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Effects of relaxation on psychobiological wellbeing during pregnancy: A randomized controlled trial

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Summary Prenatal maternal stress is associated with adverse birth outcomes and may be reduced by relaxation exercises. The aim of the present study was to compare the immediate effects of two active and one passive 10-min relaxation technique on perceived and physiological indicators of relaxation.

39 healthy pregnant women recruited at the outpatient department of the University Women's Hospital Basel participated in a randomized controlled trial with an experimental repeated measure design. Participants were assigned to one of two active relaxation techniques, progressive muscle relaxation (PMR) or guided imagery (GI), or a passive relaxation control condition. Self-reported relaxation on a visual analogue scale (VAS) and state anxiety (STAI-S), endocrine parameters indicating hypothalamic-pituitary—adrenal (HPA) axis (cortisol and ACTH) and sympathetic-adrenal-medullary (SAM) system activity (norepinephrine and epinephrine), as well as cardiovascular responses (heart rate, systolic and diastolic blood pressure) were measured at four time points before and after the relaxation exercise.

Between group differences showed, that compared to the PMR and control conditions, GI was significantly more effective in enhancing levels of relaxation and together with PMR, GI was associated with a significant decrease in heart rate. Within the groups, passive as well as active relaxation procedures were associated with a decline in endocrine measures except epinephrine.

Taken together, these data indicate that different types of relaxation had differential effects on various psychological and biological stress systems. GI was especially effective in inducing self-reported relaxation in pregnant women while at the same time reducing cardiovascular activity.

1. Introduction

Prenatal maternal stress is associated with several adverse consequences like enhanced risk for preterm delivery, foetal growth restriction, and low birth weight (Alder et al., 2007;

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Diego et al., 2006; Field et al., 2004; Lopez Bernal, 2007; Makrigiannakis et al., 2007). Moreover, some studies have shown an association of maternal stress and anxiety with increased arterial blood pressure as well as decreased uterine blood flow (Field et al., 2006a; Glover, 1999; Sjöström et al., 1997; Teixeira et al., 1999). Pregnancy-related health problems like preeclampsia or pregnancy-induced hypertension are associated with elevated maternal stress hormone levels (Hernandez-Valencia et al., 2007; Laatikainen et al., 1991). In addition to these longitudinal studies, experimental research has shown that foetuses show physiological reactivity when their mothers are exposed to a stressor (DiPietro et al., 2003; Fink et al., 2009), which is more pronounced in women with high levels of mental health problems (Monk et al., 2000, 2003, 2004).

Enhanced levels of stress, anxiety and depressed mood have been found in pregnancy to be associated with altered physiological parameters. For example, when experiencing stress or mental health problems, pregnant women's peripheral physiology is characterized by an up-regulated activity of the hypothalamic-pituitary—adrenal (HPA) axis (de Weerth and Buitelaar, 2005; Obel et al., 2005). The HPA is one of the primary stress systems in humans and regulates the release of glucocorticoids such as cortisol (Johnson et al., 1992), whereas the sympathetic-adrenal-medullary (SAM) system, a second important regulator of human stress reactivity, releases the catecholamines norepinephrine (NE) and epinephrine (E). During pregnancy, catecholamine levels have been found to be elevated in women with occupational stress (Katz et al., 1991). Assessment of E and NE is relatively uncommon during pregnancy since they need to be measured in blood plasma and have half-lives of only about 2 min in circulation (Ganong, 2001). Indirectly, SAM activity can be assessed by measuring blood pressure and heart rate changes (de Weerth and Buitelaar, 2005).

How these altered physiological processes in pregnant women contribute to adverse pregnancy outcomes is not well understood. Moreover, although research points at the connection between stress in pregnancy and course of pregnancy, foetal development and birth outcomes, there is little knowledge about the benefit of specific interventions for pregnant women to reduce stress. Relaxation techniques such as pleasant guided imagery (GI) (Daake and Gueldner, 1989), or progressive muscle relaxation (PMR) (Jacobson, 1938), have been proven to be reliable methods in reducing self-reported stress and stress-related physiological activity in various non-pregnant clinical populations, as well as in healthy subjects (e.g., Cruess et al., 2000a,b; Field et al., 1996; Pawlow and Jones, 2002, 2005; Rider et al., 1985; Tsai and Crockett, 1993; Watanabe et al., 2006). Furthermore, it has been demonstrated that brief psychological interventions with GI and PMR are appreciated by patients undergoing elective resection of colorectal cancer after surgery and have been recommended for implementation in these patients (Haase et al., 2005).

Studies on the impact of relaxation during pregnancy reveal various notable effects (e.g., Beddoe and Lee, 2008 for review). First of all, when exercising regularly, relaxation techniques contribute to a reduction in preterm delivery, longer gestation, increase in birth weight, reduction in caesarean section, and reduction in instrumental extraction (Bastani et al., 2005, 2006; Field et al., 2004, 1999; Nickel et al., 2006; Teixeira et al., 2005; Urizar et al., 2004). The immediate impact of relaxation on pregnant women indicates a reduction in experienced stress or anxiety (Bastani et al., 2005, 2006; Field et al., 2004, 1999; Nickel et al., 2006; Teixeira et al., 2005; Urizar et al., 2004). Further, decreased HPA and SAM reactivity have been documented. Most consistently, cortisol declined after induced relaxation (DiPietro et al., 2008; Field et al., 2004; Teixeira et al., 2005; Urizar et al., 2004), while adrenocorticotropin hormone (ACTH) has not been investigated so far. Effects on NE and E are controversial (Field et al., 2004, 1999; Teixeira et al., 2005). Finally, lower heart rate and blood pressure have been observed after practicing a relaxation exercise (Bastard and Tiran, 2006; DiPietro et al., 2008; Nickel et al., 2006; Teixeira et al., 2005).

Although these studies have shown the usefulness of relaxation methods during pregnancy, they are quite diverse and include a wide range of interventions like applied relaxation, massage, hypnotherapy, yoga therapy, verbal instructions, breathing instructions, PMR and GI. Whereas especially yoga therapies (Narendran et al., 2005; Satyapriya et al., 2009) and PMR over a longer period (Field et al., 1999, 2004; Nickel et al., 2006) are likely to enhance psychobiological wellbeing, most studies specify only insufficiently the particular content of the interventions, control conditions are often lacking, randomized controlled trials are sparse, and results are heterogeneous with respect to the pattern of variables that are affected by the intervention. In addition, so far only few research groups directly evaluated if different relaxation techniques have a different impact during pregnancy (Field et al., 2006a, 2004, 1999; Teixeira et al., 2005). Field et al. (1999) compared a massage therapy and a PMR relaxation group over 5 weeks. The massaged pregnant women showed reduced anxiety levels, stress hormones, fewer sleep disturbance, back pain and obstetric and postnatal complications. Women in the PMR group only had decreased anxiety levels after their first session. Teixeira et al. (2005) investigated active versus passive relaxation techniques in pregnant women. Active relaxation was based on hypnotherapeutic methods whereas women in the passive relaxation group sat quietly, reading a women's fashion magazine. A reduction in anxiety and heart rate, but not in stress hormones was found after the active relaxation. The effects of passive relaxation were comparable to those evoked by active relaxation. The diverse outcomes in these studies indicate that different relaxation techniques can have different impact on psychobiological wellbeing in pregnant women.

Therefore, the aim of the present study was to directly compare the immediate effects of two brief active relaxation exercise (PMR and GI) on pregnant women's general psychological, endocrine and cardiovascular functioning. We predicted that — compared to the passive relaxation control condition — both active relaxation techniques will have a positive impact on subjective and objective indicators of relaxation. Active relaxation was hypothesized to elevate the level of perceived relaxation and lead to a greater decline in hormones associated with the HPA-axis and the SAM-system, as well as to reduced cardiovascular activity.

2. Methods

2.1. Participants

Pregnant women from the outpatient unit of the University Women's Hospital of Basel, Switzerland, were contacted and informed about the study. If interested in participating, they were invited to a single experimental visit. Women were included if they were German-speaking, over 18-year old, and pregnant with a single, healthy foetus between the 32nd and 34th week of gestation. Accurate dating of gestational age was confirmed by ultrasound in early first trimester. Exclusion criteria were intake of glucocorticoids, preexisting cardiovascular, nephrological, neurological or metabolic diseases, bad obstetric history as well as intra uterine growth restricted (IUGR) fetuses, fetal malformations, preterm uterine contractions, pregnancy-induced hypertension (PIH) and/or preeclampsia.

Of 76 screened eligible pregnant women, 39 agreed to participate in the study. On average, participants were 33-year old and in their 33rd pregnancy week. 48.7% were primigravida and 59% nulliparous. 97.4% of the women were married or cohabiting, and 76.9% were Swiss or German. 79.5% were presently employed and 66.7% had a college, bachelor's or master's degree.

Participants were informed about the aims and the course of the study and gave written informed consent prior to participation. The local medical ethics committee approved the study protocol.

2.2. Design and procedures

39 participants were randomly assigned to PMR, GI or a passive relaxation control condition (control group, CG) using a randomized number table, resulting in 13 participants for each condition. Participants were not told about group allocation until 1 min prior to the relaxation intervention. They underwent the procedure during a 2-h visit to the hospital between 1300 and 1600 h. Participants were instructed not to eat, drink coffee, black tea, or caffeinated soft beverages, nor to smoke or do physical exercise 1 h prior to the appointment. Once the participant was seated comfortably in a semi-recumbent position on the back, a study midwife attached the blood pressure cuff to the left upper arm and inserted a permanent catheter in the right brachial vein for subsequent blood withdrawals. The foetus was brought into an active behavioral state using Leopold's manoeuvres (Oxorn, 1986) and the study midwife connected the cardiotocogram (CTG) to assess foetal parameters during the entire examination (unpublished data). An accommodation phase of 30 min followed. One minute prior to the 10-min relaxation or passive relaxation interval, pre-relaxation samples of cortisol, ACTH, NE and E were collected and blood pressure (BP) and heart rate (HR) were measured and participants were informed about the forthcoming procedure. The subsequent relaxation exercise was delivered by headphones. During this 10-min interval, experimenter and study midwife left the room in order to prevent confounding factors. The PMR exercise was adopted from Jacobson (1938) and adjusted to pregnancy by leaving out the abdominal musculature in the exercise. In the GI exercise participants were instructed to imagine a safe place and invite a person to accompany them who could promote their feeling of security and wellbeing (Reddemann et al., 2007). Participants in the CG were instructed to sit quietly in a semi-recumbent position during these 10 min without falling asleep. Immediately after the relaxation interval, HR/BP data, saliva and blood samples were collected (post-relaxation 1). Participants were instructed not to speak and, if possible, to restrict movements. During the 20-min post-relaxation period, at +10 (post-relaxation 2) and at +20 min (post-relaxation 3), BP/HR data and samples of saliva and blood were collected again.

After the procedure, participants in the relaxation groups were given a CD with the practiced exercise and it was recommended to them to practice the particular relaxation technique at home.

2.3. Psychological responses

General demographic and pregnancy-related information (e.g., gestational week, pregnancy complications) were assessed during the accommodation period. Before and after the relaxation exercise (pre-relaxation, post-relaxation 1, post-relaxation 2, post-relaxation 3) participants were asked to rate their experienced level of relaxation on a visual analogue scale (VAS) consisting of a horizontal line, 100 mm in length, ranging from "not at all relaxed" at the left end to "extremely relaxed" at the right end. Participants marked on the line the point that represents their perception of the current state. The VAS score could range from 0 to 10 and was determined by measuring in centimeters (with millimeter accuracy) the distance from the left hand end of the line to the point that the participant marked. In addition, in the end all participants were asked if they liked doing their specific relaxation exercise. This was scored on a 5-point Likert-type scale ranging from 1 = "not agreeable at all" to 5 = "very agreeable".

Furthermore, the *Spielberger State-Trait Anxiety Inventory-State Scale* (STAI-S) was used to measure current levels of anxiety before and after the intervention (or control) interval (Spielberger, 1983). STAI-S consists of 20-items scored on a 4-point Likert-type scale and measures the subject's emotional reactions in terms of momentary anxiety. STAI-S has an internal consistency between .86 and .95. Cronbach's alpha is $>$.88 (Spielberger, 1983). The STAI has been used in studies with pregnant women before (Bastani et al., 2005, 2006; Teixeira et al., 2005). In the present study, the German version validated by Laux et al. (1981) was used.

2.4. Cardiovascular responses

Maternal cardiovascular responses were measured four times (pre-relaxation, post-relaxation 1, post-relaxation 2, post-relaxation 3) with a GE DINAMAP® ProCare 400. It records systolic (SBP, mmHg) and diastolic (DBP, mmHg) blood pressure as well as heart rate (HR, bpm).

2.5. Endocrine sampling methods and biochemical analyses

Blood samples were collected at four time points (pre-relaxation, post-relaxation 1, post-relaxation 2, post-relaxation 3) using EDTA-monovettes with anticoagulant for plasma.

Immediately after sampling, blood-plasma samples were centrifuged at 3000 rotations/min during 10 min at 4 °C and stored in test tubes at −80° until analysis. For cortisol sampling, participants were asked to chew on a bite-sized item of paraffin wax to increase salivation (Odusola, 1991). Saliva was then collected into 2 ml tubes and stored at −20 °C until analysis.

The hormonal assays were conducted at the biochemical laboratory of the University of Trier, Germany. For the quantitative determination of cortisol in saliva, a time-resolved fluorescence immunoassay (TF-FIA) was performed. TF-FIA showed excellent correlation with a commercially available radioimmunoassay kit for salivary cortisol measurement (Dressendorfer et al., 1992). Variation coefficient for intra-assay variation ranged between 4.0% and 6.7%, and 7.1% and 9.0% for inter-assay variation. Recovery test scores ranged from 91% to 106%.

ACTH was determined using the ACTH Immunoassay Kit (SG51041). It is a two-site ELISA for the measurement of the biologically active 39 amino acid chain of ACTH and shows a cross reactivity of −5.7% to low amounts (200 pg/ml) of added α-Melanotropine. No further limitations of the specificity (>.01) are reported. In recovery tests where known amounts of ACTH were added to a previously assayed serum sample the kit detected on average 97% of the added ACTH. Controls were run on every plate for determination of inter- and intra-assay variability, which were <7% for this procedure.

NE and E in plasma were assigned with the ClinRep® Complete Kit (Cat.-Nr.: 1000), which is based on high performance liquid chromatography (HPLC) according to the method of Kringe et al. (1982). Intra-assay variation is expected to be around 8%.

2.6. Behavioral response

Participants in the relaxation conditions were recontacted within 10–12 weeks and asked if they followed the recommendation to use the CD and practice the exercise at home at least once.

2.7. Data analysis

Data preparation of all dependent variables included tests for normality, homogeneity of variances, and examination of outliers. If not normally distributed, variables were subjected to transformation by natural logarithm before statistical procedures were applied.

Primary analyses for all dependent variables evaluated differences between groups (PMR, GI, CG) in response to the intervention using analysis of covariance (ANCOVA). ANCOVA is based on the linearity assumption using a general linear model (GLM). To measure immediate treatment response, post-relaxation 1 measurements were compared using pre-relaxation measurements (pre) as covariates. Further, post-relaxation measurements (post-relaxation 1, 2 and 3) were averaged (post) to optimize reliability of intervention response measurement. Again, pre-relaxation measurements (pre) served as covariates. ANCOVA reduces between-subject variance not related to the intervention and is especially suited for evaluating effects of the intervention. Secondary analyses also examined effects of time using repeated measures analysis of variance (RM ANOVA) with the between-subject factor Group (PMR, GI, CG) and within-subject factor Time (pre-relaxation, post-relaxation 1, 2 and 3). All reported results were corrected by the Huynh-Feldt procedure when the assumption of sphericity was violated. Effect sizes are reported as Cohen's *d* (*d*). Data were analyzed using SPSS 15 (SPSS Inc., Chicago, USA).

3. Results

3.1. Sociodemographic and pregnancy-related variables

Participants randomly assigned to the three conditions PMR, GI and CG did not differ in any of the sociodemographic and pregnancy-related variables. Group characteristics are presented in Table 1.

3.2. Psychological responses

3.2.1. Relaxation

In the ANCOVA, ratings on the relaxation scale showed an immediate Group effect $F(2,35) = 6.51$, $p = .004$, $d = .61$ from pre- to post-relaxation 1 and a significant Group effect, if post-relaxation measurements were averaged (post) $F(2,35) = 5.77$, $p = .007$, $d = .57$. Pairwise group comparisons revealed significantly higher relaxation increase in the GI group compared to the other two groups (GI vs. CG: $F(1,23) = 12.11$, $p = .002$, $d = .73$; GI vs. PMR:

Table 1 Characteristics of experimental groups (progressive muscle relaxation, PMR, guided imagery, GI, and control groups, CG).

		PMR (n = 13)	GI (n = 13)	CG (n = 13)	
Age (year)[a]		33.1 (4.7)	34.1 (5.2)	33.0 (4.8)	$F(2,38) = .20$, $p = .82$
Gestational age (week)[a]		32.5 (1.2)	32.3 (1.0)	32.3 (.9)	$F(2,37) = .19$, $p = .82$
Nulliparous[b]		9 (69.2)	7 (53.8)	7 (53.8)	$X^2 = .35$, $p = .84$
Marital status[b]	Married/cohabiting	13 (100)	12 (92.3)	13 (100)	$X^2 = .05$, $p = .97$
Origin[b]	Switzerland/Germany	9 (69.2)	11 (84.6)	10 (76.9)	$X^2 = .20$, $p = .91$
Education[b]	College, bachelor or master degree	9 (69.2)	10 (76.9)	7 (53.8)	$X^2 = .54$, $p = .76$
Presently employed[b]		12 (92.3)	9 (69.2)	10 (76.9)	$X^2 = .45$, $p = .80$

[a] Mean (SD).
[b] Frequency (%).

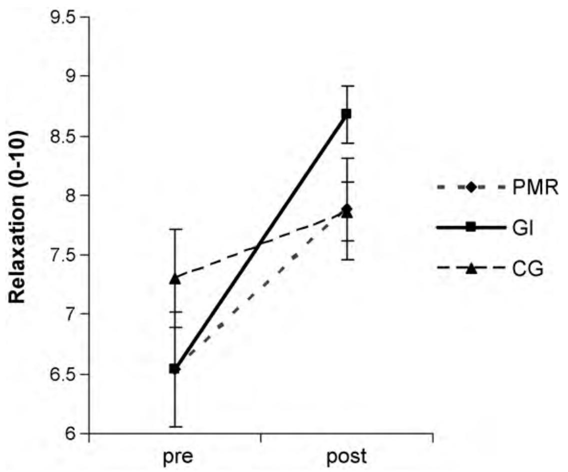

Figure 1 Means (SE) of self-reported relaxation before (pre: pre-relaxation) and after (post: average of post-relaxation 1, 2 and 3) the intervention (PMR = progressive muscle relaxation; GI = guided imagery; CG = control group).

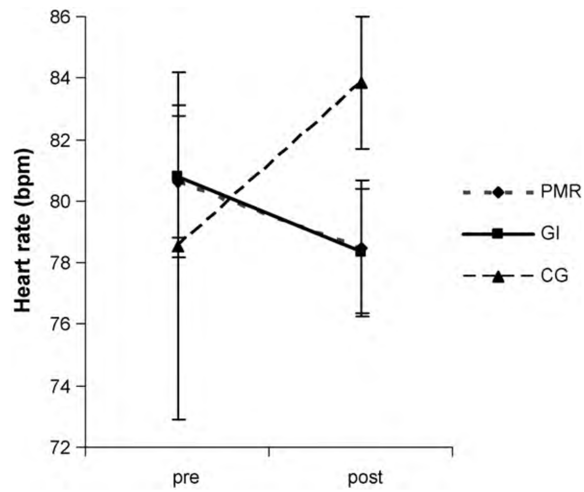

Figure 2 Means (SE) of heart rate values before (pre: pre-relaxation) and after (post: average of post-relaxation 1, 2 and 3) the intervention (PMR = progressive muscle relaxation; GI = guided imagery; CG = control group). Since PMR and GI group showed almost same results, lines are lying on top of one another.

$F(1,23) = 4.52$, $p = .044$, $d = .44$; PMR vs. CG: $F(1,23) = 1.64$, $p = .213$, $d = .27$), indicating that the GI intervention was particularly effective in increasing experienced level of relaxation (see Fig. 1). In addition, participants felt more comfortable with GI than PMR ($F(1,25) = 6.59$, $p = .017$, $d = .52$). The RM ANOVA revealed a significant Time $\times$ Group Group Interaction ($F(6,108) = 2.52$, $p < .025$, $d = .37$) and time effects over the four assessment points were highly significant ($F(3,108) = 25.35$, $p < .001$, $d = .84$).

3.2.2. State anxiety

No Time $\times$ Group Interaction was found and Groups did not differ significantly in change of state anxiety from pre to post, indicating that anxiety was not differentially affected by the interventions. Anxiety decreased equally in all three groups from pre- to post-relaxation, $F(1,35) = 5.14$, $p = .030$, $d = .38$.

3.3. Cardiovascular responses

With regard to HR change, groups differed in the ANCOVA immediately from pre- to post-relaxation 1 at the level of trend ($F(2,35) = 2.55$, $p = .094$, $d = .40$) and significantly, if post-relaxation measurements were averaged (post) ($F(2,35) = 4.01$, $p = .027$, $d = .48$). Pairwise group comparisons showed significantly more HR decline in both relaxation groups compared to the control group (GI vs. CG: $F(1,23) = 5.38$, $p = .030$, $d = .48$; GI vs. PMR: $F(1,23) = .039$, $p = .846$, $d = .04$; PMR vs. CG: $F(1,23) = 4.83$, $p = .038$, $d = .46$) (see Fig. 2). However, in the RM ANOVA no significant effect was found. SBP and DBP did not show any effects of Group or Time.

3.4. Endocrine responses

The ANCOVA analysis revealed no significant Group differences within the endocrine measurements. The RM ANOVAs showed no significant Time $\times$ Group Interactions, however, cortisol, ACTH and NE levels changed significantly over the course of the procedure, whereas in E no significant effects of Time were found (see Table 2 for overall changes). Comparing these Time effects, cortisol declined steadily over time and, together with NE, showed an immediate decrease at post-relaxation 1 (cortisol: $F(1,38) = 16.64$, $p < .001$; NE: $F(1,38) = 15.82$, $p < .001$). On the contrary, ACTH levels declined only 10 min after the relaxation intervention ($F(1,38) = 20.58$, $p < .001$) (post-relaxation 2), but main-

Table 2 Statistics for overall change of cortisol (nmol/l), ACTH (pg/ml), norepinephrine (NE, pg/ml), epinephrine (E, pg/ml) and values during the procedure from pre-relaxation to post-relaxation 1, 2 and 3.

	Overall change			Pre-relaxation [a]	Post-relaxation 1 [a]	Post-relaxation 2 [a]	Post-relaxation 3 [a]
	F	p	d				
Cortisol	10.90	$<.001^{**}$	.56	6.81 (2.44)	6.19 (2.07)**	6.13 (2.22)	5.89 (2.09)*
ACTH	11.68	$<.001^{**}$	.57	31.56 (18.05)	32.07 (15.72)	27.38 (13.64)**	28.64 (13.83)**
NE	4.78	.004**	.36	225.62 (80.95)	200.24 (74.87)**	217.97 (73.67)*	210.07 (76.81)
E	.49	.71	.11	35.74 (20.54)	32.26 (18.58)	33.39 (19.65)	32.26 (19.08)

d: Cohen's d, measure of the effect size. (*) $p < .1$.
[a] Mean (SD).
* $p < .05$.
** $p < .01$.

tained this effect until post-relaxation 3 ($F(1,38) = 7.8$, $p = .008$). Groups did not differ significantly in these declines.

3.5. Voluntary home relaxation exercise

Over one-third of participants in the two relaxation groups (10 out of 26) practiced their relaxation exercise at home at least once. There was no difference between GI and PMR groups (60% of the practicing women applied GI and 40% PMR, $X^2 = .527$, n.s.).

4. Discussion

The present study evaluated the effects of a brief PMR and GI relaxation exercise, as well as a passive relaxation control condition on pregnant women's psychological, endocrine and cardiovascular activity. Our results indicate specific beneficial effects of the active relaxation techniques on pregnant women's psychological and/or cardiovascular state.

So far, only few studies examined levels of anxiety and perceived stress after relaxation exercises, however not using GI as relaxation procedure (Bastani et al., 2005; Bastard and Tiran, 2006; Field et al., 2004; Nickel et al., 2006; Teixeira et al., 2005; Urizar et al., 2004). The prediction that the level of perceived relaxation of pregnant women will improve after engaging in active relaxation exercises was supported by one of the applied interventions. The GI, but not the PMR condition, was effective in increasing self-reported relaxation more than a passive relaxation control condition. In addition, in a direct comparison the GI condition was more effective for inducing relaxation than PMR. Moreover, participants were more comfortable with GI than PMR. On the physiological level, HR values decreased during the active relaxation exercises and were significantly lowered in both active relaxation groups compared to the passive relaxation control condition. While this is consistent with the experienced relaxation effect in the GI condition it indicates a discrepancy between experience and physiology in the PMR condition. Apparently, cardiovascular arousal was reduced by the muscle relaxation exercises whereas participating women did not perceive the exercises as particularly relaxing. As a result, the subjective relaxation measure indicates superiority of GI. This has implications for clinical practice. Psychological interventions can be especially motivating and effective when immediately perceived efficacy is high. Since GI is a comfortable relaxation technique and appears to be especially agreeable to participants, it is likely that this will enhance compliance in pregnant women in a longer-term exercise program. GI not only fosters these psychological effects but also has beneficial effects on physiological reactions associated with the relaxation response.

Our data indicate significant reductions of HPA-axis and SAM-system activity as well as state anxiety in pregnant women after both active relaxation exercises. However, these need to be considered nonspecific since similar reductions were seen in the passive relaxation control condition. Apparently, the passive relaxation exercise was also effective in suppressing stress hormone release. Similar to Teixeira et al. (2005), this result suggests that quiet sitting can be considered a passive relaxation exercise and may be as effective as an active relaxation technique, particularly on objective relaxation parameters. However, long-term effects of active relaxation might overweigh those of plain resting (Field et al., 2004) which may be associated with differential outcomes in HPA-axis and SAM-system variables during a long-term exercise program.

The present study for the first time reports a sustained decline in ACTH concentrations in pregnant women in a relaxation condition. Additionally, we found a decline in salivary cortisol and NE, but not in E concentrations. These findings are in line with those of previous studies that indicated hormonal suppression ascertained by cortisol output (DiPietro et al., 2008; Teixeira et al., 2005; Urizar et al., 2004) after induced relaxation. Only one study assessed SAM-system reactivity by measuring NE and E reactivity (Teixeira et al., 2005). In contrast to our findings, no alterations of NE and E concentrations after GI were found. In pregnant women, lower levels of NE can be interpreted as beneficial as they are associated with less anxiety (Field et al., 2006b) and reduced vasoconstriction, especially in the uterine artery (Fried and Thoresen, 1990).

There are at least two other studies that noted a substantial decline in cortisol after a period of quiet and comfortable resting (DiPietro et al., 2008; Teixeira et al., 2005). On the other hand, similar to the non-pregnant population, pregnant women's hormonal profiles exhibit a pronounced circadian rhythm (Allolio et al., 1990) and the temporal variation observed in our study may have merely been a reflection of this. However, cortisol levels of women in the GI group showed an average decline of .511 nmol/l from post-relaxation 1 to post-relaxation 3, which is almost four times higher than the decline estimated for non-relaxed pregnant women during a 20 min period in the time between 1100 and 1700 h (.138 nmol/l) (Harville et al., 2007). Therefore, it is unlikely that this decline is merely a result of circadian effects. In contrast, the decline in cortisol noted for women in the PMR and control condition (PMR: .185 nmol/l; CG: .208 nmol/l) did not differ substantially from the decline expected for non-relaxed pregnant women. Although groups did not differ significantly in their decline on this measure, likely due to insufficient statistical power, this observation should be followed up in future studies.

It is of note that the decrease of HR in the active relaxation groups may indicate increased activation of the parasympathetic system, which is particularly involved in processes of regeneration and relaxation. This may explain the discrepancy in the pattern of HR, BP and SAM-system results: While BP and SAM-system parameters predominantly reflect sympathetic nervous system activation, HR is dually innervated by the sympathetic and parasympathetic branches (Berntson et al., 1997). Future studies should particularly include vagal activity quantified by ECG-derived respiratory sinus arrhythmia in the assessment.

In summary, the current study demonstrates that different types of relaxation had differential effects on various psychological and biological stress systems. However, it remains unclear to what extent neurological alternations, recently investigated in meditation studies (Lutz et al., 2008), contribute to these outcomes. Although reciprocal relationships between subjective experience and biological systems are often complex, our findings indicate that the GI relaxation technique is particularly effective for elevating pregnant women's level of relaxation while at the same time reducing cardiovascular activity.

Several limitations of our study are noteworthy. The majority of participating women were highly educated, motivated to learn more about the obstetric benefits of relaxation techniques and had stable partners and jobs, making them not completely representative of the general population. Our sample consisted of healthy participants. Future investigations may examine the relaxation response in pregnant women with mood or anxiety disorders or high levels of reported stress since these may especially benefit from the relaxation exercises (Bastani et al., 2006; Beddoe and Lee, 2008; Vythilingum, 2008). Finally, we examined a single and brief relaxation intervention and therefore, drawing of specific conclusions is limited. Repetitions of the relaxation trial at different times of the day and on different days could have made the design more robust. Furthermore, frequent relaxation training over a longer period is likely to induce larger effects and highlight differences between the studied relaxation techniques, with pronounced differential psychobiological effects for both mother and foetus (Schommer et al., 2003).

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Conflict of interest

All authors declare that they have no conflicts of interest.

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