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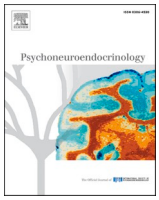

Associations between stress, resources, and hair cortisol concentration in teachers

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ABSTRACT

Challenging interactions are the main source of teacher' stress in the classroom. We investigated the association of chronic stress and characteristics of teacher-student interactions with teachers' Hair Cortisol Concentration (HCC). Forty-one teachers (27 women; M_{age} = 39.65 ± 12.14 years; $M_{lesson\ number}$ = 23.15 ± 3.99 lessons per week; grade: elementary, secondary, high, and vocational school teachers) participated in the present study, with participation lasting over the length of one year. HCC was assessed from a 3 cm hair segment near the scalp. Self-reported chronic stress in the last three months was further assessed using the 'Trier Inventory for Chronic Stress' (TICS). Additionally, four consecutive, same-day lectures of each teacher were videotaped and coded offline in an event sampling procedure by trained external observers. The videos were analyzed for two stressors, i.e., classroom disruptions and total student aggression, as well as two resources, i.e., teacher-student relationship and classroom management. Overall, hair samples were collected M = 120.34 days (SD = 84.39) after the distribution of the questionnaires, and M = 67.63 days (SD = 18.40) prior to the observations. Lesson number, classroom disruptions, as well as total student aggression were all significantly positively correlated with HCC. In addition, both teacher-student relationship and classroom management were significantly negatively related to HCC. With regard to self-rated chronic stress, only the TICS subscale 'Pressure to perform' was positively related to HCC. Exploratory moderation analyses revealed that an increasingly good, observed teacher-student relationship buffered the positive association between lesson number and HCC. Our findings show significant associations between HCC and mainly objectively assessable stress, supporting HCC as a biological indicator of chronic stress. In this association, a good relationship between teachers and students acts as a buffer. While the findings underline the importance of examining objective and behavioral data for better understanding the psychobiology of stress, they also support the importance of boostering teachers' (social) resources to increase their overall resilience.

1. Introduction

Stress is a major risk factor for mental and physical health. The work environment is a common source of stress, and under certain circumstances, work stress can elicit burnout, a syndrome characterized by emotional exhaustion, depersonalization, and low personal

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accomplishment (Maslach and Jackson, 1981). On the long-term, work stress can lead to depression through the experience of burnout (Aloha and Hakanen, 2007).

Teachers are considered a particularly stressed occupational group with high burnout rates (Aloe et al., 2014: meta-analysis considering all levels, i.e., elementary, middle, high and vocational teachers). Reports from the Netherlands, Germany, and the United Kingdom show that teachers report higher than average levels of self-perceived workplace stress (Smith et al., 2000: examined teachers, no further specification provided; Unterbrink et al., 2007: examined secondary and high school teachers) and higher rates of burnout (Schaufeli, 2003: literature overview) when compared to other professions. Many teachers prematurely leave their profession or retire early due to stress (Ingersoll, 2001: examined elementary and secondary school teachers). The main source of teacher stress in the classroom are problems in social interactions. Because classroom interactions are highly complex due to their high social density, simultaneity, immediacy, unpredictability, informality, and publicness (Doyle, 1986: literature overview), they are prone to disruptions. Aggression as a problematic social interaction includes any behavior intended to harm another person (physically or mentally). It includes direct forms such as hitting or threatening, and more subtle forms such as spreading rumours. Student aggression and discipline problems are considered to be main stressors of teachers in the classroom (Boyle et al., 1995: examined primary school teachers; Evers et al., 2004: examined teachers of 16–23 year old students; Tsouloupas et al., 2010: examined elementary, middle and high school teachers). In fact, student misbehavior as a primary source of teachers' stress (McCormick and Barnett, 2011: examined high school teachers; Dicke et al., 2014: examined teacher candidates teaching at primary schools, vocational high school tracks or university high school tracks) has been found to increase the risk of burnout among teachers (Kokkinos, 2007: examined primary school teachers; Tsouloupas et al., 2010: examined elementary, middle- and high-school teachers) and is frequently reported as a major reason for teacher attrition (Ingersoll, 2001: examined elementary and secondary school teachers). Given that teachers' level of emotional exhaustion likely affects their teaching quality and reduces students' performance and motivation (Klusmann et al., 2016: examined elementary school teachers), it may potentially trigger a vicious circle.

One way, how stress contributes to the development of somatic and psychiatric morbidity is by chronic activation of major stress-physiological systems, such as the hypothalamic-pituitary-adrenal (HPA) axis. In fact, depression is a disorder linked to increased cortisol levels as biomarker of HPA axis function (Pariante and Lightman, 2008). In their influential meta-analysis on acute stress and the cortisol response, Dickerson and Kemeny (2004) revealed that stress tasks with uncontrollable and social-evaluative elements elicited the strongest and longest lasting cortisol responses. Therefore, one can assume that teachers are prone to regular cortisol responses during their challenging working days. This assumption was supported by findings of higher cortisol levels on days of teaching as compared to leisure days, a finding mainly based on higher cortisol levels after awakening (Bellingrath et al., 2008: examined elementary/primary, secondary, grammar, comprehensive, vocational and not further specified school teachers; Wettstein et al., 2020: examined primary school teachers). In line with these findings, Chida and Steptoe (2009) concluded in their review and meta-analysis that CAR was positively associated with job stress as well as with general life stress. Interestingly, at least when considering studies calculating the area under the curve with respect to increase and/or assessing three or more samples after awakening, they also found a negative association with fatigue, burnout, and exhaustion. A stronger cortisol awakening response (CAR) on workdays might reflect anticipatory effects of the demands of the upcoming day (Kunz-Ebrecht et al., 2004), so that an increased release of cortisol and the associated higher energy provision might prepare the organism to better cope with the upcoming challenges.

In contrast to salivary or plasma cortisol, hair cortisol allows for a retrospective analysis of long-term cortisol secretion and for the inference of chronic physiological stress loads (Iglesias et al., 2015; Iob and Steptoe, 2019; Ullmann et al., 2016). Reviews and a meta-analyses (Staufenbiel et al., 2013; Stalder et al., 2017) have revealed that samples exposed to major and/or chronic stress (e.g., unemployment, shift work, caregiving stress, natural disaster) typically show increased levels of hair cortisol concentration (HCC) compared to respective control samples, especially if the stressor is still ongoing at the time of examination. Similarly, also samples exposed to high levels of physical stress seem to show a higher HCC (Stalder et al., 2017). Interestingly, studies have often failed to find a significant association between HCC and perceived stress ratings (e.g., Boesch et al., 2015; Stalder et al., 2017). However, the lack of association with self-reported stress is not only restricted to HCC, but is true also for other HPA axis indices, with literature pointing to at least partial dissociation between the psychological experience and physiological stress responses (Campbell and Ehlert, 2012).

Appraisals of perceived environmental demands and of available resources are key elements of the transactional stress theory by Lazarus and Folkman (1984), with appraised resources counteracting appraised demands. With regard to teachers, a good teacher-student relationship and teachers' efficacy in classroom management are considered key resources not only for teacher health (Spilt et al., 2011: literature overview; Aldrup et al., 2018: examined secondary teachers), but also for students' psychosocial development, motivation, and learning success (Obsuth et al., 2017: examined elementary and secondary school teachers; Wentzel, 2010: literature overview). One could therefore expect an inverse association between resources such as a good teacher-student relationship and HCC. Unfortunately, however, social support was not related to HCC in the meta-analysis by Stalder et al. (2017). This raises the question of whether an inverse association would be found with more objectifiable indicators of resources.

This study's main aim was to shed light on cross-sectional associations between work stress and HCC in teachers. For this purpose, we assessed self-rated as well as objectifiable indicators of stress derived from behavioral data assessed in the classroom (i.e., total student aggression and classroom disruptions) above and beyond the objective number of taught lessons per week. Additionally, we aimed at examining self-rated (i.e., social support) and objectifiable behavioral indicators of resources (i.e., teacher-student relationship and classroom management) and their associations with HCC. Last, we set out to examine the potential of the objectifiable indicators of stress and resources to moderate between the various stress indices and HCC. We hypothesize that objective and behavioral indicators of stress are significantly positively related to HCC, while self-reported stress levels are not. Additionally, we assume that behavioral indicators of resources are significantly inversely related to HCC, while self-reported levels are unrelated. Regarding the moderation analyses, we refrained from formulating a directed hypotheses, since the analyses are exploratory in nature and various associations could apply.

2. Materials and methods

The present study is part of a larger project on the psychobiology of stress in teachers (see also Schneider et al., 2022).

2.1. Participants and study design

Participants were recruited via flyers and circular emails. Classroom management and teacher-student relationships are both variables with large effect sizes in classroom research (Hattie, 2009). A priori conducted power analysis with G*Power 3.1.9 (Faul et al., 2007) revealed that in order to detect medium to large correlational effect sizes with a power of 80% and a significance level of $\alpha = .05$, 40 teachers would be sufficient. With regard to moderation analyses, we expected medium to large effect sizes. An a priori power analysis with a power of 80% and a

significance level of α = .05 resulted in a sample size between N = 35–38. The inclusion criteria for participation in the study were working as teacher (e.g., elementary, secondary, high, and vocational school), working inside the canton of Bern, and a workload of a minimum of 16 lessons per week (equivalent to at least a 60% occupation). Exclusion criteria were working outside of the canton of Bern, acute infections, cardiovascular or other chronic diseases, use of cardiovascular drugs or other medication in the past two months (besides phytopharmaceuticals), substance abuse, consumption of psychoactive substances in the last four weeks, more than two standard alcoholic drinks per day, smoking more than ten cigarettes per day, long-distance flights within the last two weeks, as well as pregnancy. All teachers were screened in a short interview to ensure that they met inclusion and exclusion criteria. Enrolled participants signed an informed consent. The study was approved by the ethics committee of the canton of Bern, and by the Internal Review Board (IRB) of the University of Bern and was conducted in strict compliance with current data protection laws and in accordance with the declaration of Helsinki.

Data was assessed over the time span of approximately 1 year. The mean time delay between filling out the questionnaires and the hair collection was M = 120.34 days (SD = 84.39). The time delay between the hair sampling and the video recordings was M = 67.63 days (SD = 18.40).

2.2. Psychometric measures

Chronic Stress was assessed using the Trier Inventory of Chronic Stress (TICS; Schulz and Schlotz, 2002). The questionnaire consists of 57 items and is composed of different subscales: Work overload (10 items), Social Overload (6 items), Pressure to perform (9 items), Work discontent (8 items), Excessive demands at work (6 items), Lack of social recognition (4 items), Social tensions (6 items), Social isolation (6 items), and Chronic worrying (4 items). Additionally, a 'Chronic Stress Screening Scale' is defined by 12 items. The items can be answered on a 5-point Likert scale, from 0 = 'never' to 4 = 'very often'. Higher mean values indicate higher chronic stress levels. Cronbach's alpha for the subscales was between.68 and.95, the alpha for the 'Chronic Stress Screening Scale' is .94.

Social support was assessed using the two subscales of the Berlin Social Support Scale (BSSS; Schulz and Schwarzer, 2003): Emotional support and instrumental support. Both subscales consist of four items each, which can be answered on a 4-point Likert scale, from 1 = 'not true' to 4 = 'absolutely true'. Cronbach's alpha was .74 and .80, respectively.

Demographic and work-related variables were assessed in all teachers (i.e., age, sex, lesson number per week, teaching level).

With regard to hair sampling, participants were further asked about hair treatment details (i.e., hair coloring, bleaching, and washing).

2.3. Behavior observation

For each teacher, GoPro cameras and microphones were installed in their individual classroom in order to assess four consecutive, same-day lectures per teacher. Observers, prior trained to a criterion of.80 agreement (Cohen's kappa), coded classroom disruptions and total student aggression using the software MAXQDA Analytics Pro 2020 version 20.4.1 in an event sampling procedure using the Observation System BASYS (Wettstein, 2008). Classroom disruptions included a working atmosphere marked by interruptions, lack of concentration, and restlessness. Total student aggression comprised any behavior intended to harm another person or to destroy property and takes many forms: verbally or physically, direct (e.g., insulting, hitting), or subtly indirect (e.g., hiding objects, spreading false rumors). In contrast to a previous publication related to this project (Wettstein et al., 2023), we here determined all observed student aggressions (i.e., total observed student aggressions), independent of the fact, if the teacher was present or not (e.g., to go photocopy documents). Higher values represent higher numbers of disruptions and total aggressive behavior. After the coding of classroom disruptions and total student aggression, teacher-student relationships and classroom management were rated by the observers with the Classroom Questionnaire (Scherzinger and Wettstein, 2019). Higher values represented a better relationship and a better management of the challenges faced in the classroom.

2.4. Hair cortisol concentration

Hair strands were cut from the posterior vertex as close to the scalp as possible. Hair cortisol concentrations (HCC) were determined from the 3 cm segment closest to the scalp. Given an average hair growth of 1 cm per month, this segment represents the cumulative GC secretion over three months before sampling. The washing procedure and GC extraction followed the laboratory protocol described by Gao et al. (2013). All samples were analyzed by liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS). This analysis' lower limits of quantification (LOQ) were below 0.1 pg/mg for cortisol. The inter-and intra-assay coefficients of variance for cortisol were below 15% (Gao et al., 2013).

2.5. Data analyses

All data were analyzed using IBM SPSS Statistics (IBM SPSS Statistics, Version 28). Normal distribution was tested using the Kolmogorov-Smirnov test, and skewed variables were log transformed using the natural logarithm (ln(x)) or where appropriate (ln(x + 1)). Potential confounders, i.e., sex, age, smoking status, and BMI, were tested for significant influences on the main variables (i.e., stress and resource variables), by applying Mann-Whitney-U tests or bivariate correlations. Additionally, with regard to HCC, hair dying, straightening, bleaching, and washing was accordingly examined. When confounders were significant (see Section 3.1), confounder-adjusted standardized residuals of the main variables were calculated (cf. La Marca-Ghaemmaghami et al., 2017). Descriptive statistics were computed to investigate the study's variables.

In order to examine the hypotheses assuming a positive association between objective and behavioral stress and resource variables and HCC, first, Pearson correlations were conducted. Second, due to a possible interdependency between the predictors, multiple regression analyses were conducted to examine once the effect of stress variables, and once the effect of resource variables on HCC. Due to the limited sample size, we included a maximum of the three strongest correlating independent variables (i.e., one variable per approximately 13 participants) and applied a backward elimination (Fields, 2009).

For exploratory purposes, moderation hypotheses were tested using ordinary least square path analytic models in SPSS with the macro PROCESS (version 4.0; Hayes, 2018). HCC was entered as dependent variable in the moderation analyses. Stress variables, which in the correlational analyses would reveal to be significantly associated with HCC, were entered as predictors The same stress variables as well as resource variables significantly associated with HCC were entered as moderators. The interaction terms were built as a product of the mean-centered variables involved. The significance of the indirect effects was tested with a 95% confidence interval based on 5000 bias-corrected bootstrap samples. Significant interaction terms were followed up by simple slope tests at low (16th), middle (50th), and high (84th) percentiles of the moderator (Hayes, 2018). Main correlational and multiple regression analyses were one-tailed, moderation analyses two-tailed, with the significance level set at $p < .05$.

3. Results

3.1. Sample characteristics

Of initially 76 teachers expressing their interest to participate, four discontinued the contact with the study team and 17 did not meet study criteria. From the remaining 55 teachers, seven participants withdrew their consent before and six during the data collection. One participant was excluded due to the use of a hair product containing cortisone, leading to a final sample size of N = 41 teachers. Twenty-seven teachers (65.85%) taught in elementary school (−2nd to 6th grade), eleven (26.83%) in secondary school (7th to 9th grade), and three (7.32%) in high school and vocational school (10th to 12th grade). Twenty-seven participants (i.e., 65.85%) were females. Mean age was 39.65 years (SD = 12.14), while the mean body mass index (BMI) was 24.05 kg/m2 (SD = 3.26). Five participants (i.e., 12.20%) were smokers. With regard to hair samples, three subjects were missing hair samples due to baldness, while 38 provided hair samples, ratings of their hair color (blond: n = 14; light brown; n = 7; red: n = 1; brown: n = 14; dark brown: n = 2) and information about hair treatment. Eight participants reported dying their hair, four bleaching their hair, while one participant straightened the hair. Overall, participants reported washing their hair 3.81 times per week (SD = 1.68). Participants stated teaching a mean of 23.15 lessons (SD = 3.99).

Raw values (M +/- SD) of the dependent and independent variables are reported in Table 1.

HCC, stress and resources were examined for potential confounders. Sex was related to the number of 'classroom disruptions' (i.e., female teachers showed a higher number of disruptions; U = 113.000, p = .037, medium effect size r = .33). Age was further related to the 'number of lessons', (i.e., older teachers with less lessons; r = −.31, p = .045) and 'total observed student aggressions' (i.e., less total observed aggressive student behavior in classes of older teachers; r = −.40, p = .009). Teaching level was significantly associated with chronic social tensions (TICS; r = .51, p < .001). The other confounders as well as the time delay between assessments were not significantly related to the stress and resource variables. In the following analyses, the significant confounders were adjusted for where appropriate.

3.2. Correlates of hair cortisol and multiple regression analyses

Self-rated and observer-rated variables were checked for associations with HCC, after adjusting for skewness and appropriate confounders.

Regarding significant correlates of HCC (ln), Pearson correlations revealed that lesson number (adj. for age(ln)) (r = .30, p = .035), classroom disruptions (ln; adj. sex) (r = .38, p = .009), and total observed student aggressions (ln; adj. for age(ln)) (r = .38, p = .010) were all significantly positively correlated with HCC (ln). Therefore, higher values of objective stress indicators were associated with higher HCC. Further, as hypothesized, teacher-student relationship (ln) (r = −.39, p = .007) and classroom management (ln) (r = −.48, p = .001) were both significantly negatively correlated with HCC (ln). Higher observer-rated resources were, therefore, associated with lower HCC.

With regard to self-rated chronic stress (TICS), only one out of ten sub- or screening scales, i.e., pressure to perform, was significantly related to HCC (ln) (r = .29, p = . 037), while the other scales were unrelated to HCC (ln) (all p > .19). Similarly, emotional support (ln) as well as instrumental support (ln) (BSSS) were not significantly associated with HCC (both p > .43).

A multiple regression analysis including the three strongest stress-related correlates (i.e., amount of lessons (adj. age(ln)), classroom disruptions (ln; adj. sex), and total observed student aggressions (ln; adj. age(ln))) as independent variables and HCC (ln) as dependent variable revealed that total observed student aggressions (ln; adj. age(ln))) (t = 2.36, p = .012) and the amount of lessons (adj. age(ln)) (t = 1.77, p = .043) predicted HCC (ln) levels (F(2, 35) = 4.75, p = .015, R^2adj. = .17) (Model 1, Table 2), while classroom disruptions (ln; adj. sex) was not significant (t = 1.49, p = .07) and therefore eliminated. This represents a medium effect (Cohen, 1992).

A second multiple regression analysis including significant resources-related correlates (i.e. teacher-student relationship (ln), and classroom management (ln)) as independent variables and HCC (ln) as dependent variable found that classroom management (ln) (t = −3.27 p = .001) predicted HCC (ln) levels (F(1, 36) = 10.70, p = .001, R^2adj. = .21) (Model 2, Table 2), while teacher-student relationship (ln) was not significant (t = −.42 p = .34) and therefore eliminated. This represents a medium effect (Cohen, 1992).

Table 1
Descriptive statistics of the study's dependent and independent variables.

	M	SD
1. Amount of lessons	23.15	3.99
2. Classroom disruptions (BASYS)	2.08	0.29
3. Total student aggression (BASYS)	4.19	7.50
4. Teacher-student relationship (CQ)	3.16	0.74
5. Classroom management (CQ)	2.75	0.94
6. Work overload (TICS)	12.78	7.33
7. Social overload (TICS)	11.61	3.83
8. Pressure to perform (TICS)	15.02	6.10
9. Work discontent (TICS)	7.88	4.59
10. Excessive demands at work (TICS)	5.85	4.77
11. Lack of social recognition (TICS)	4.32	2.64
12. Social tensions (TICS)	3.56	3.34
13. Social isolation (TICS)	4.12	3.64
14. Chronic worrying (TICS)	4.63	3.84
15. Chronic Stress Screening Scale (TICS)	14.20	9.54
16. Emotional Social Support (BSSS)	3.79	0.31
17. Instrumental Social Support (BSSS)	3.81	0.33
18. HCC [pg/mg]	7.77	7.71

N = 41, HCC: n = 38, Values represent means (M) and standard deviations (SD) of raw values. BASYS = Observation System for the Analysis of Aggressive Behavior in Classroom-Settings, CQ = Classroom Questionnaire, TICS = Trier Inventory for Chronic Stress, BSSS = Berlin Social Support Scale, HCC = Hair Cortisol Concentration

Table 2
Regression results using HCC as the criterion.

Predictor	β	SE	95% CI		p	Fit
			LL	UL		
Model 1						
Total observed student aggressions	.36	.10	.07	.41	.012	
Total lessons	.27	.10	.01	.35	.043	
						$R^2_{adj.}$ = .17
Model 2						
Classroom management	-.48	.39	-1.91	-.61	.001	
						$R^2_{adj.}$ = .21
Model 3						
Total lessons	.39	.13	.11	.66	.007	
Teacher-student relationship	-.53	.15	-.83	-.23	< .001	
Total lessons x teacher-student relationship	-.51	.17	-.85	-.16	.005	
						R^2 = .41

n = 38, β = standardized regression weight, SE = standard error, CI = confidence interval, LL = lower limit, UL = upper limit, model 1 & 2 one-tailed, model 3 two-tailed.

3.3. Moderating effect of observed stress on the association between stress and hair cortisol concentration

Exploratory moderation analyses were performed to test whether stress variables, which were correlated with HCC (i.e., amount of lessons, classroom disruptions, total observed student aggressions, pressure to perform), would enhance the effect of the same stress variables on HCC. No moderation analyses considering these stress variables as predictors as well as potential moderators revealed to be significant.

3.4. Moderating effect of observed resources on the association between stress and hair cortisol concentration

In a next step, exploratory moderation analyses were performed to test whether significant resources (i.e., observed teacher-student relationship, classroom management) buffered the effect of stressors (i.e., amount of lessons, classroom disruptions, total observed student aggressions, pressure to perform) on HCC. We analyzed the moderating role of observed teacher-student relationship (ln) on the relationship between total number of lessons (adj. for age(ln)) and HCC (ln). The moderation model ($F(3, 34) = 7.74$, $p < .001$, $R^2 = .41$) showed a significant interaction effect ($\beta = -.51$, $p < .01$), which is shown in Fig. 1and Table 2 (Model 3).

For teachers who had a bad relationship with their students, the number of lessons was positively associated with the level of hair cortisol (simple slope: $\beta = .82$, SE =.22, $p < .001$), while for teachers with a good teacher-student relationship, there was no such association (simple slope: $\beta = -.12$, SE =.19, $p = .52$). The medium slope was $\beta = .33$, SE = .13, $p = .017$. All other analyses considering teacher-student relationship or classroom management as potential moderators were not significant.

4. Discussion

The main aim of the present study was to examine the associations of self-rated as well as objectifiable (behavioral) indicators of stress and resources with HCC in a sample of teachers. Additionally, we aimed at examining objectifiable stress and resource indicators as potential moderators of the association between stress and HCC. We found that all objectifiable markers of stress (i.e., number of lessons, observed classroom disruptions, and total observed student aggressions) were significantly positively correlated with HCC, while objectifiable resources (i.e., teacher-student relationship, classroom management) were significantly negatively related to HCC. Differently, of the self-reported chronic stress variables only pressure to perform was significantly positively associated with HCC. All other self-reported chronic stress subscales (i.e., Work overload, Social overload, Work discontent, Excessive demands at work, Lack of social recognition, Social tensions, Social isolation, Chronic worrying, Chronic Stress Screening Scale) were unrelated to HCC, as well as self-reported social support (i.e., emotional support, instrumental support). We further found that the relationship between the number of lessons and HCC was buffered by a better teacher-student relationship. Therefore, the association between workload (i.e., number of lessons) and HCC became weaker when teacher and students had better relationships.

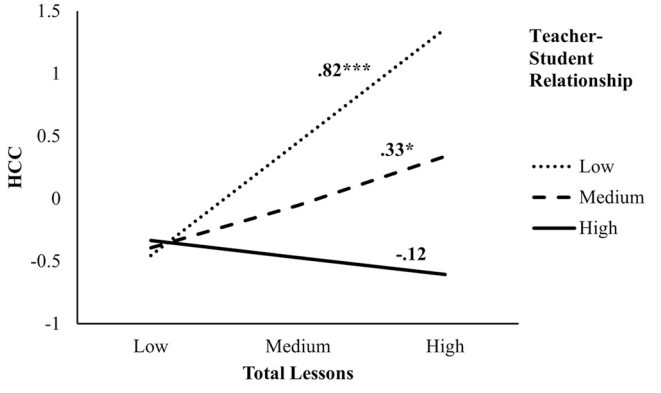

Fig. 1. Interaction plot for teacher-student relationship as moderator between total lessons and HCC. Legend: n = 38, HCC = hair cortisol concentration, conditional effects of standardized variables, * $p < .05$, * ** $p < .001$.

All objectifiable indicators of stress were significantly related to HCC. Overall, a multiple regression analysis revealed that total observed student aggression and the amount of lessons were the strongest stress predictors of HCC, while the variable classroom disruptions was eliminated. Above and beyond workload, both classroom disruptions as well as student aggression are known to be significant sources of stress in teachers (Tsouloupas et al., 2010). This is in line with the notion that samples with chronic stress-exposure show increased HCC (Staufenbiel et al., 2013; Stalder et al., 2017). However, in the present study, instead of a group difference between more and less chronically stressed individuals, we found a significant correlation between objectively determined stress and HCC.

The significant association between HCC and total lessons as well as total observed student aggressions seems to be in contrast to our previously published manuscript from this study (Wettstein et al., 2023), where we reported no significant association with HCC. The main difference here is that in the present work we considered all observed student aggressions, also the ones when the teachers were absent, assuming that they could indirectly also affect the teachers stress level. Differently, in Wettstein et al. (2023) we considered only observed aggressions in the presence of the teachers.

While CAR seems to be higher in working vs. leisure days (Bellingrath et al., 2008; Wettstein et al., 2020), and an association of CAR with objective workload (i.e., number of lessons) as well as job stress can be expected (Chida and Steptoe, 2009), findings related to CAR cannot be transferred to HCC. In fact, studies seem to indicate no association between the CAR and HCC (e.g., Short et al., 2016; Sugaya et al., 2020), while, differently, HCC seems to be significantly positively correlated with single time and mean diurnal cortisol measures (Stalder et al., 2017).

The duration of stress exposure (Miller et al., 2007; Rohleder, 2018) as well as the presence or absence of a (chronic) stressor at the time of measurement (Stalder et al., 2017) have been linked to the activity of the HPA axis, potentially explaining inconsistent findings linking chronic stress to increased, unaltered or decreased activity of the HPA axis or HCC levels. In fact, stress is known to initially lead to a hyperactivity of the HPA axis, with activity decreasing over longer lasting exposure, finally resulting in hypoactivity. Furthermore, a still ongoing stress-exposure is associated with higher cortisol levels than a past or absent exposure (Stalder et al., 2017). Both, hypoactivity as well as hyperactivity of the HPA axis have been related to morbidity and adverse outcomes. In fact, a prolonged hypoactivity has been discussed to cause, among other things, fatigue, anorexia, weight loss, myopathy, and neuropsychiatric symptoms (Laugesen et al., 2021). Differently, hyperactivity has been discussed to cause hippocampal neurodegeneration, decreased immunocompetence, pain, and fibromyalgia, to name a few (Sharpley et al., 2013). The fact that we examined voluntarily participating and apparently healthy teachers during everyday work life, i.e. during an ongoing potential chronic stress exposure, supported the assumption of increased HCC levels with higher stress levels.

Similar to findings with the objectifiable stress measures, we found HCC to be significantly positively correlated also with self-reported levels of chronic stress (i.e., pressure to perform). However, in contrast to the objectifiable variables we found this association only for one out of ten stress scales. The question arises why specifically 'pressure to perform' was significantly correlated with HCC. We assume that it has to do with the social-evaluative content of the items (e.g., "I have tasks

to do where I am under critical observation.", "Contacts with other people with whom I need to make a good impression.", "Situations where I have to make an effort to please others."), since the meta-analyses by Dickerson and Kemeny (2004) has revealed that social-evaluative threat is linked to the highest acute cortisol stress responses. Since teachers are by the nature of their job most often socially exposed, individuals with a higher "pressure to perform" have probably regularly higher acute cortisol stress responses, which then can potentially lead to higher HCC. On the one hand, the weak association between HCC and self-rated chronic stress is in line with the literature, which often fails to find a significant association (e.g., Boesch et al., 2015; Stalder et al., 2017), and which reveals limited match between self-rated and biological stress variables (e.g., Campbell and Ehlert, 2012; Rohleder, 2018). On the other hand, van der Meij et al. (2018) found that self-reported stress was related to HCC, but only in a high workload sample and only for variables represented in the effort-reward-imbalance (ERI) model. Therefore, significant association between self-reported stress and HCC seem to be restricted to certain conditions. In accord with this reasoning, a recently published systematic review rated the association between HCC and self-reported stress measures as "inconclusive" (Koumantarou Malisiova et al., 2021). Therefore, our findings support the use of objectifiable stress measures in psychobiological research.

It is worthwhile mentioning that we found almost no significant association between the observational and the self-reported stress indicators (data not presented). On the one hand, the behavioural assessment was assessed objectifiable by trained observers, while self-reported stress was assessed by 41 untrained individuals (i.e., the participants), leading to an increased variability due to different interpretation of the items and constructs and to different biases. On the other hand, behavior and subjective experience seem to represent two distinct aspects of emotions, with studies showing inconsistent and small correlations between different measures or dimensions of emotions, medium at best (Mauss and Robinson, 2009). Furthermore, the observations focused on specific stressors, while the questionnaire assessed broader and different categories of stress.

As expected, both kinds of resources, i.e., teacher-student relationship and classroom management, were significantly negatively related to HCC. When combined in a multiple regression analysis, classroom management predicted HCC while teacher-student relationship was eliminated. Independent of the available HPA axis literature, evidence generally supports a stress buffering as well as an overall beneficial effect of social support (Cohen and Wills, 1985). However, studies examining the association between HPA axis indicators and social resources such as social support or relationship quality have repeatedly yielded inconsistent findings. With regard to HCC, the meta-analysis by Stalder et al. (2017) found no significant association with self-ratings of social support, which is in line with our findings on self-reported emotional and instrumental social support. Nevertheless, our finding of teacher-student relationship being significantly negatively related to HCC is in line with the findings of a newer, large study with more than 2500 participants that showed an inverse relationship between HCC and self-rated positive social support (Iob et al., 2018). Regarding relationship quality, previous literature usually considered cortisol reactivity to stressful tasks or diurnal cortisol slopes (DCS), pointing again at inconsistent findings. For example, in the meta-analytic review by Robles et al. (2014), marital quality was unrelated to cortisol reactivity during conflicts as well as to DCS. However, a study examining coach-athlete relationships, found relationship quality to be inversely related to the cortisol response to high-intensity exercise (Davis et al., 2018), supporting a buffering effect of a good relationship. Similarly, a study examining teacher-child relationship found a teacher-reported close relationship between the teacher and the child to be significantly related to a smaller cortisol response to challenging tasks as well as almost significantly associated with a smaller cortisol response to a teacher-child interaction (Lisonbee et al., 2008). Unexpectedly, the authors also found higher pre-challenge cortisol values to be related to teacher-reported close relationship quality. Again, similar to stress measures, our findings support the use of objectifiable (social) resource measures in psychobiological research.

Exploratory moderation analyses revealed that the quality of the teacher-student relationship moderated the association between the total number of lessons and the HCC. Therefore, in a positive and cooperative context, workload as indicated by number of lessons did not increase HCC. This is in line with a study by Shrout et al. (2020), in which the authors found a stress buffering effect of positive couple-behavior on the association between perceived partner stress and salivary cortisol levels. In other words, when participants showed low levels of positive behavior, high partner stress was associated with higher average cortisol level. In contrast, when participants showed high levels of positive behavior, the level of partner stress did not affect salivary cortisol levels. Thus, "couples' relationship-promoting behaviors helped protect people from their partners' high stress" (Shrout, 2021; p. 4). Concordantly, a good teacher-student relationship protected the teachers from their objective workload.

This study holds several strengths. First, most teacher stress studies are conducted as questionnaire surveys or as laboratory studies, and studies examining stress correlates of HCC often consider only self-ratings. In the present study, we examined HCC, self-ratings of stress, as well as objectifiable data in teachers, resulting in clear associations between stress, resources, and HCC. Second, we examined teachers in their work environment under real-life conditions, making the findings more valid. Third, teachers might be an ideal occupational group when examining stress effects on the HPA axis, since individuals are constantly immersed in an only partially controllable social environment, factors known to booster HPA axis activation. The present study also holds some limitations. First, the findings are based on a small sample of teachers. Second, the examined teachers were all apparently healthy and medication-free, therefore, findings cannot be generalized to teachers or other professional groups in general. Third, especially when considering the high study-related effort of participants, one can assume that the participating teachers were more resilient and/or less stressed then the average teacher. Supporting this, some teachers withdrew after initial declaration of interest. Fourth, being a field study, several aspects could not be controlled for. Teachers for example were allowed to choose the day of video-taping, so that teachers may have chosen working days with lower or at least different stress intensities. Fifth, due to the high workload necessary for analyzing the video data, observational data was assessed only on one working day. Therefore, results heavily depend on the condition and performance of the teachers and students on the specific days. Sixth, the presented data was collected cross-sectionally and the direction of causality remains unclear. Seventh, the variables were assessed within one year, but not at the same time. Even though the delay was significantly unrelated to the dependent and independent variables, a simultaneous assessment of the study variables would have potentially shown stronger associations. Finally, one has to keep in mind that teaching is a complex, dynamic process. Teachers are not passively exposed to classroom disruptions but may contribute to further disruptions in the interactional process through their handling of perceived disruptions (Wettstein, 2008).

5. Conclusions

Structural and objectifiable indicators of stress are positively related to HCC, while objectifiable resources display a stress-buffering effect. Furthermore, a positive and constructive working environment seem to buffer potentially aggravating effects of structural indicators of stress on HCC. From an interventional perspective, it seems crucial to strengthen teachers' resources and skills and prevent them from applying dysfunctional coping strategies to undesired student behavior, which may unintentionally reinforce the problem. Thereby, we strongly believe that the need to improve teachers' health, which has manifold

impacts on the teachers as well as the students, does not lie in the sole responsibility of the teachers, but even more in the responsibility of the schools and the education system. They should promote resources, inter-school programs and support measures and make sure not to overburden teachers by exposing them to too large workloads, areas of responsibility, and class sizes. From a research perspective, the present findings underline the strength and necessity of comparably coded and rated observational data when examining the psychobiology of stress and resources.

CRediT authorship contribution statement

Roberto La Marca: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization, Supervision. **Sandra Schneider**: Investigation, Writing – review & editing. **Gabriel Jenni:** Formal analysis, Visualization. **Fabienne Kühne:** Investigation, Writing – review & editing. **Martin grosse Holtforth:** Writing – review & editing. **Alexander Wettstein:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

none.

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