



# Stress, mental and physical health and the costs of health care in German high school students

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## Abstract

Stress is a mind–body phenomenon, which affects both mental and physical health and is highly relevant to the health care system. Yet, knowledge on the costs of stress and related health problems in adolescence is missing. The present study addresses this gap by investigating direct health care costs in relation to stress, mental health problems and physical health in high school students. The sample comprised 284 pupils from four schools in Heidelberg (mean age  $16.75 \pm 0.64$  years, 59.64% female). Self-reported health care utilization and medication intake within 1 month were translated into costs. We established correlative associations of the dichotomized overall costs (no vs. any) with stress, mental health problems and physical health within generalized structural equation models. In particular, mental health problems and physical health were examined as mediators of the association between stress and costs. An increase of stress by 1 SD corresponded increased chances for costs by OR 1.39 (Odds Ratio; 95% CI 0.13–0.53,  $p=0.001$ ). When mediators were analysed separately, both mental and physical health (problems) fully mediated the association. Yet, when examined together, only mental health problems acted as a mediator. Our results indicate the health economic relevance of stress-related mental health problems in high school students. The finding is meant to set the stage for further cost-of-illness studies of stress and related health problems, as well as economic evaluations. Longitudinal research is needed to allow conclusions on directionality.

**Keywords** Direct costs · Health care utilization · Stress · Mental health · Adolescence

## Introduction

Stress is a mind–body phenomenon, which affects both mental and physical health and thus is highly relevant to the health care system [1]. While hormones associated with stress promote adaptation and protect the body in the short

run, in the long run the physiologic response to stress causes changes in the body, especially in the brain, which can lead to diseases [2]. Besides the physiologic pathway via cortisol and the autonomic, metabolic and immune system, the behavioural stress responses such as increased smoking, decreased exercise and sleep, and poorer adherence to medical regimens pose a second pathway to allostatic (over-) load and disease [3, 4].

Not only adults, but also children and adolescents experience detrimental levels of stress. One out of ten adolescents in high school reports symptoms which can be classified as signs of chronic stress [5]. A large European study in 6–13 year old children finds comparable levels of severe stress [6]. Stress levels seem to be higher in academic compared to vocational schools [7] and seem to increase throughout adolescence [8–10].

Onset and progression of several diseases have empirically been linked to stress. Substantial consistency between findings from different methodological approaches strongly supports the hypothesis of a causal link, mainly regarding depression, HIV/AIDS and cardiovascular diseases [3].

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Recent reviews and meta-analyses of studies in adult samples form a solid database on the relevance of stress in, e.g., headache [11] or cardiovascular diseases [12, 13]. Exposure to acute and chronic stressful events and adversity increases the risk for externalizing and internalizing psychopathology [e.g., 14, 15]. In their meta-analysis of 27 studies on adolescence, March-Llanes, Marqués-Feixa, Mezquita, Fañanás, and Moya-Higueras [16] reported a large effect for the cross-sectional correlation of aggregated life events and psychopathology. Within longitudinal analyses, the authors also show that stress is a general risk factor for as well as a consequence of impulsive- and emotional disorders (sensitivity-stress vs. stress-generation hypothesis).

Psychological- and physical symptoms of stress lead to substantial health care utilization. Physical manifestations of stress such as headache, back pain, insomnia, gastroesophageal reflux disease, irritable bowel, and chest discomfort are among the most frequent reasons for consulting the general practitioner (GP) [1]. In a retrospective survey among a representative sample of adolescents, the most frequently reported physical complaints were head/face problems (33%), followed by back (24%) and stomach complaints (22%), typical symptoms discussed in relation to stress [17]. The study further suggests that these complaints come with a substantial burden for the individual and the health care system, as more than 90% of those suffering from stress-related problems had sought treatment in primary care for this reason. The findings align with studies on frequent health care use, which is predicted by social- and psychiatric difficulties in adolescents [18, 19]. Data on health care expenditures attributable to stress-related mental disorders in adolescence are scarce. Direct and indirect costs of mental disorders in general, which encompass health care as well as secondary costs such as loss of earnings, amounted to US\$ 2.5 trillion worldwide in 2010. Within the restriction that cost estimates depend on the analytic approach, mental disorders can be assumed to account for more costs than chronic somatic diseases such as cancer and diabetes, comparable to cardiovascular diseases [20].

Overall, a causal link between stress and physical as well as mental illness appears probable, and stress-related illness is likely leading to costs in the health care system. Whether adolescent stress is also independently associated with costs is however unclear. There is prospective evidence on occupational stress as a predictor of health care costs in adults [21, 22]. Only one study approximates this question during adolescence, even though it investigates psychological distress instead of stress. Therein, increases in health care costs over a 3-year period are prospectively predicted by mild traumatic brain injury and psychological distress [23].

On the basis of the depicted evidence, managing stress appears promising to achieve public mental and somatic health and to use resources appropriately [1]. In the realm

of adult and especially work-related stress, potential societal- and financial benefits of stress prevention appear to have fostered research. Some studies have, e.g., examined the relevancy of preventing stress to decrease incidence rates of coronary heart disease compared to preventing standard risk factors such as smoking [24]. Other studies have investigated the economic benefit of eliminating job strain as a risk factor for depression [25]. For adolescents, there is a repeated call for stress prevention, especially in schools [e.g., 26, for reviews on the efficiency see 27, or 28]. Still, to the knowledge of the authors, neither are there comparable studies on the economic burden of adolescent stress nor are there evaluations of societal or economic benefits of stress prevention during adolescence [for a review on the impact of universal (stress) prevention on academic achievement see 29, for reviews of economic evaluations see 30–34]. Respective studies have the potential to reinforce the legitimacy of prevention and can foster basic and implementation research.

The present research intends to help fill this research gap. It targets health care expenditures associated with stress in a sample of high school students. As stress is a mind–body phenomenon, this shall be done within the context of mental and physical health problems. In particular, the following hypotheses were formulated: (1) Health care costs are related to subjective stress levels in high school students. (2) The association between costs and stress is partially mediated by mental as well as physical health (complaints). This means that costs are accounted for directly by stress, as well as indirectly via mental and physical health (problems). The hypotheses are clearly motivated by the empirical hints on causal paths from stress-to-illness and illness-to-health care costs. We however refrain from formulating causal hypotheses, as they will be examined in terms of concurrent associations and hence do not inform on temporal sequence or causality. As mentioned before, reverse paths from illness-to-stress probably exist just alike. In the present research, our argumentation follows the reasoning of a causal link from stress-over-illness-to-costs, which we deem more relevant with regards to prevention and public health.

## Method

### Recruitment and procedure

Sampling and data collection were part of a randomized controlled trial (RCT) on stress prevention in high school students [35]. The study was conducted in four grammar schools in Heidelberg in 2014. All pupils in grade 11, the 1st year of secondary high school, were eligible for study inclusion. Participation in the survey was optional. Adolescents and parents were informed and had the opportunity to consent (adolescents) or opt-out of participation (parents). In the

case of non-participation, students stayed in the classroom. Research staff administered paper–pencil questionnaires to the pupils inside the classroom. Completing the survey took approximately 60 min. The present research refers to the baseline and postline data. Baseline assessment took place in March prior to the intervention, postline assessment in July. This was 4–8 weeks after the intervention group had participated in the program.

## Measures

The reference period was set to *the 4 weeks before assessment* in all instruments.

### Stress

Stress was operationalized as the appraisal of minor stressors and measured with the Problem Questionnaire [PQ; 36]. Adolescents indicated the stressfulness of 64 problems typical for adolescence on a scale from 1 *not stressful at all* to 5 *highly stressful*. The problems pertain to the domains school, future, parents, peers, leisure time, romantic relations, and self. Internal consistencies of the scales had previously been confirmed in a representative German sample, with Cronbach's alpha ranging between 0.70 and 0.84 [36]. In the present analysis, the mean was calculated as measure of stress.

### Mental health problems

Emotional- and behavioural problems were measured with the Youth Self Report [YSR; 37, 38]. Adolescents indicated whether each of 101 problems applied to them on a scale from 0 *not at all*, 1 *sometimes or somewhat* to 2 *a lot*. The YSR comprises the subscales anxious-depressed, withdrawn-depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behaviour, and aggressive behaviour. In the present study, answers were totalled to obtain a general index of mental health problems. In a non-clinical sample of German 12–16 year olds, Cronbach's alpha was 0.92 [39]. The German version also appears to have adequate criterion validity, as well as convergent and discriminant construct validity [40, 41].

### Physical health

The subscale physical well-being of the KIDSCREEN-52 served as measure of physical health. It is subsequently referred to as KIDSCREEN scale (KS). It constitutes one out of ten dimensions of health-related quality of life [42, 43]. The KS comprises five items. Moderate correlations with psychosomatic health complaints (HBSC  $r = -0.41$ ),

consultations of a health care professional (past month; ES = 0.39), and hospitalisation (past year; ES = 0.34) indicate the construct validity of the subscale. Internal consistency of the scale was good (Cronbach's alpha = 0.80) and test–retest reliability within 2 weeks adequate ( $r = 0.66$ ) [43, 44].

### Health care costs

As a first step, health care utilization and pharmacological drug use were assessed. We administered the Mannheimer Modul Ressourcenverbrauch [MRV; 45], a scale that lists health care services or medical treatments for a specific sample or risk group. It assesses the frequency of use over a given period of time, separately for each service. The scale is based on the internationally applied Client Sociodemographic and Service Receipt Inventory [CSSRI; 46]. In the case of this study, the MRV has been adapted to the specific characteristics and conditions of German high school students. The list included all possible health care services or treatments either being reimbursed by health insurance or covered by out-of-pocket payment. It further comprised a section on the pharmacological drug intake (prescription or self-medication). Participants were asked to indicate brand name, dosage, frequency, and type of intake (oral, injection, depot etc.). Free text information of drug brand names was edited and standardized according to ATC-Codes [Anatomical Therapeutic Chemical Classification System, 47]. This pharmaceutical coding system divides drugs into different groups according to the organ or system on which they act and/or their therapeutic and chemical characteristics.

In the second step, individual health care utilization patterns (frequency of services used or treatments received) were transferred into cost-information. This was done with the help of a catalogue of unit costs. The catalogue was specifically compiled for the study purpose. Unit costs indicate per diem charges of services or market prices of all types of treatments, services and therapeutic products that were used or consumed. The cost catalogue was compiled from sources and catalogues available from the literature [48–50], supplemented by cost-information collected for study-specific treatments or service types. The lowest market prices available per drug were applied to costing of the medication intake. Cost data from both assessments were assumed to be representative for service use within 1 month. Referring to the content structure of the MRV [45, 51], we created aggregated cost measures for outpatient treatment at the hospital, day-care and inpatient care, supplementary services and medication. Referring to the above cited literature, general- and specialist practitioner were also included as separate categories.

## Statistical analyses

Mean and standard deviation were established for stress, mental and physical health (problems). A median-split was made for stress, mental and physical health (problems). Percentiles of costs per capita were calculated for the resulting subsamples and the whole sample. We calculated the median, as well as the 75th, 90th, and 95th percentiles and indicate the maximum value. As the median of costs was consistently zero, Table 2 shows the 75th–95th percentiles and maximum values only. Due to skewness and kurtosis of the cost data, we dichotomized the cost variable before inference-statistical analyses (0 no costs, 1 any costs). (Relative) frequencies were calculated for any vs. no costs. They are indicated for overall costs and costs in different realms of the health care system. The number of participants with costs in the different categories, e.g., specialist or general practitioner, was too small for separate calculations according to cost category. Consequently, we only used the aggregated cost variable in inferential statistical analyses. To test the hypotheses, we established associations of the dichotomized overall costs with stress, mental health problems and physical health within generalized structural equation models [52]; command “gsem” in Stata 15. The regressions of costs were logistic regressions. Linear regression analyses were used to test all remaining associations. To account for the non-independence of the repeated measurement of the pupils (baseline and postline), we used clustered sandwich estimators for the estimation of the variance–covariance matrix with subject ID as cluster variable. In particular, hypothesis 1 was tested with a univariate logistic regression of costs on stress. To determine whether hypothesis 2 was correct, we calculated three generalized-structural equation models (mental health complaints as a mediator, physical health as a mediator, both variables as mediators in one model). The joint analysis of both mediators within one model was conducted for determining the relative importance of the mediators in the association between costs and stress. To improve comparability, all variables except costs were standardized before inferential statistics. While the mediator analyses were conducted with the full YSR to maintain psychometric properties in the first place, analyses were repeated with a reduced YSR score, excluding somatic complaints in a second step. Thereby risk for confound between mental and somatic health variables should be reduced. Both results were compared afterwards. Last, we examined whether the final model holds for different parts of the stress range. A median-split for PQ stress was made, so that the mediation model could be calculated with different coefficients for the subsamples below, respectively, above the median. We estimated Bayes’ Information Criterion (BIC) for this alternative model ( $M_1$ ), and compared it to the initial model (null model,  $M_0$ ). The null model had the same coefficient for both

stress groups. According to Bayesian Model Selection [53], models with smaller BIC values are to be preferred. BIC differences ( $M_0 - M_1$ ) above 2 can be regarded as positive, above 6 as strong and above 10 as very strong evidence for the alternative model. All analyses were performed with the statistical software Stata 15.

## Results

### Sample characteristics

The sample comprised 284 pupils with health care costs, which correspond to 568 cases (baseline and postline). 15 cases were excluded due to missing values in the PQ, YSR or KS, leading to 553 cases (277 baseline and 276 postline). 59.64% were female and 40.36% were male. Mean age was 16.75 ( $\pm 0.64$ ) years. Descriptive statistics of all study variables can be found in Tables 1 and 2. The cell sizes of different cost categories are displayed in Table 1. Percentiles of per-capita costs can be found in Table 2. Costs are depicted depending on the subgroups arising from median-splits regarding stress, mental and physical health (problems). Descriptively, a pattern of higher costs in groups with more stress, respectively, poorer health emerged.

### Stress, mental and physical health and health care costs

In the inferential statistical analysis, stress had a significant effect on overall costs. An increase of stress by 1 standard deviation corresponded an increased chance for costs instead of no costs by OR 1.39 (Odds Ratio; 95% CI 1.14–1.69,  $p = 0.001$ ). When testing the potential mediators separately, proof for both mediators was found: stress predicted mental health problems, which in turn predicted overall costs. As the previously established effect of stress on costs lost significance, we can conclude that the effect of stress on costs is fully mediated by mental health complaints. The same pattern of results was obtained for physical health. The estimated regression coefficients are displayed in Table 3. When investigated conjointly in one model, mental health problems, but not physical health, mediate the effect of stress on costs.

To rule out confound of mental and physical health, we repeated the calculations with the YSR score excluding somatic complaints. The same pattern of results emerged. The association is thus rather mediated through mental as opposed to physical health. In Fig. 1, we show the results in a path diagram. The therein reported results pertain to the full YSR index, including somatic complaints.

Last, we examined whether the mediation model holds for different parts of the stress range. We estimated an

**Table 1** Descriptive statistics of the study variables

Study variables	M	SD
PQ stress	2.16	0.50
YSR mental health problems	42.26	22.34
KS physical well-being	43.95	7.94
Dichotomized costs <sup>a</sup>	Any costs <i>n</i> (%)	No costs <i>n</i> (%)
Total costs	196 (35.44)	357 (64.56)
Drugs	192 (34.72)	361 (65.28)
General practitioner	99 (17.90)	454 (82.10)
Specialist practitioner	128 (23.15)	425 (76.85)
Suppl. services	64 (11.57)	489 (88.43)
Hospital		
Outpatient	34 (6.15)	519 (93.85)
Day-care	4 (0.72)	549 (99.28)
Inpatient	6 (1.08)	547 (98.92)

<sup>a</sup>The variable pertains to the number of persons reporting costs within 1 month in Euros [€]. We included baseline and postline data for all participants. When counting baseline and postline separately, the number of cases reporting health care use rises to 553

alternative model with different coefficients for pupils with stress levels above, respectively, below the median ( $M_1$ ; BIC = 3409.28) and compared it to the initial model ( $M_0$ ; BIC = 3394.95). The BIC difference is  $-4.33$ , indicating very strong evidence for the null model. Consequently, the same mediation model appears to be suitable in the subsamples of stress below and above the median.

## Discussion

The aim of the present study was to establish empirical evidence for the relevance of stress in adolescents from an economic point of view. We analysed self-report data of high school students, grade 11, on health care use and concurrent stress from everyday problems. In addition, we aimed to further disentangle this association and investigated somatic and mental health as mediators. A brief summary of the results is given in the following sections and linked to the initially depicted research.

Higher levels of stress were positively associated with the presence of health care costs in high school students in the univariate analysis, confirming hypothesis 1. In the enlarged model, there was a full mediation, showing that stress and costs are related only indirectly through health. Inspected individually, both mental health problems and somatic health mediated the effect. The comparative analysis showed that the effect of stress on health care costs was fully mediated by mental health problems but not somatic health. The model appeared to be appropriate for students with stress levels above and below the median, giving rise to the assumption that the relationship is linear over different

parts of the stress range. One can conclude that there is a concurrent association between stress and health care costs only via mental health problems. Neither does the direct path nor an indirect path via physical health account for an independent share of variance in costs. Hence, hypothesis 2 is supported partially only.

To our knowledge, the present study is the first to examine the association between adolescent stress and health care costs. While Rockhill et al. [23] only approximated this question by identifying mild traumatic brain injury and psychological distress as prospective predictors of increasing health care costs in adolescents, a more direct test originates from employee-related research. As mentioned in the introduction, stressful work events prospectively predict health care costs but not mental health in a study by Ganster et al. [22], indicating that stress might indeed be directly related to costs in adults. It is important to mention though that stress was operationalized in terms of subjective- and objective work load, and that both variables interacted with perceived control in predicting costs in this study. The findings contrast with our results, which do not show direct associations between stress and costs. Yet, there are methodological discrepancies between the studies, which might inform on potential explanations: (i) the different age group (adults versus adolescents); (ii) the different operationalization of outcomes (e.g., psychological distress versus mental health problems); (iii) the different study designs (prospective study controlling for baseline levels of health and healthcare costs versus our cross-sectional design).

Further, even though both mental and physical health (problems) appeared to mediate the stress costs link when examined individually, only the path via mental health

**Table 2** Percentiles of health care costs in the whole sample and subsamples after median-split

	Percentile				Percentile				
	P75	P90	P95	max	P75	P90	P95	max	
Type of costs (in €)					Type of costs (in €)				
<b>Total costs</b>					<b>Supplementary services</b>				
Total sample	51	179	370	4711	Total sample	0	40	120	926
PQ Stress					PQ				
< 50%	26	140	285	4711	< 50%	0	0	75	926
> 50%	90	202	462	3521	> 50%	0	65	195	617
YSR Mental Health Problems					YSR				
< 50%	19	110	263	4711	< 50%	0	0	52	926
> 50%	103	271	510	3521	> 50%	0	77	195	617
KS Physical Health					KS				
< 50%	90	235	505	4711	< 50%	0	65	166	926
> 50%	20	113	268	802	> 50%	0	0	77	478
<b>Drugs</b>					<b>Hospital: ambulatory treatment</b>				
Total sample	2	11	22	2444	Total sample	0	0	93	373
PQ Stress					PQ				
< 50%	0	8	21	2444	< 50%	0	0	93	280
> 50%	4	12	22	1749	> 50%	0	0	93	373
YSR Mental Health Problems					YSR				
< 50%	0	5	15	2444	< 50%	0	0	0	280
> 50%	4	15	27	1749	> 50%	0	0	93	373
KS Physical Health					KS				
< 50%	4	15	37	2444	< 50%	0	0	93	373
> 50%	0	6	14	1749	> 50%	0	0	0	280
<b>General practitioner</b>					<b>Hospital: day-care treatment</b>				
Total sample	0	40	59	198	Total sample	0	0	0	370
PQ Stress					PQ				
< 50%	0	20	40	198	< 50%	0	0	0	370
> 50%	0	40	59	198	> 50%	0	0	0	370
YSR Mental Health Problems					YSR				
< 50%	0	20	20	198	< 50%	0	0	0	370
> 50%	10	40	59	198	> 50%	0	0	0	370
KS Physical Health					KS				
< 50%	0	40	59	198	< 50%	0	0	0	370
> 50%	0	20	40	119	> 50%	0	0	0	0
<b>Specialist practitioner</b>					<b>Hospital: inpatient treatment</b>				
Total sample	0	80	137	549	Total sample	0	0	0	4552
PQ Stress					PQ				
< 50%	0	66	115	549	< 50%	0	0	0	4552
> 50%	25	89	170	430	> 50%	0	0	0	2845
YSR Mental Health Problems					YSR				
< 50%	0	50	99	549	< 50%	0	0	0	4552
> 50%	33	99	198	430	> 50%	0	0	0	2845
KS Physical Health					KS				
< 50%	25	90	158	549	< 50%	0	0	0	4552
> 50%	0	55	99	408	> 50%	0	0	0	569

A median-split was made for the variables PQ stress, YSR mental health problems and KS physical health. Percentiles of costs per capita are displayed for the resulting subsamples in Euros [€]. Higher values for PQ stress and YSR emotional health problems indicate a higher burden. The KS scale physical health is reverse coded, so that higher values stand for higher well-being. We calculated the median, the 70th, 90th and 95th percentiles and the maximum value of costs. We do not report the median, which was zero in all subsamples

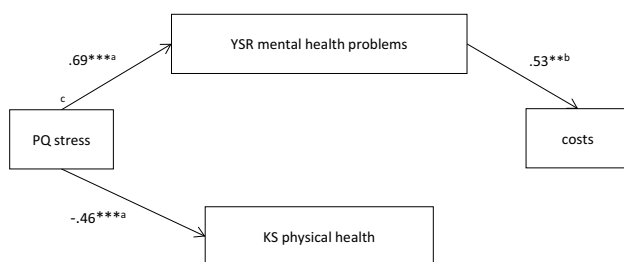
**Table 3** Generalized structural equation model for the effect of stress on costs

Model	Effects IV on M <sup>a</sup>			Effects M on DV <sup>b</sup>			Effects IV on DV <sup>b</sup>				
	Coeff.	<i>p</i>	95% CI	OR	<i>p</i>	95% CI	OR	<i>p</i>	95% CI		
Reduced model: no mediator								1.39	0.001	1.14	1.69
YSR as mediator	0.69	<0.001	0.61 0.76	1.83	<0.001	1.31 2.55	0.92	0.607	0.68	1.25	
KS as mediator	-0.46	<0.001	-0.56 -0.37	0.73	0.004	0.59 0.90	1.20	0.108	0.96	1.51	
Full model: 2 mediators							0.89	0.444	0.65	1.21	
YSR	0.69	<0.001	0.61 0.76	1.70	0.003	1.21 2.41					
KS	-0.46	<0.001	-0.56 -0.37	0.82	0.081	0.66 1.02					

IV independent variable (PQ stress), M mediator (YSR mental health problems/KS physical health), DV dependent variable (costs), *Coeff.* standardized coefficient, *CI* confidence interval, *OR* odds ratio

<sup>a</sup>The effects IV on M result from linear regressions

<sup>b</sup>The effects M on DV and IV on DV result from logistic regressions



**Fig. 1** Mediation model. <sup>a</sup>These coefficients were estimated using linear regressions of YSR, respectively, KS on PQ. <sup>b</sup>This coefficient results from a logistic regression of costs on YSR. <sup>c</sup>Only those paths are depicted for which a significant coefficient had been estimated. The results pertain to the combined model with the independent variable stress and both physical and mental health (problems) as mediators. Due to the concurrent assessment of data, the arrows signal potentially bidirectional relations. The displayed diagram corresponds to the statistical formulation of the model

problems remained significant in the combined model. The available evidence from adolescent research has yet examined mostly stress-related physical symptoms, and has not incorporated both variables in one analysis. In line with our finding from the individual analysis, previous studies have shown that potentially stress-related physical symptoms drive health care utilization. Within a representative sample of adolescents, almost half of the most frequently reported physical symptoms were regarded as stress-related by adolescents themselves [17]. In a study by Vila et al. [19], somatic symptoms made worse by stress were elevated in adolescents frequently attending care. The consistency of findings across different operationalizations of stress-related problems and of the economic burden, such as frequency of consultations and any vs. no costs, suggests the validity of the link between stress-related symptoms and costs. At the same time, the present study is the first to disentangle adolescent stress from stress-related symptoms and explicitly introduce both constructs into one cost analysis.

Our results suggest that—if all paths are included in one model and their relative importance is determined—only mental health mediates the effect of stress on costs. The mediation via mental health problems is in line with the convincing evidence on the etiologic role of stress in externalizing as well as internalizing psychopathology (and vice versa) [16]. It also coincides with the previously established link between levels of psychopathology and service use by adolescents [54]. A study more comparable to the present research was done by Vila et al. [19]. It shows that frequent attendance to primary care by adolescents is independently predicted by past consultations for mental health problems, over- and above medical problems. Hence, in addition to physical symptoms, mental health is relevant for frequent health care use.

If we interpret the depicted evidence against the background of the assumption that stress is a risk factor for illness, the findings suggest that stress leads to both physical- and mental health problems which in turn lead to health care costs, but that stress does not directly impact costs. Further research is needed to test these questions of causality. From the perspective of developmental psychology, one may reason whether the relatively greater importance of mental health opposed to physical health in the mediation model is a manifestation of an increased adolescent vulnerability for stress-related mental problems that subjectively require support compared to the vulnerability for physical stress-related symptoms. In adults, there is clear evidence on the mediating role of the biological stress reaction between prospective associations of stress and costs [22]. Regarding adolescence, the relationships among the response systems (cognitive, behavioural, and biological) have rarely been studied [55]. Vulnerability to cardiovascular problems as a biological consequence of stress and respective help seeking might for example increase only later in life. Further investigation with longitudinal studies including, e.g., somatic markers of stress and disease are needed to clarify this reasoning. The

present finding may also reflect the increasing relevance of adolescent mental health for public health in high-income countries. Analysing data from the WHO Global Burden of Disease Study, Gore et al. [56] show that neuropsychiatric disorders during adolescence have been largely overlooked in public health. With regards to causes of disease burden that rarely lead to death, they are the leading cause of disability in young people aged 10–24 years all over the world. When looking both at the non-fatal and fatal disease-burden, neuropsychiatric disorders are the main cause of burden in high-income countries, especially in those aged 15–24 years. In low- and middle-income countries the burden of disease of neuropsychiatric disorders likewise is high, yet communicable diseases and injuries are also highly relevant. Analysing non-communicable diseases across all age ranges with regards to costs of illness, both mental health conditions and cardiovascular diseases pose the dominant contributors to the global economic burden [57]. This raises the question of whether (stress-related) mental health is especially relevant in the young, while (stress-related) physical illness plays a larger role in health care costs throughout the life span.

Furthermore, our finding may mirror a particular relevance of mental health problems in primary and somatic health care. As Hessel et al. [17] show, even though the share of psychosomatic constraints was high (47.7%), the amount of psychosocial consultations because of these complaints was rather low (5.4%). To compare, 92.8% consulted the general practitioner and 25.2% consulted the orthopaedist because of the symptoms. In light of these studies, the present results can be regarded as another hint to the need for awareness of stress and mental health problems in all areas of the health care system. One may even go further and hypothesize, that adolescents with stress and related mental health problems primarily present to the general practitioner or other somatic services, instead of consulting mental health specialists or psychosocial services. This idea is supported by a 5-year prospective study on mental distress and health care use and costs in adults [58]. Therein, baseline depression and somatization were independently related to in- and outpatient health care costs at follow-up. Even after excluding visits to mental health professionals, both factors predicted outpatient visits and costs. A nationwide, representative study on health care use by German children and adolescents presents converging evidence [54]. Psychopathology scores predicted service use. Affected children or teenagers with borderline or abnormal psychopathology scores consulted the GP or paediatrician more frequently than expected according to the size of the subgroup. Accordingly, amongst those subjects with an abnormal score only 18.6% used mental health services. Of the subjects with mental health service use, 80% additionally frequented somatic health service providers, mainly GPs and paediatricians. It has to be taken into account that in

Germany, the intense GP use also reflects the organisation of the health care system. GPs are assigned a gate keeping function and refer patients to a specialist if necessary. Still, taken together, the findings from diverse studies suggest that there is an overrepresentation of mental health problems in somatic realms of health care. Even though our findings do not provide information on causality and directions of the associations, in combination with the depicted studies it points to the importance of recognition and handling of stress and related mental health problems throughout all services and especially in primary care.

The present research has several limitations that have to be taken into account. It was part of an RCT on stress management training. As no intervention effects emerged, we do not assume that the intervention altered the associations [35]. Attention should rather be drawn to the correlational nature of the data. Even though we conducted a RCT with baseline and postline assessment, we could not examine prospective associations in the present manuscript due to matters of sample size. The distribution of the cost variable would have required a larger sample to examine prospective associations. Hence, the applied study design does not allow for inferences on causality or on directionality of the associations found. Moreover, it should be taken into account that stress and psychopathology relate with each other bidirectionally [16]. According to the stress-generation hypothesis, psychopathology also generates stress, which is likely to be reflected in the present results. This goes along with a conceptual overlap between stress, operationalized in the PQ, and mental health problems in the YSR. As it is a measure of stress but not stressors, the subjective appraisal is part of the stress measure. Consequently, there is an increased risk for confound between both variables which might have inflated correlations in the present study. Continuing with the choice of instruments, the assessment of health care costs with the self-report instrument MRV can be regarded as strength of the study. It encompasses a wide range of services and similar scales are applied in international cost studies [45]. Still, it lacks objectivity compared to medical case registries or questioning service providers. While the former approach is not available in Germany, the latter is highly resource intense and requires the cooperation of many players in health care [51]. In the analysis of the cost data, a larger sample size would have been advantageous. The skewed distribution did not allow for inferential statistical analyses according to cost category or with a dimensional measure of costs. Dichotomizing led to a loss in information and effects are presumably underestimated. Further, we had to apply generalized structural equation modelling due to the dichotomous cost data, which does not allow for the assessment of model fit in the classical sense. We also need to critically reflect on the measurement of health.



While mental health problems were assessed with an instrument of 101 items, physical well-being was measured with a scale of only five questions. This argument can be countered with results from the validation study of the KIDSCREEN-52 [43]. Therein, construct validity of the physical well-being dimension was shown. The scale was correlated with psychosomatic health complaints (HBSC  $r = -0.41$ ), consultation of a health care professional in the past 4 weeks ( $ES = 0.39$ ) and hospitalisation during the past 12 months ( $ES = 0.34$ ). Internal consistency of the scale was good (Cronbach's  $\alpha = 0.80$ ) and test-retest reliability within 2 weeks adequate ( $r = 0.66$ ). These findings show that indeed the scale can be regarded as a valid and reliable measure of physical well-being. Last but not least, sample characteristics limit generalizability. The results pertain to the sample of high school students in Heidelberg. As lower socioeconomic status is associated with higher levels of stress [59–61] and health care utilization [19, 54], the generalizability of the results is limited to cities with comparable socioeconomic status.

To conclude, the present research is consistent with an important role of stress in mental and physical health problems and seeking health care for these stress-related symptoms. Stress itself does not appear to be directly related to costs in adolescents; thus, costs occur only in the presence of stress-related mental health problems. Given concurrent assessment of stress, health and costs as well as the small sample size, further research is needed to substantiate our findings. Nonetheless, the study contributes to the evidence base in favour of the investment of resources in research on adolescent stress, prevention and treatment of related health problems, and shows the particular role of stress-related mental health problems with regards to health care costs. The findings are supposed to pave the way for longitudinal studies in larger samples which verify causal relations and conduct analyses specific to the different types of costs.

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### Compliance with ethical standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical approval** Before recruitment, approval of the local ethics committee was obtained. The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

**Informed consent** All participants gave their informed consent before being included in the study.

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