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ARTICLE

Teachers' physiological and self-reported stress, teaching practices and students' learning outcomes in Grade 1

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Abstract

Background: Teachers' self-reported stress is related to the quality of teacher–student interactions and students' learning outcomes. However, it is unclear if teachers' physiological stress is related to child-centred teaching practices in the classroom and whether teaching practices mediate the link between teachers' stress and students' learning outcomes.

Aims: We studied the effect of teachers' physiological stress and self-reported stress on their teaching practices and thereby on students' learning outcomes in math.

Sample: A total of 53 classroom teachers and 866 Grade 1 students participated in the study.

Methods: Salivary cortisol in the middle of the school day and cortisol slope from morning peak to evening were used as indicators of teachers' physiological stress, in addition to self-reported teaching-related stress. Teaching practices were observed with the ECCOM instrument. Students' math skills controlled for gender and previous skills were used as a measure of learning outcomes. Data were analysed with a two-level SEM.

Results: Teachers' physiological stress did not have an effect on teaching practices or students' math skills. Teachers reporting less stress used relatively more child-centred teaching practices compared with teacher-directed ones. These practices had a marginal effect on classroom-level differences in the gain of students' math skills in Grade 1. There was neither a direct nor indirect effect from teachers' stress on students' math skills. Altogether, our model explained 77% of classroom-level variance in math skills.

Conclusions: Teachers' self-reported stress has an effect on their teaching practices, which, in turn, have a marginal effect on students' learning outcomes.

KEYWORDS

math skills, physiological and self-reported stress, primary school, teachers' stress, teaching practices

INTRODUCTION

Teachers' stress and general well-being are crucial determinants of the classroom environment, as these are reflected in instructional and classroom management decisions teachers make and, therefore, affect students' learning experiences in the classroom (Jennings & Greenberg, 2009; Roeser et al., 2013; Travers, 2017; Wettstein et al., 2021). We already know that teachers' well-being is related to their students' math achievement (Klusmann et al., 2016) and that their teaching practices are related to the students' gain in math skills in Grade 1 (Lerkkanen et al., 2016). Furthermore, teachers' well-being, like their enjoyment of teaching, has a positive effect on students' learning outcomes through teachers' more effective instructional practices (Kunter et al., 2013). Conversely, teachers' lower well-being has a negative effect on students' outcomes in math through the instruction teachers employ (McLean & Connor, 2015). Yet, it is unknown how teachers' stress, both physiological and self-reported, affects the development of their students' academic skills during Grade 1 through observed teaching practices deployed by teachers in the classroom.

Teachers' physiological and self-reported stress

Stress is considered as an interaction between a person and an environment that the person considers exceeding their resources and that interferes with their equilibrium (Lazarus & Folkman, 1984). Teachers' stress is considered to be of great importance, as it is reflected in both their general well-being and job satisfaction and is also manifested in their students' learning outcomes (Johnson et al., 2005; Travers, 2017). In their theoretical–empirical model of teachers' stress, Montgomery and Rupp (2005) summarized teachers' stress as a response that depends on stressors in the school environment and teachers' coping skills, which might reveal to burnout. The response can be affective, cognitive, behavioural or physiological, and as the stress itself cannot be detected, we can only observe the stress response (Schlotz, 2019).

Teachers' stress responses can be examined as physiological stress or self-reported stress. Physiological stress as an objective measure refers to the evaluations of the potentially stressful situations, while self-reported stress as a subjective measure refers to the considerations about one's coping ability (Weckesser et al., 2019). Furthermore, measuring teachers' objective stress during the working day allows for avoiding the retrospective bias of evaluations (Wettstein et al., 2021). In the school context, teachers' physiological stress during working days has gained increasing interest in recent years (Katz et al., 2016; Wettstein et al., 2020). Still, there remains a striking lack of knowledge on how teachers' objective, physiological stress affects their teaching practices in the classroom, and thereby also their students' learning experiences and academic outcomes.

As referenced above, physiological stress and self-reported stress address various aspects of the stress construct, and both are important to consider while studying the effect of teachers' stress on students' learning experiences. To date, studies addressing between-person differences have shown that adults' self-reported stress is not related to their long-time physiological stress (e.g. higher hair cortisol levels), while the average number of daily hassles or stress appraisal are associated with higher hair cortisol levels (Gidlow et al., 2016; Weckesser et al., 2019). Research addressing teachers' objective and subjective stress measures has shown the same results: teachers' self-reports are not related to their higher physiological stress compared with the sample mean, measured by salivary cortisol levels in the morning and daily cortisol output (Katz et al., 2016). On the contrary, the perceived job strain is related to some extent to participants' higher salivary cortisol levels (Steptoe et al., 2000). Comparing teachers' stress in the fall and spring semesters revealed that although self-reported stress did not change over the year, physiological stress response showed some dysregulation, exhibiting higher morning cortisol levels in spring compared with fall (Katz et al., 2017). Also, it has been shown that teachers' morning cortisol response is higher on working days compared with days off (Bellingrath et al., 2008; Wettstein et al., 2020).

Teachers' stress and teaching practices

Studies using classroom observations have shown that teachers with higher self-reported stress used less instructional dialogue for supporting students' higher-order thinking skills (Bottiani et al., 2019), offered less emotional support, showed a lower quality of classroom organization (Penttinen et al., 2020) and were more likely to criticize their students (Herman et al., 2020). Teachers' well-being is also related to their use of individualized instruction and expression of warmth in the classroom (McLean & Connor, 2015). In relation to the classroom observations, the self-reports on classroom practices led to comparable results. Teachers who reported less stress also reported that they paid more attention to the meaningfulness of each student's individual learning experiences, responded more to students' needs and changes in their behaviour, praised students' achievement and used less reactive classroom management strategies (Clunies-Ross et al., 2008; Turner & Thielking, 2019; Wong et al., 2017). However, it has to be pointed out that the relation between child-centredness in teaching and teachers' well-being is not completely uniform. For example, child-centred beliefs about teaching can also be related to higher self-reported stress, which has been explained through teachers' high demands on themselves if they emphasize child-centred learning (Hur et al., 2015). Although there have been studies combining teachers' self-reported stress or general well-being with their self-reported or observed classroom instruction, to the best of our knowledge, there have been few investigations of the relation between teachers' physiological stress and teaching practices. Only very recently has it been shown that higher physiological stress measured by heart rate is related to increased teacher-directed activities in the classroom at the within-teacher level (Junker et al., 2021).

To address teaching practices, we focused on the proportion that teachers use child-centred practices compared with teacher-directed practices (Roubinov et al., 2020). The first highlights constructivist learning experiences manifested in teachers relying on students' previous knowledge and skills and emphasizing students' interests, active role, social relationships and self-regulation during the learning process. Teachers deploying child-centred practices also support children's social skills and are sensitive to their individual needs and interests. Teacher-directed practices, in contrast, emphasize didactic learning experiences focusing on the content and structure of learning materials and the teacher's control of the classroom (Stipek & Byler, 2004). Teachers using teacher-directed practices emphasize drill and practice and subscribe to the premise that basic skills should be acquired before advanced learning (Stipek et al., 1998).

Teachers' stress and teaching practices affecting students' learning outcomes

Previous studies have shown that teachers' well-being is reflected in students' well-being, learning outcomes and general competencies. For example, teachers' emotional exhaustion is shown to be related to students' lower academic outcomes at the classroom level (Arens & Morin, 2016; Klusmann et al., 2016; Madigan & Kim, 2021). Students' math skills are lower if their teacher feels stressed, exhausted or depressed, and this is typical in classes of students with lower prior skills (Herman et al., 2018; McLean & Connor, 2015). Higher teacher stress is also associated with their students' lower social competence in the classroom (Siekkinen et al., 2013). Thus, teachers' ability to better cope with stress is related to students feeling less stressed (Braun et al., 2020). It is worth mentioning that students also notice their teacher's level of well-being. For example, the more exhaustion the teacher exhibits, the less social and emotional support students perceive from the teacher (Oberle et al., 2020).

Teaching practices also have an effect on students' learning experiences in the classroom. In general, it can be concluded that teachers who use child-centred practices that encourage collaboration and students' interaction with their teacher and the learning content have a clearly positive effect on their students' learning outcomes and academic interest in the classroom (Lerkkanen, Kiuru, et al., 2012; Lerkkanen et al., 2016). Teachers' use of more child-centred practices compared with teacher-directed ones in the classroom is related to less externalizing behaviour by students (Roubinov et al., 2020). Teachers' positive responses while managing the classroom and giving feedback to students are related to students being more focused on learning tasks, while negative responses and feedback are related to students being less focused (Clunies-Ross et al., 2008). However, the benefits of different instructional approaches on students' learning behaviour might depend on the overall classroom composition. Child-centredness is more beneficial in classrooms with more task-focused students, while teacher-directedness has a positive effect on students' learning behaviour in classrooms characterized by high task-avoidance (Kikas et al., 2014).

The effect of teachers' well-being on students' academic skills manifests in the teaching practices teachers employ in the classroom. Less stressed teachers deploy effective and student-centred instruction (Jennings & Greenberg, 2009; Roeser et al., 2013). The few studies combining teachers' well-being, teaching practices and students' learning outcomes have so far shown that teachers' classroom practices mediate the relation between their low well-being and students' lower academic gains (McLean & Connor, 2015). Also, teachers' enthusiasm during instruction mediates the link between teachers' job satisfaction and students' better math skills (Kunter et al., 2013).

The results referred above demonstrate the effects of teachers' self-reported stress or well-being on students' well-being, learning outcomes or learning experiences. However, the study of teachers' physiological stress in relation to students' learning experiences is in its initial stages. So far, we know that adults' physiological stress or arousal is at least to some extent related to challenging situations (Khan et al., 2019; Roos et al., 2021). From classrooms, it has been shown that teachers' physiological stress is related to their students' motivation, as teachers have higher heart rates in classes with less engaged students (Junker et al., 2021). Students, in turn, perceive teachers' well-being through their classroom instruction (Oberle et al., 2020). Still, to the best of our knowledge, no evidence has been shown to this point about the effect of teachers' physiological stress on students' learning outcomes and, furthermore, on the role of teaching practices in this relationship.

Aims

In the current study, we examined the relations among teachers' physiological (i.e. objective) and self-reported (i.e. subjective) stress, their teaching practices and students' learning outcomes in math. Teachers' age and students' gender were used as control variables explaining teachers' stress and students' math skills, respectively, in a two-level structural equation model (SEM). Specific research questions and respective hypotheses were as follows:

1. How are teachers' physiological stress and self-reported stress associated with teaching practices?

Hypothesis 1: We expected that teachers with both lower physiological stress (i.e. have lower cortisol levels and a steeper slope) and self-reported stress use more child-centred practices compared with teacher-directed ones (Junker et al., 2021; Penttinen et al., 2020).

2. How are teachers' physiological stress and self-reported stress related to the gain of students' math skills during the academic year?

Hypothesis 1: We expected that students learn more in math in classes where teachers are less physiologically stressed (i.e. have lower cortisol levels and a steeper slope) and also perceive less stress (Arens & Morin, 2016; Herman et al., 2018).

3. Do teachers' teaching practices mediate the relation between teachers' stress and students' math skills?

Hypothesis 1: We expected that the relationship between teachers' stress and students' math skills would be mediated by teachers' practices (Jennings & Greenberg, 2009; Kunter et al., 2013; McLean & Connor, 2015).

METHOD

Participants and procedure

Our study was part of a larger longitudinal research project exploring teachers' and students' stress and interaction in the classroom. In total, 866 Grade 1 students (50% boys) and their 53 (3 male) teachers participated in the current study. All teachers were classroom teachers who taught all subjects, including math.

Students' math skills were evaluated at the beginning of Grade 1 in 2017 with individual tests and in the spring of Grade 1 in 2018 as group tests administered by trained research assistants. Teachers' stress and teaching practices were investigated in the spring of Grade 1. Salivary cortisol samples for measuring physiological stress were collected by teachers themselves on two working days. Teachers answered a questionnaire concerning their stress on approximately the same days as physiological stress was measured. Teaching practices were video recorded on the first cortisol sampling day by trained research assistants.

All teachers and parents of the engaged students provided written consent to participate in the study. The study was approved by the university ethics committee before the data collection started, and it was determined to be in line with the Finnish National Board on Research Integrity (Finnish Advisory Board on Research Integrity, 2012).

Measures

Teachers' physiological stress

Salivary cortisol was used as an indicator of teachers' physiological stress as it is suitable for ecologically valid ambulatory assessments (Kudielka et al., 2012). Cortisol is a corticosteroid hormone, released from hypothalamic–pituitary–adrenal (HPA) axis during the stress response (Black, 2002). It affects a wide range of tissues in the body with an aim of helping the organism to cope with stress and maintain the homeostasis (de Kloet et al., 1998). Increased cortisol levels can indicate either chronic stress, changes in the cortisol feedback system or acute stress response (Herman et al., 2016). Cortisol release in the body has a certain diurnal rhythm—increasing rapidly in the morning, after awakening (i.e. cortisol awakening response—CAR), followed first by a sharp decrease and then a steady decline during the day (Kudielka et al., 2012).

Cortisol was sampled on two working days. On both days, teachers were asked to collect six saliva samples per day: on awakening, 30 and 45 min after awakening, in the middle of the school day at approximately 10:00 a.m., at the end of the school day between 12:00 and 1:00 p.m. and at bedtime. Teachers collected saliva samples using synthetic Salivette® Cortisol swabs (Sarstedt). Samples were assayed in Dresden LabService GmbH using the Cortisol Luminescence Immunoassay (CLIA RE62011; IBL International Corp.). Samples with cortisol concentrations greater than 73 nmoL/L (n = 5) were excluded from the analyses as being physiologically impossible (73 nmoL/L assayed with IBL CLIA corresponds approximately to 60 nmoL/L assayed by LC-MS/MS; Miller et al., 2013). Samples (n = 4) were also excluded if a participant violated the 30 min eating restriction or reported being sick on the sampling day.

Our cortisol sampling protocol required teachers to take the first cortisol sample on awakening and to record the sampling time but not the awakening time. In 11 cases from Day 1 and 8 cases from Day 2, teachers' morning CAR was negative, indicating the high probability of protocol noncompliance and having not taken the sample immediately after awakening (Kupper et al., 2005; Stalder et al., 2016). Therefore, we decided not to use diurnal cortisol curve from awakening or the area under the curve as physiological stress indicators. We instead employed two cortisol indicators based on previous literature. First, a higher cortisol level at the middle of the school day (at approximately 10:00 a.m.) was interpreted as higher physiological stress (Berry et al., 2014; Nakajima et al., 2012; Steptoe et al., 2000). We also estimated the highest value of three morning samples, aggregated by days and interpreted this cortisol morning peak as the highest level of cortisol during the CAR. As the second cortisol indicator, a flatter (less positive) cortisol slope for the change from the cortisol morning peak to bedtime sampling was interpreted as higher physiological stress (Adam et al., 2017; Wolf et al., 2008).

Cortisol values from two measurement days were aggregated to diminish the within-person variability in salivary cortisol (Massey et al., 2016; Wolf et al., 2008). Aggregated indicators were natural logarithm transformed in order to reduce positive skewness (Adam & Kumari, 2009). One teacher had given only one valid cortisol sample on one measurement day, and cortisol data from this teacher were excluded from the analyses.

Teachers' self-reported stress

Teachers' self-reported teaching-related stress was measured by a questionnaire adapted for teachers from Gerris's Parental Stress Inventory (Gerris et al., 1993). In previous literature, it has been shown a good reliability and validity. Self-reported stress is negatively related to the instructional support and classroom management observed in the classroom and positively related to the teachers' self-reported exhaustion (Penttinen et al., 2020; Virtanen et al., 2018). Teachers were asked to rate on a 5-point Likert scale (1 = 'does not apply to me at all', and 5 = 'applies to me very well') how much they agreed with three items (e.g. 'I sometimes feel that guiding children is an overwhelming task for me.'). Internal consistency of the scale was good (α = .76). The mean of three items was used in further analyses.

Teaching practices

The Early Childhood Classroom Observation Measure (ECCOM; Stipek & Byler, 2004; for Finnish validation, see Lerkkanen, Kikas, et al., 2012; Tang et al., 2017) was employed to observe the extent to which child-centred and teacher-directed practices related to instruction, management and social climate were present in three video-recorded lessons on one school day. For assessing inter-rater reliability, the teaching practices of 11 teachers were rated by two observers. Agreement between observers was good (intraclass correlation coefficient ICC[1] = .88 for child-centred practices and ICC[1] = .79 for teacher-directed practices). For further analyses, one observation out of two was randomly chosen for each teacher.

Both dimensions of teaching practice were assessed on three subscales: classroom management (4 items), climate (4 items) and instruction (7 items) and rated on a 5-point scale (see Table S1 for the description of subscales). On each item, scale points corresponded to the percentages of instructional time teachers used either child-centred or teacher-directed practices (1 = '0%–20%', 5 = '81%–100%'). Means of all items over all three subscales were used for estimating child-centred and teacher-directed practices (Tang et al., 2017). According to the theory, teachers deploy both child-centred and teacher-directed practices in the classroom, but usually one of these is dominating (Stipek & Byler, 2004). In authentic classroom practice, child-centred and teacher-dominated practices are often highly negatively correlated ($r = -.89$ in our sample) and cannot be added into the same statistical model because of the multicollinearity. Therefore, we used the ratio of child-centred practices to teacher-directed practices, observed in the classroom, in the analysis (Lerkkanen, Kiuru, et al., 2012; Roubinov et al., 2020). A ratio score larger than one means that the teacher employs more child-centred practices, compared with the teacher-directed ones. A ratio score less than one means that teacher-directed practices are dominating in the classroom.

Students' math skills

Students' math skills were assessed with the Basic Arithmetic Test in both measurement times (Aunola & Räsänen, 2007). There were 28 addition and subtraction tasks in the test. Tasks gradually became more difficult. Students had three minutes to complete as many tasks as possible. A sum of correct answers was used in the further analyses. Internal consistency of the math skills test was high in both measurement times (Cronbach's $\alpha = .80$ for fall and $\alpha = .86$ for spring). The amount of variance of the math test attributed to the classroom level (intraclass correlation) was 9% in the fall measurement and 14% in the spring measurement.

Covariates

Teachers' physiological and self-reported stress indicators were controlled for teachers' age in years. In the within level, students' math skills in both fall and spring were controlled for gender (0 = girls and 1 = boys).

Analysis strategy

A two-level SEM with maximum likelihood (ML) estimator in statistical package Mplus 8.5 (Muthén & Muthén, 1998–2020) was used for testing the hypothesized model. At the student level, classroom-mean centred math skills in fall predicted math skills in spring. Math skills in both measurement times were predicted by gender. At the classroom level, math skills in fall were used as a classroom-mean averaged observed variable and math skills in spring as a latent variable. Teachers' stress indicators predicted both teaching practices and students' math skills at the classroom level. Teaching practices were designated to explain students' math skills. Teachers' stress indicators were predicted by teachers' age. Residuals of all three stress indicators were allowed to correlate.

The indirect effects of teachers' stress indicators on students' math skills through teaching practices were evaluated using the MODEL CONSTRAINT command. Three parameters of indirect effects were added to the model, from each of three stress indicators through teaching practices to students' math skills at the classroom level.

We used the chi-square test and conventional model fit indices (CFI, RMSEA and SRMR) to estimate the consistency of the hypothesized model and data. The nonsignificant ($p < .05$) chi-square test

TABLE 1 Descriptives and bivariate correlations of student- and classroom (teacher)-level measures used in the study

Measure	*N*	Mean/%	*SD*	Min	Max	1.	2.	3.	4.	5.	6.	7.	8.	9.
Student level														
1. Math Grade 1 fall	845	4.87	3.13	0	20	–								
2. Math Grade1 spring	866	9.76	4.19	0	25	.68***	–							
3. Gender (% of boys)[a]	866	50	–	–	–	.06	.08*	–						
Classroom (teacher) level														
4. Math Grade 1 fall	53	4.89	1.36	2.00	8.80	–	–	–	–					
5. Math Grade1 spring	53	9.74	2.07	4.33	14.20	–	–	–	.77***	–				
6. Teacher's age	53	44.60	8.92	27	62	–	–	–	.20	.22	–			
7. Cortisol at 10:00 am[b]	52	2.30	0.52	1.31	3.73	–	–	–	−.08	−.13	−.29*	–		
8. Cortisol slope[c]	50	3.50	0.45	1.91	4.16	–	–	–	.01	−.02	−.12	−.07	–	
9. Self-reported stress	52	2.14	0.74	1.00	4.00	–	–	–	−.13	−.06	−.07	−.04	.22	–
10. ECCOM CC/TD[d]	53	1.33	0.76	0.30	3.70	–	–	–	−.01	.10	.04	−.06	−.09	−.46***

[a]Gender is coded as 0 = girls, 1 = boys.

[b](nmol/l), natural logarithm transformed.

[c]Difference between the maximum cortisol level (nmol/l) in the morning and the cortisol level at bedtime (nmol/l), natural logarithm transformed.

[d]Ratio of child-centred practices to teacher-directed ones.

$*p < .05$. $***p \leq .001$.

indicated that the data fit the model well. Model fit indices (CFI > .95, RMSEA < .06 and SRMR < .08) referred to the good model fit (Hsu et al., 2019; Hu & Bentler, 1999).

RESULTS

Descriptive statistics and intercorrelations of all indicators are provided in Table 1. The results of the two-level regression analysis are presented in Figure 1. Overall, the model fit indices of the tested regression model were very good ($\chi^2 = 2.02$, $df = 6$, $p = .918$, RMSEA = .00, CFI = 1.00, SRMR < .001 for within and SRMR = .03 for the between level), indicating that our data fit the hypothesized model well.

First, we were interested in the effects of teachers' physiological and self-reported stress on their teaching practices. Neither of the two physiological stress indicators were related to teaching practices (β = .08, $p = .458$ for cortisol at 10:00 a.m. and β = −.01, $p = .951$ for cortisol slope from the peak). Teachers' self-reported stress, in turn, was negatively related to using more child-centred practices (β = −.47, $p < .001$). Altogether, stress indicators explained 22% of the variance in teaching practices. We also have to note that teachers' self-reported stress was not related to their physiological stress at 10:00 a.m. ($r = -.09$, $p = .634$) in the model and had a marginal positive correlation with the cortisol slope from morning peak to bedtime ($r = .21$, $p = .072$). Teachers' age was negatively related to the cortisol level at 10:00 a.m. (β = −.30, $p = .026$) and was not related to the cortisol peak and self-reported stress.

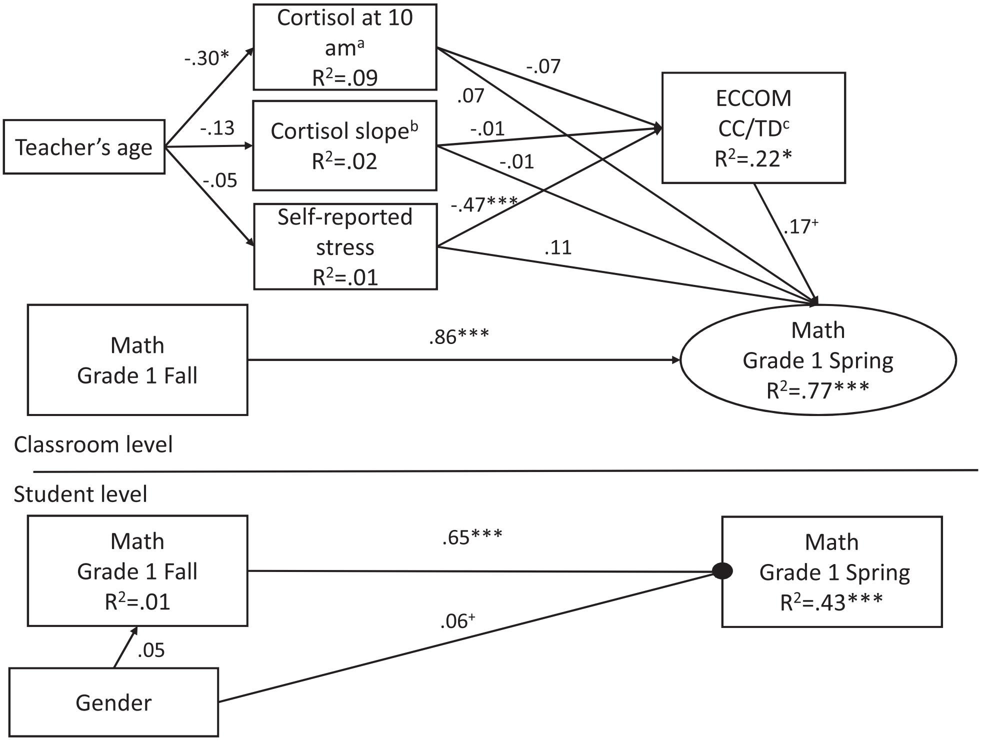

FIGURE 1 Relations between teachers' physiological and self-reported stress and their teaching practices and students' learning outcomes. Results from two-level SEM. *Note*. Grade 1 fall math skills at the student level were classroom-mean centred, and at the classroom level, the mean of math test scores in the classroom was used. Insignificant correlation coefficients between residuals of stress variables have been omitted from the figure. [a]Cortisol at 10:00 a.m. from Day 1 and Day 2 averaged and natural logarithm transformed. [b]Cortisol slope from the morning peak to evening sampling from Day 1 and Day 2 averaged and natural logarithm transformed. [c]Ratio of child-centred practices to teacher-directed ones. $^{+}p < .10$, $^{*}p < .05$, $^{***}p < .001$

Next, we were interested in how teachers' physiological stress and self-reported stress are related to students' math skills. Students' math skills in Grade 1 spring were first controlled by students' gender and their math skills at the beginning of the school year at the student level. Previous math skills explained a large proportion of the differences between students in their math skills in spring ($\beta = .65$, $p < .001$). Boys had slightly better math skills in spring compared with girls ($\beta = .06$, $p = .055$). At the classroom level, differences between classrooms in students' average math skills in spring were also largely explained by students' average skill level at the beginning of the school year ($\beta = .86$, $p < .001$). Still, teaching practices had a marginal effect on students' math skills at the classroom level ($\beta = .17$, $p = .067$). In classrooms where teachers used more child-centred practices compared with teacher-directed ones, students' math skills developed faster during Grade 1. Teachers' stress had no direct effect on the gain of students' math skills at the classroom level.

Finally, we evaluated the classroom-level indirect effect of teachers' physiological and self-reported stress on students' math skills through teaching practices. We found no significant indirect effect from any of the three teachers' stress indicators on students' math skills through teaching practices.

DISCUSSION

We investigated teachers' physiological and self-reported stress linked to the observed teaching practices in primary school classrooms and to students' learning outcomes in math. The novelty of our study is in combining the effects of both objective and subjective stress indicators on teaching practices and students' learning (see Wettstein et al., 2021). Our results revealed that self-reported stress is related to teachers' using fewer child-centred teaching practices compared with teacher-directed ones, but physiological stress is not associated with teaching practices. Furthermore, we took into account students' math skills at the beginning of the academic year and thus investigated the effect of teacher-related factors on the average gain in students' math skills during the first school year. The results showed a marginal effect of child-centred practices prevailing in teaching and the increase in students' learning outcomes. We also studied the classroom-level path from teachers' stress to students' learning outcomes through the practices of teachers, although our data did not support the mediation hypothesis.

Physiological and self-reported stress and teaching practices

First, the results showed that teachers' physiological stress and self-reported stress were not related in our sample of Grade 1 teachers. This supports previous findings in the educational context showing no relations between physiological and self-reported stress (Katz et al., 2016) or physiological stress and objectively observed stressors, such as students' disruptive behaviour in the classroom (Junker et al., 2021). Thus, our results endorse suggestions provided by previous studies that teachers' stress in authentic classroom settings is a diverse construct and that there is a difference between physiological stress response and psychologically perceived stress (Junker et al., 2021; Katz et al., 2016). As self-reported stress might indicate the presence of stressors in the classroom, physiological stress more likely refers to teachers' chronic exhaustion (Katz et al., 2016; Wong et al., 2017).

Thus far, several studies have linked teachers' self-reported stress and well-being with their classroom practices (Clunies-Ross et al., 2008; McLean & Connor, 2015; Penttinen et al., 2020; Turner & Thielking, 2019; Wong et al., 2017). All these studies have shown that lower teachers' stress and higher well-being are related to more supportive, responsive, individualized and warmer teaching practices. Our study confirms the results referred to above about teachers' lower self-reported stress being associated with using more child-centred teaching practices in the classroom. As self-reported stress is interpreted as evaluations about one's coping abilities (Weckesser et al., 2019), we suggest that teachers not believing in their ability to manage stressful situations is a key factor related to using fewer child-centred teaching practices in primary school classrooms. Previously, teachers' lower stress has been shown to be related to offering more instructional support to students, including supporting their higher-order thinking skills and facilitating discussions (Bottiani et al., 2019; Penttinen et al., 2020), indicating that feeling stressed might diminish using more demanding practices in the classroom. Also, as stressed teachers tend to use more reactive classroom management strategies (Clunies-Ross et al., 2008; Herman et al., 2020), it might be difficult for them to switch to a child-centred approach during the teaching process.

To date, there remains a lack of knowledge about the relations between teachers' physiological stress and the teaching practices they provide. Recently, it has been shown that teachers' higher situational (within-teacher level) physiological stress in the classroom is linked to using more teacher-centred activities (Junker et al., 2021). Our results obtained with aggregated physiological stress indicators did not confirm this relation with teaching practices. If we consider physiological stress as indicating reflections of the situations and self-reports as denoting coping abilities (Weckesser et al., 2019), it might be that in actual classroom situations, teachers' evaluating situations as stressful might not lead them to change their teaching practices accordingly. In turn, it seems that teaching practices become stricter, emphasizing teacher control and focusing on the acquisition of basic skills if the teacher subjectively feels they do not have enough resources for coping with stressful situations.

Teachers' stress, teaching practices and students' math skills

Next, we investigated how teachers' stress affects students' math skills in Grade 1. We applied two-level SEM for separating within- and between-classroom variances of students' math skills. We also accounted for students' math skills at the beginning of the school year when estimating the effect of teachers' stress on the average classroom level gain in math skills during the school year. Our hypothesis relied on previous studies on the negative effect of teachers' exhaustion (Arens & Morin, 2016; Klusmann et al., 2016), stress and burnout (Herman et al., 2018; Madigan & Kim, 2021) on students' learning outcomes. Nevertheless, our data did not support the hypothesis of the negative effect of physiological stress and/or self-reported stress on classroom-level academic achievement. Our study differs from previous studies in terms of accounting students' skills at the beginning of the school year and modelling the effect of teachers' stress on the classroom-level increase in students' math skills over the year. Our results also suggest that teachers' everyday stress that is not considered chronic as well as has not having reached the level of acute exhaustion might not be revealed directly in students' learning outcomes, contrary to the conclusions by Madigan and Kim (2021) in their recent review of teachers' burnout and students' academic achievement.

Our final research question concerned the mediational effect of teachers' classroom practices in the relation between teachers' stress and students' math skills. McLean and Connor (2015) showed that the direct effect of teachers' low well-being on students' lower math skills disappears if teachers' emotional support and individualized instruction are added into the model. They suggested that teaching practices mediate the relation between teachers' self-reported depressive symptoms, as an indicator of low well-being, and students' learning outcomes (McLean & Connor, 2015). Concerning the positive side of the teachers' well-being, it has been shown that teachers' enjoyment of teaching is related to the high school students' math achievement through teachers' classroom management strategies (Kunter et al., 2013). Both of these results are consistent with theoretical approaches of the effect of teachers' well-being on students' learning outcomes (Jennings & Greenberg, 2009; Travers, 2017).

Our data did not support the mediation effect from teachers' stress through their teaching practices to students' gain in math skills during the school year. However, altogether, we demonstrated the effect of teachers' stress on their teaching practices and also the marginal effect of teaching practices on students' math skills at the classroom level. At the very least, teachers' subjective stress seems to make a difference in their classroom behaviour and the instructional choices they make. It can be expected that this, in turn, shapes students' overall learning experiences, including acquiring academic skills. It is also possible that teachers' stress and teaching practices have a different effect depending on teachers' experience

(Montgomery & Rupp, 2005) or the classroom composition (Kikas et al., 2014) or that stress interacts with teachers' personal characteristics, such as self-efficacy or empathy, in its effect on students' learning outcomes. In our sample, teachers' age added as a control variable was related to their lower physiological stress. As teachers' age is highly correlated with their work experience, the possible mediation of experience in the relation between teachers' stress and their classroom practices is worth further investigation.

Limitations and practical implications

Our study has some limitations that need to be pointed out. First, due to the cortisol protocol (see the Measures section), we used single cortisol samples from the middle of the school day and cortisol slope from morning peak to bedtime, both averaged over two sampling days. Although these cortisol indicators have been used in previous studies (Nakajima et al., 2012; Wolf et al., 2008), they do not incorporate the time after awakening and, therefore, must be considered rough measures. Future studies might want to include a wider variety of cortisol indicators to increase understanding of teachers' physiological stress. We also followed teaching practices only on one school day and measured physiological stress on two school days. In further studies, our results should be tested with longer observations and sampling. Next, although our sample size and number of groups was very satisfactory for two-level analyses, as well as the classroom-level variance of students' learning outcomes (Maas & Hox, 2005), the number of groups still might not have had sufficient power for detecting between-level effects in two-level mediational analyses (Zhang et al., 2009).

From a practical standpoint, our study showed that there is a large effect of teachers' subjective stress on their teaching practices and thereby on students' learning experiences in Grade 1. The main practical implication we would like to emphasize is the importance of teachers' perceptions about their coping abilities that are manifested in subjective stress measures (Weckesser et al., 2019). Teachers' beliefs in their ability to cope with stressful or unexpected situations can be supported both in pre- and in-service training. This should also include increasing teachers' knowledge on the effect of their well-being on students' learning experiences. Concerning the school climate, the support and encouragement from colleagues and school leaders help teachers to be aware of their stress and well-being and intervene if needed. In addition, our study emphasizes that while talking about teachers' stress and how it is related to students' learning experiences and academic outcomes, we need to consider the mechanisms of this effect. Based on our results, we suggest increasing teachers' awareness that their perceptions of stress and coping abilities manifest in their teaching practices, especially in their ability to employ child-centred instruction in the classroom.

CONCLUSIONS

Overall, our study showed that subjective, self-reported stress affects teaching practices teachers employ in the Grade 1 classroom. We found no effect of objective, physiological stress on teaching practices. This means that these are teachers' subjective feelings about their ability to cope with stress that are expressed in the classroom through teaching practices and thereby shape students' learning experiences. Therefore, we suggest to direct teachers' stress interventions to their coping abilities and subjective beliefs about coping and to the school environment, which supports coping with stress.

AUTHOR CONTRIBUTIONS

Anna-Liisa Jõgi: Conceptualization; formal analysis; investigation; methodology; writing – original draft; writing – review and editing. **Eija Pakarinen:** Conceptualization; funding acquisition; methodology; project administration; supervision; writing – review and editing. **Marja-Kristiina Lerkkanen:** Conceptualization; funding acquisition; project administration; supervision; writing – review and editing.

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CONFLICT OF INTEREST

All authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1 Description of ECCOM child-centred and teacher-directed dimensions – subscales and scale items (based on Stipek & Byler, 2005; Lerkkanen, Kikas et al., 2012)

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