through healthier biological function and restorative health behaviours.

Keywords

biological responses, gratitude, intervention, sleep, subjective well-being

Introduction

There are many conceptualisations of subjective well-being (SWB), but recent categorisations have identified three broad but distinct constructs: hedonic well-being, eudemonic well-being and evaluative well-being (Steptoe et al., 2014; Stone and Mackie, 2013). Hedonic well-being refers to feelings or moods such as happiness or sadness, while eudemonic well-being captures judgements about autonomy and the meaning and purpose of life. The third component of SWB, namely evaluative well-being aligns with life satisfaction and relates to the cognitive-judgmental appraisals that people make about their lives (Ryan and Deci, 2001). Although eudemonic and hedonic well-being are related, each represents a unique aspect of well-being. For example, some people perceive

their life as unfulfilling but nonetheless rate themselves as happy, while others report low levels of happiness or affect despite pursuing their life goals (Ryan and Deci, 2001). However, there is controversy about the distinction between hedonic and eudemonic well-being since the constructs overlap conceptually (Fredrickson et al., 2013; Kashdan et al., 2008; Telzer et al., 2014). Studies

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into SWB have also focussed on positive or adaptive trait-like factors or dispositions such as optimism, sense of humour and emotional vitality (Fredrickson and Joiner, 2002; Gallagher and Lopez, 2009; Kubzansky and Thurston, 2007).

Individuals with greater SWB enjoy longer and healthier lives (Boehm and Kubzansky, 2012; Chida and Steptoe, 2008). SWB correlates with healthier biological profiles, suggesting that it may exert beneficial effects on health through optimising biological function (Fredrickson et al., 2013; Kok and Fredrickson, 2010; Pressman and Cohen, 2005). Higher levels of SWB may buffer the effects of stress and/or enhance stress recovery (Boehm and Kubzansky, 2012). Indeed, experimental research has found that SWB is associated with smaller inflammatory and blood pressure (BP) responses to acute stressors (Dockray and Steptoe, 2010). Studies conducted in everyday life also reported that individuals with higher levels of positive states have lower heart rate (HR), lower ambulatory BP, and lower concentrations of the stress hormone cortisol and inflammatory markers (Ryff et al., 2006; Steptoe et al., 2005, 2012). Observational studies suggest that positive trait-like dispositions such as optimism also have healthier biological correlates including lower levels of cortisol and inflammatory markers (Endrighi et al., 2011; Ikeda et al., 2011).

Greater SWB may also engender better physical health through health behaviours (Steptoe et al., 2009). A recent longitudinal study demonstrated that eudemonic well-being predicted greater use of preventive health-care services relevant to serious illness at older ages (Kim et al., 2014). Good sleep is linked to better health outcomes (Cappuccio et al., 2011), and individuals reporting optimal sleep patterns also enjoy higher SWB. For example, in the Midlife in the United States study, SWB was inversely related to insomnia symptoms (Hamilton et al., 2007). We have previously found that disturbed sleep is less prevalent in respondents who report greater well-being (Steptoe et al., 2008). Little research has explored prospective links between SWB and sleep, but one longitudinal study showed that

higher well-being was linked to a lower likelihood of disturbed sleep 10 years later (Phelan et al., 2010).

Most research relating SWB with biological responses is observational and cannot shed light on the causal processes involved. Greater well-being may promote more favourable biological responses, but it is also plausible that biological processes contribute to greater SWB. Relatedly, the research on sleep and SWB remains largely cross-sectional, so it is uncertain whether SWB leads to better sleep, or if good sleep enhances SWB. One method of clarifying temporal precedence is to modify well-being to see whether this has a beneficial impact on biology and sleep. There are a small number of short-term laboratory studies suggesting that experimentally induced positive affect can result in health-promoting cardiovascular and neuroendocrine responses (e.g. Buchanan et al., 1999; Hucklebridge et al., 2000; Pressman and Cohen, 2005), but the significance of these brief responses is uncertain, and they have limited relevance to sleep. We therefore sought to test the impact of an intervention that might increase SWB over a number of days.

Expressing gratitude has been shown to increase life satisfaction (Boehm et al., 2011) and to reduce negative affect (Emmons and McCullough, 2003). Other interventions that may boost SWB include visualising best possible selves (Boehm et al., 2011) and performing acts of kindness (Lyubomirsky et al., 2005). However, when this study was designed, only the gratitude approach had been successfully used to improve sleep (Emmons and McCullough, 2003).

In light of these findings, we used a gratitude intervention to explore whether increasing SWB would have a beneficial impact on cardiovascular and neuroendocrine activity as well as on sleep in everyday life. Since past gratitude interventions have been criticised for not including a true control group (Wood et al., 2010), our study involved two control conditions: an active control condition and a no treatment control condition. We predicted that in comparison with the control conditions, participants randomised to the gratitude condition

would experience greater increases in SWB that would be associated with lower cortisol and lower ambulatory BP and HR. We selected these biological markers since they can be conveniently collected in everyday life and have shown associations with SWB (Dockray and Steptoe, 2010). We also hypothesised that randomisation to the gratitude programme would lead to improvements in sleep in individuals with sleep problems as baseline. Finally, we conjectured that across the complete sample, participants who reported greater improvements in SWB would show larger increases in sleep quality and reductions in physiological activity.

Methods

Design

This study was a single-blind randomised controlled experiment that compared the gratitude intervention with an active control condition (everyday events) and no treatment condition. The study lasted 4 weeks with a baseline measurement week, 2 weeks of intervention and a post-intervention measurement week (see Supplementary Figure 1 available online). Salivary cortisol, ambulatory BP and HR were assessed over one working day before and after the intervention period. All participants also provided daily positive affect and sleep ratings for a week before and after the intervention.

Participants

Participants were 119 women either working or studying at University College London (UCL). Volunteers were eligible to take part if they reported emotional distress between 2 and 9 on the 12-item General Health Questionnaire (Goldberg et al., 1997), and moderate sleep disturbance indicated by a mean score between 1.5 and 4 on the Jenkins Sleep Problems Scale (Jenkins et al., 1988). These cut-off points were guided by the literature (Goldberg et al., 1997; Vahtera et al., 2006), and the scales were used at the screening selection stage due to their good

psychometric properties and brevity. To avoid floor and ceiling effects, participants with no/very low or high emotional distress and/or no/low or very high sleep disturbance were not recruited. The remaining inclusion criteria included not being pregnant, not taking any medications apart from the contraceptive pill and being free of any medical or psychiatric condition in the last 2 years. Since sleep patterns change with age (Ohayon et al., 2004), women older than 45 years old were not invited to take part.

Sample size was determined using nQuery Advisor 4.0 (Statistical Solutions, Cork, Ireland). Based on Emmons and McCullough's (2003) study 2, we estimated that we would detect a moderate effect size in positive affect with a sample of 40 per group ($\alpha=0.05$, 85% power). The study was approved by UCL Research Ethics Committee.

Procedure

During the first visit to the laboratory participants provided written consent; weight and height were measured; and baseline questionnaires to assess socio-demographic characteristics, SWB and sleep were distributed. We fitted participants with ambulatory BP monitors and gave them a set of seven plastic tubes to collect saliva for the assessment of cortisol. The second visit to the laboratory took place a week later during which participants were informed about the condition to which they had been randomly assigned. We used a computer-generated block randomisation list to allocate 40 participants to the gratitude condition, 41 to the everyday events condition and 38 to the no treatment condition. Participants in the gratitude and everyday events conditions were provided with diary booklets in which to write their assignments, and were instructed to practise the writing tasks for 2 weeks. Respondents in both conditions received two emails during this period encouraging them to persist with their writing assignments. Participants in the no treatment condition were informed that they would receive their writing task in 3 weeks'

time and were asked to go on about their lives as usual. During the third visit to the laboratory (2 weeks later), participants returned their writing tasks and were fitted for post-intervention physiological assessments. The fourth and final visit, scheduled a week later, was conducted solely to collect completed questionnaires and to reimburse participants for taking part in the study.

Measures

Background measures. Education, socio-demographic, economic and health variables (e.g. smoking) were measured by questionnaire.

Well-being measures. In our study, SWB was assessed with evaluative, hedonic and eudemonic measures, as well as with optimism.

Evaluative well-being was indexed with the Satisfaction with Life Scale (Diener et al., 1985) rated on a 7-point Likert scale. Scores were summed, and higher scores were reflective of greater life satisfaction. The scores could range from 5 to 35 (Cronbach's $\alpha=0.86$).

Hedonic well-being was measured with the Positive Emotional Style scale (Cohen et al., 2003), which is a shortened version of the scale originally used to study stress and infectious illness. The scale consisted of 16 adjectives (e.g. 'Happy') rated on a 5-point Likert scale, and it was completed every evening for 7 days during baseline and post-treatment assessment weeks. Average affect ratings were computed for each day and were then used to calculate an average weekly positive affect measure excluding days 1 and 7 since they could have been unusual for participants ($\alpha=0.86$).

Emotional distress was assessed with the Hospital Anxiety and Depression Scale (HADS) (Zigmond and Snaith, 1983). The HADS consists of 14 items referring to anxiety and depressive symptoms. The items were rated on a 4-point Likert scale, and total scores (possible range 0–42) were computed ($\alpha=0.84$).

Eudemonic well-being was indexed with the Flourishing Scale (Diener et al., 2010). This consists of 8 items (e.g. 'I lead a purposeful and

meaningful life') rated on a 7-point Likert scale. The scores were totalled with higher scores reflecting greater eudemonic well-being ($\alpha=0.86$).

Optimism was measured with the Revised Life Orientation Test (Scheier et al., 1994) which consists of 6 items rated on a 5-point Likert scale. Scores were summed and could range from 0 to 24, with higher ones indicating greater optimism ($\alpha=0.82$).

Sleep measures. The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) was the measure of global sleep disturbance. The PSQI comprises 19 items assessing various aspects of sleep including duration and efficiency. Apart from sleep duration and latency, items are rated on a 4-point Likert scale. Total scores were calculated and greater scores were indicative of more disturbed sleep, and in this study the scores ranged from 1 to 15 at baseline ($\alpha=0.76$).

Participants also provided daily sleep quality ratings (ranging from 0 = 'Very good' to 3 = 'Very bad') over 1 week at baseline and 1 week post-intervention. Average daily sleep quality scores were computed by taking a mean of sleep ratings from nights 2 to 6; responses from nights 1 and 7 were excluded since these could have been unusual for participants. Higher scores were indicative of poorer sleep quality. For clarity, this measure will be referred to as daily sleep quality in this article.

Biological measures. Cortisol was obtained by taking seven saliva samples collected using Salivette plastic tubes (Sarstedt, Leicester, UK). The first sample was collected during the initial visit to the laboratory between 8:00 and 9:30 a.m., and the remaining samples were taken at the following times: sample 2: 10:00 a.m.; sample 3: 12:00 p.m.; sample 4: 5:00 p.m. and sample 5: before going to bed. Sample 6 was taken immediately upon waking up the next day, and sample 7 precisely 30 minutes later. The same procedure of cortisol collection was followed post-intervention.

We measured BP and HR with the SpaceLabs 90217 ambulatory BP monitor (Redmond, WA, USA). The monitor was fitted on a participant's

arm by a member of the research team during the initial visit to the laboratory between 8:00 and 9:30 a.m. The device was programmed to take readings every 30 minutes and was worn for at least 10 hours.

Experimental and control writing tasks. The instructions for the writing tasks were an abridged version of those used by Sheldon and Lyubomirsky (2006). Briefly, we asked participants in the experimental condition to write a gratitude diary in which they expressed gratitude towards previously unappreciated people and things in their lives. Participants in the everyday events condition were requested to write a diary to record things that happened to them and/or things that they noticed each day; to keep the task neutral, respondents were encouraged to notice things and/or events irrespective of whether they were pleasant, neutral or unpleasant. Participants in the gratitude condition were asked to express gratitude about three things or towards three people each day they wrote in their diary, while those in the everyday events condition were requested to write about three events and/or things they noticed on that particular day. Participants in both conditions were asked to complete three writing exercises per week.

We assessed the effort invested into writing the diaries by asking respondents to note how many times they completed the writing exercises and how much effort they put into it, with the possible responses being 'Very little effort', 'Quite a bit of effort' and 'A lot of effort'.

Data processing

BP and HR. Ambulatory BP and HR recordings were scrutinised for outliers and failed recordings. Values were then averaged across the recording period. Participants provided between 10 and 32 values for each variable, with the average ranging from 21.4 to 26 at different time points.

Cortisol. Cortisol output was analysed by computing two parameters. First, the cortisol

awakening response (CAR) was calculated as the difference between the sample taken on awakening and 30 minutes later (Chida and Steptoe, 2009). Participants who reported taking their first sample more than 15 minutes after awakening were excluded from analyses since this can lead to erroneous estimations of the CAR (Dockray et al., 2008). Second, we calculated total cortisol output across the day as the area under the curve (AUC), using the method described previously (Pruessner et al., 2003). The cortisol AUC was log transformed prior to analysis.

Statistical analysis

Four participants dropped out of the study (see Supplementary Figure 1 available online), but they did not differ from those who completed the study on any variables described here. The results were analysed on an intent to treat basis using the last observation carried forward method, but the same pattern of results emerged when analyses were restricted to participants with complete data. We compared the baseline characteristics of the three groups using chi square and analysis of variance for categorical and continuous variables, respectively. Responses to the treatments were assessed using difference scores between baseline and post-treatment in the analysis of covariance with baseline value and age since sleep and SWB may change with age (Ohayon et al., 2004; Stone et al., 2010). The analyses of physiological variables included body mass index (BMI) as an additional covariate as it is related to BP and cortisol (Carroll et al., 2003; Steptoe et al., 2004). Results are presented as mean difference scores with 95 per cent confidence intervals (CI) and *p* values.

The associations between changes in SWB and changes in sleep and physiology were analysed by regressing change in SWB on the change in sleep and physiological activity, entering age and baseline sleep score as covariates in analyses relating sleep, and age, BMI and baseline physiological activity in models relating physiological variables. These analyses were conducted across the whole sample, and

Table 1. Baseline characteristics of participants in the three experimental conditions.

| | Gratitude group (n = 40) Mean (95% CI)/ frequency (%) | Everyday events group (n = 41) Mean (95% CI)/ frequency (%) | No treatment group (n = 38) Mean (95% CI)/ frequency (%) |
|--|--|--|---|
| Age (years) | 26.0 (24.5 to 27.5) | 26.8 (25.2 to 28.3) | 26.0 (24.4 to 27.6) |
| Education (graduate or higher) | 17 (42.5%) | 19 (46.3%) | 15 (39.5%) |
| Ethnicity (minority status) | 13 (32.5%) | 10 (24.4%) | 10 (26.3%) |
| Household income (>£20,000) | 26 (65.0%) | 23 (56.1%) | 21 (55.3%) |
| Body mass index (kg/m ²) | 22.4 (21.2 to 23.6) | 22.3 (21.4 to 23.2) | 22.5 (21.5 to 23.5) |
| Life satisfaction ^a | 23.1 (21.2 to 25.1) | 21.7 (19.8 to 23.7) | 22.9 (20.8 to 24.9) |
| Positive emotional style ^a | 1.9 (1.7 to 2.1) | 1.9 (1.7 to 2.1) | 2.0 (1.8 to 2.2) |
| HADS total ^a | 13.4 (11.6 to 15.2) | 13.5 (11.8 to 15.3) | 12.9 (11.1 to 14.8) |
| Flourishing scale ^a | 42.2 (39.9 to 44.5) | 41.8 (39.6 to 44.1) | 43.6 (41.2 to 46.0) |
| Optimism ^a | 15.5 (13.9 to 17.2) | 14.7 (13.1 to 16.2) | 13.9 (12.3 to 16.2) |
| PSQI ^a | 6.3 (5.5 to 7.2) | 6.2 (5.4 to 7.1) | 7.0 (6.1 to 7.8) |
| Daily sleep quality ^a | 1.1 (1.0 to 1.2) | 1.0 (0.8 to 1.1) | 0.9 (0.8 to 1.1) |
| Systolic BP (mmHg) ^b (n = 117) | 112.6 (110.2 to 115.1) | 112.2 (109.8 to 114.5) | 115.5 (113.0 to 118.0) |
| Diastolic BP (mmHg) ^b (n = 115) | 74.3 (72.3 to 76.3) | 73.7 (71.8 to 75.6) | 73.7 (71.7 to 75.8) |
| HR (bpm) ^b (n = 117) | 77.8 (75.1 to 80.5) | 76.1 (73.5 to 78.8) | 75.8 (73.1 to 78.6) |
| Cortisol awakening response (nmol/L) ^b (n = 105) | 8.4 (5.0 to 11.7) | 7.1 (3.6 to 10.6) | 8.4 (5.0 to 11.9) |
| Cortisol AUC (log, nmol/L) ^b (n = 115) | 9.5 (9.4 to 9.6) | 9.5 (9.4 to 9.6) | 9.6 (9.5 to 9.7) |

CI: confidence interval; HADS: Hospital Anxiety and Depression Scale; PSQI: Pittsburgh Sleep Quality Index; BP: blood pressure; HR: heart rate; AUC: area under the curve.

^aAdjusted for age.

^bAdjusted for age and body mass index.

the results are presented as *B* values with 95 per cent CI and *p* values.

Results

Baseline characteristics of participants are summarised in Table 1. Participants were predominantly well-educated young women with healthy weights and normal BPs. We did not find any significant differences on demographic, psychological or biological variables between the three experimental conditions. Bivariate correlations between baseline SWB, sleep and biological measures, conducted across the whole sample, are depicted in the supplementary table (available online). There were no significant associations between biomarkers and SWB at baseline,

but sleep quality was greater among participants who reported greater life satisfaction and hedonic well-being. The compliance with writing tasks was good. The average number of completed writing tasks in the gratitude condition was 5.4 (standard deviation (*SD*) = 1.1) and 5.3 (*SD* = 1.2) in the everyday events. In both groups, the majority of participants completed all six writing tasks.

Effects of interventions on SWB measures

Table 2 summarises responses to the interventions. There were no differences in changes in life satisfaction between groups, although improvements in life satisfaction were only observed in the gratitude

Table 2. Changes in psychological, sleep and biological outcomes in the three experimental conditions.

| | Gratitude group Mean (95% CI) | Everyday events group Mean (95% CI) | No treatment group Mean (95% CI) |
|--|-----------------------------------|--|-------------------------------------|
| Life satisfaction ^a | 1.9 (0.8 to 2.9) | 1.8 (0.8 to 2.9) | 0.6 (−0.5 to 1.7) |
| Positive emotional style ^a | 0.06 (−0.08 to 0.20) ^b | 0.06 (−0.08 to 0.19) ^b | −0.15 (−0.29 to −0.01) |
| HADS total ^a | −1.8 (−3.3 to −0.4) ^c | 0.2 (−1.2 to 1.6) | 0.8 (−0.7 to 2.2) |
| Flourishing scale ^a | 1.7 (0.4 to 2.9) | 1.5 (0.2 to 2.7) | 0.1 (−1.2 to 1.3) |
| Optimism ^a | 1.8 (1.0 to 2.6) ^b | 0.6 (−0.2 to 1.4) | 0.5 (−0.4 to 1.3) |
| PSQI ^a | −0.7 (−1.6 to 0.2) | −0.4 (−1.2 to 0.5) | −1.1 (−2.0 to −0.1) |
| Daily sleep quality ^a | −0.1 (−0.3 to 0.02) ^b | −0.1 (−0.2 to 0.1) | 0.1 (−0.01 to 0.3) |
| Systolic BP (mmHg) ^d | −1.9 (−3.6 to 0.2) | 1.6 (−3.2 to 0.1) | 0.5 (−2.3 to 1.3) |
| Diastolic BP (mmHg) ^d | −1.2 (−3.1 to −0.4) ^b | −0.4 (−1.7 to 0.9) | 0.2 (−1.1 to 1.6) |
| HR (bpm) ^d | −0.5 (−2.9 to 1.9) | 0 (−2.3 to 2.3) | 1.4 (−1.0 to 3.9) |
| Cortisol awakening response (nmol/L) ^d | −1.1 (−4.2 to 2.1) | −3.1 (−6.4 to 0.1) | −2.2 (−5.4 to 0.9) |
| Cortisol AUC (log, nmol/L) ^d | −0.1 (−0.2 to 0.1) | −0.1 (−0.2 to 0.1) | −0.1 (−0.2 to −0.02) |

CI: confidence interval; HADS: Hospital Anxiety and Depression Scale; PSQI: Pittsburgh Sleep Quality Index; BP: blood pressure; HR: heart rate; AUC: area under the curve.

^aAdjusted for age.

^bDifferent from no treatment group.

^cDifferent from everyday events and no treatment group.

^dAdjusted for age and body mass index.

and everyday event groups. The increase in positive emotional style was greater in the gratitude (0.21, CI (0.01 to 0.40), $p=0.037$) and everyday events (0.20, CI (0.01 to 0.40), $p=0.033$) than no treatment group. The decrease in distress measured with the HADS was greater in the gratitude than everyday events (−2.06, CI (−4.05 to −0.06), $p=0.057$) and no treatment groups (−2.63, CI (−4.67 to −0.60), $p=0.013$). Changes in flourishing did not differ between conditions, but the increase in optimism was greater in the gratitude than everyday events (1.24, CI (0.08 to 2.40), $p=0.043$) and no treatment group (1.40, CI (0.15 to 2.52), $p=0.028$).

To rule out the possibility of over-adjustment, we repeated the above analyses controlling only for age but not for baseline value of SWB measure; however, the results remained unchanged (data not shown).

Effects of interventions on sleep and biological measures

Daily sleep quality was slightly but significantly improved to a greater extent in the gratitude

group (−0.26, CI (−0.46 to −0.05), $p=0.014$) than in the no treatment group. We did not show any differences in changes in sleep disturbances indexed by the PSQI. Our analyses of the biological measures revealed no differences between conditions in systolic BP, HR or cortisol. However, a greater decrease in ambulatory diastolic BP was recorded in the gratitude than no treatment condition (−2.00 mmHg, CI (0.05 to 3.88), $p=0.041$) after adjustment for age, BMI and baseline diastolic BP value. The everyday events condition showed an intermediate response that did not differ from the other two groups. The comparison between experimental conditions therefore showed effects corresponding to the well being measures only for diastolic BP. There was no relationship between the number of completed diary entries and changes in diastolic BP.

When the analyses were repeated controlling only for age (sleep measures) or age and BMI (biological measures) but not for baseline sleep or biological values, as appropriate, the results were identical to those in fully adjusted models (data not shown).

Correlations between changes in SWB, sleep and biology

Using data from the whole sample, we analysed whether changes in SWB measures were correlated with favourable changes in sleep indices. Greater increases in positive emotional style were associated with improved daily sleep quality ($B = -0.28$, CI $(-0.4 \text{ to } -0.1)$, $p < 0.001$), while reduced emotional distress was correlated with lower global sleep disturbance ($B = 0.10$, CI $(0.02 \text{ to } 0.2)$, $p = 0.023$).

The analyses of biological parameters revealed that participants who reported larger increases in life satisfaction showed greater reductions in systolic BP ($B = 0.29$, CI $(0.04 \text{ to } 0.55)$, $p = 0.028$), diastolic BP ($B = 0.32$, CI $(0.15 \text{ to } 0.52)$, $p = 0.003$), and HR ($B = 0.48$, CI $(0.13 \text{ to } 0.83)$, $p = 0.011$). Furthermore, the reduction in HADS distress was associated with greater reductions in diastolic BP ($B = 0.17$, CI $(0.01 \text{ to } 0.34)$, $p = 0.041$); reductions in diastolic BP were also related to increases in flourishing ratings ($B = 0.23$, CI $(0.03 \text{ to } 0.43)$, $p = 0.027$). There were no significant associations between changes in SWB and cortisol. Further analyses without adjustment for baseline values of biological measures were largely unchanged (data not shown).

Discussion

We tested whether an intervention to promote SWB would favourably impact cardiovascular and neuroendocrine responses as well as self-reported sleep. A total of 2 weeks of keeping a gratitude diary led to reductions of emotional distress as well as increases in optimism and positive emotional style. The gratitude intervention was also associated with improved daily sleep quality and with reductions in diastolic BP, when compared with control conditions. However, flourishing and life satisfaction as well as the remaining biological parameters were not sensitive to the experimental manipulation. Notably, we also found that across the complete sample, increases in evaluative, hedonic and eudemonic measures were correlated with reductions in diastolic BP

and HR as well as with improved daily sleep quality and reduced global sleep disturbance.

Cross-sectional studies are consistent with the notion that SWB may be health-protective through its direct effects on biological function, but longitudinal data are lacking. Our study, to the best of our knowledge, is one of the first prospective studies to demonstrate that increases in SWB are correlated with improved biological function in a controlled study design, suggesting that changes in positive well-being may drive healthier biological activity.

In line with the literature (Emmons and McCullough, 2003), our intervention decreased emotional distress and increased positive emotional style. We also found that expressing gratitude led to a significant increase in optimism. Optimism has not been measured in studies that used the gratitude paradigm, so it is difficult to compare our finding with past research.

We demonstrated that across the whole sample, increases in SWB were correlated with favourable cardiovascular responses in a sample of young healthy women, an interesting finding since baseline BP was low, potentially leaving little scope for reductions. The positive effect may be due to the use of ambulatory BP monitoring which provides an index of BP and HR under naturalistic circumstances, instead of standard clinical conditions, making it more sensitive to detect even subtle changes. The analysis of ambulatory data also involved aggregating large numbers of readings over the day, potentially providing more robust estimates than measures obtained under standard clinical conditions.

Changes in well-being were not related to cortisol in our investigation. A number of studies have reported that SWB measures are correlated with lower cortisol levels (Dockray and Steptoe, 2010), but there are large individual differences in cortisol concentrations and it is plausible that our study lacked power to detect changes in cortisol values. Another explanation why cortisol responses were not sensitive to changes in SWB could be that the study was too short. It is possible that neuroendocrine function requires more extended periods of enhanced SWB before changes can be recorded.

We found modest associations between increased SWB and sleep since only daily sleep quality was improved, but not global sleep disturbance. An explanation for these inconclusive findings may be that our experimental manipulation was too brief or the changes in SWB were too small to impact sleep perceptions. Nonetheless, to date, there has been only one (published) gratitude intervention that successfully improved sleep, and our findings partly support these data (Emmons and McCullough, 2003). The correlational analyses across the whole sample revealed that improvements in SWB were associated with favourable sleep perceptions, corroborating past evidence (Hamilton et al., 2007; Steptoe et al., 2008) and lending tentative support to the hypothesis that well-being may promote better sleep (Phelan et al., 2010).

An important feature of this study was the monitoring of objective markers of biological function, which are often not included in health-related studies. The biomarkers were assessed in everyday life outside of the constraints of laboratory settings, potentially increasing ecological validity. However, our study has limitations. The sample comprised mostly White, young and university educated women, so findings cannot be extrapolated to less educated, older, male or more ethnically diverse populations. The measures described here were assessed in the days after the experimental manipulation, so our data shed no light on longer term effects of gratitude paradigm on SWB, sleep and biology. The experimental intervention was only carried out over a few days, and more extended training may be needed to stimulate more comprehensive improvements in SWB, sleep and biology. We included an active control condition so that this group was matched with the experimental condition in terms of attention from the researchers, the materials provided and tasks scheduled. It is notable that in the active control condition some of the SWB measures improved post-intervention, and to some extent, these responses mirrored those in the gratitude condition. A similar trend can be observed across sleep and BP measures, tentatively suggesting that our

results show a difference between active and no treatment groups, rather than between the gratitude and two control conditions. It is plausible that by asking participants to pay attention to everyday events we might have increased their mindfulness. Since mindfulness can reduce anxiety, depressive symptoms and stress (Fjorback et al., 2011), the everyday events condition may have functioned as a mild intervention instead of a neutral condition. We collected a large number of measures, but so as to not increase participant burden any further we did not ask them to wear BP monitors at night. It would have been valuable also to include other measures such as heart rate variability or inflammation. Finally, we focussed only on self-reported sleep, which is susceptible to biases (Jackowska et al., 2011).

Notwithstanding, our study suggests that enhanced SWB is correlated with favourable sleep perceptions and cardiovascular responses. This is consistent with the hypothesis that SWB contributes towards lower morbidity and mortality through healthier biological function and restorative health behaviour.

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