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Childhood maltreatment and sleep apnea: Findings from a cross-sectional general population study

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ABSTRACT

Objective: Cumulative evidence indicates that childhood maltreatment (CM) is associated with sleep disturbances possibly suggesting sleep apnea. However, the relation between CM and objective measures of sleep apnea as determined by polysomnography (PSG) has not yet been assessed.
Methods: Using a cross-sectional design and based on PSG measurements from $N = 962$ subjects from the SHIP-Trend general population study, we used linear regression models to investigate the relationship between apnea-hypopnea (AHI) and oxygen desaturation index (ODI) and Epworth sleepiness scale (ESS) metrics and the Childhood Trauma Questionnaire (CTQ). All significant models were additionally adjusted for obesity, depression, metabolic syndrome, risky health behaviors, and socioeconomic factors.
Results: While both AHI and ESS were positively associated with the CTQ sum score, ODI was not. Investigating the CTQ subscales, ESS was associated with emotional abuse and emotional neglect; AHI was associated with physical and sexual abuse as well as physical neglect. For both the sum score and the subscales of the CTQ, ESS effects were partially mediated by depressive symptoms, while AHI effects were mediated by obesity, risky health behaviors, and metabolic syndrome.
Conclusion: The findings of this general population study suggest an association between CM, particularly physical neglect, and objective as well as subjective indicators of sleep apnea, which were partially mediated by depressive symptoms and obesity.

1. Introduction

Adverse childhood experiences (ACEs) including childhood maltreatment (CM) such as child abuse or neglect represent a global phenomenon with one or more ACEs reported by at least 50% of the adult population [1] and detrimental effects on physical and mental health over the entire life span [2,3]. This also applies to sleep health as cumulating evidence indicates an association between ACE and CM, respectively, and sleep disturbances in adulthood in clinical as well as community populations [4–8]. As summarized by systematic reviews and meta-analysis [3,4], ACEs have been associated with lower subjective sleep quality, longer sleep onset latency, trouble staying asleep throughout the night, and sleep disorders in adulthood using both prospective and retrospective study designs,

Although poor sleep quality including sleep fragmentation and daytime sleepiness may be suggestive of sleep apnea, this clinical syndrome has not yet been related to childhood adversity or maltreatment. This is all the more surprising given that some studies on the relationship between ACE and sleep health have used overnight polysomnography (PSG) [9–13] being the gold standard for the assessment of sleep apnea

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[14,15].

This common condition as manifestation of chronic sleep-disordered breathing caused by a recurrent upper-airway collapse during sleep, leading to brain arousal, sympathetic activation, and blood oxygen desaturation affects around one-seventh of the world's population [16]. Its risk factors comprise older age, male sex, and obesity (reviewed by [14]), and sleep apnea itself represents a risk factor for cardiovascular [17], metabolic [18,19], neurodegenerative [20,21], and mental disorders [22]. Thus, sleep apnea may play an important role in the complex relation between CM and poor physical as well as mental health later in life (e.g. [2,3,23]).

Considering the detrimental consequences of CM for brain development [24–26], functional and structural network alterations, dysregulations of the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system, as well as altered neuronal brain activity have been suggested as neurobiological pathways linking ACEs to poor sleep health [5,27]. All of these mechanisms may lead to respiratory events and might affect oxygen saturation.

In light of these considerations, our general population study aimed to assess the association of self-reported CM with objective indicators of sleep apnea, i.e. the PSG-derived apnea-hypopnea index (AHI), a combined measure of airflow absence or reduction and the oxygen desaturation index (ODI) assessing the average number of oxygen desaturations >3% during sleep. In addition to these objective markers, we also investigated excessive daytime sleepiness (EDS) using the Epworth Sleepiness Scale (ESS) [28] as third and subjective outcome because it is considered a clinically important symptom, i.e. one among other behavioral manifestations of sleep apnea [14]. Because CM has been related to several well-established risk factors for sleep apnea including obesity [29], metabolic alterations [30], risky health behaviors [2,3,23], and low socioeconomic status [31,32], these conditions were taken into account as potential mediators. Moreover, depression is associated with both CM and sleep apnea [22,33], and might be another mediator. In addition, as evidence suggests that CM types differ in their negative impact on health outcomes in general [34,35] and sleep problems in particular with a more devastating effect of abuse compared to neglect [4,36], we analyzed whether types of childhood adversity are differentially related to objective and subjective markers of sleep apnea. Finally, we focussed on specific combinations for CM types representing threat (i.e. all forms of abuse), deprivation (all forms of neglect), and emotional maltreatment (including emotional both abuse and neglect) [37]. This empirically based classification allows us to link specific patterns of childhood adversity to distinct health outcomes including objective and subjective markers of sleep apnea [37].

2. Methods

2.1. Procedure and participants in SHIP-Trend

The Study of Health in Pomerania (SHIP) represents a population-based, large-scale cohort project designed to assess the prevalence, incidence and complex interplay of common risk factors, subclinical disorders, and clinical diseases [38]. For the current study, the SHIP-Trend sample was used, which was drawn from an age, sex, and city/county of residence stratified sample of 10,000 subjects from the central population registry in the federal state of Mecklenburg-Vorpommern, Germany. Out of the net sample of 8826, after the exclusion of deceased and relocated subjects, 4420 (2275 women) participated (response 50.1%). The invitation procedure included three written invitations, phone calls, and home visits [38,39]. Baseline data collection for SHIP-TREND started in 2008 and examinations were finalized in 2012, including PSG [39,40]. The data presented in this study were collected from several health- and risk factor-related self-report questionnaires (see below), a computer-assisted health-related interview, a medical baseline examination (e.g. anthropometric measurements, blood sampling), and the overnight PSG, which was offered to all SHIP-TREND participants [40]. For the purpose of the current study, we included all subjects with sleep apnea data, who spent more than four hours sleeping during the PSG examination as well as complete CTQ data (cf. Supplementary Fig. 1 depicting the flow chart of eligible, excluded, and analyzed participants in the current study according to the Strengthening the Reporting of Observational Studies in Epidemiology [STROBE] statement [41]). SHIP-TREND was conducted following the Helsinki Declaration and was reviewed and approved by the Institutional Review Board of the University Medicine Greifswald. All subjects provided informed written consent.

2.2. Assessment of objective and subjective sleep-based markers

Having invited all SHIP-TREND participants, $N = 1264$ subjects volunteered to undergo an enhanced sleep assessment consisting of a lab-based one-night polysomnography (ALICE-5, Philips Respironics, Eindhoven, The Netherlands) performed and rated according to standards of the American Academy of Sleep Medicine (AASM) [40,42]. Sleep apnea severity was assessed by using the polysomnography-based apnea-hypopnea index (AHI), assessing the average number of apnea and hypopnea events per hour of sleep, and the oxygen desaturation index (ODI), assessing the number of episodes of oxygen desaturation (>3%) per hour of sleep.

For the assessment of EDS as common symptom of sleep apnea [14], the Epworth Sleepiness Scale (ESS) [28] was administered. It is a very short scale asking the respondent to rate his or her probability of falling asleep on a scale of increasing probability from 0 to 3 for eight different situations. Sum scores for the eight questions ranging between 0 and 9 are considered to be normal, while sum scores of 10 or above indicate that expert medical advice should be sought [28].

2.3. Psychological assessment and covariates

The German version of the Childhood Trauma Questionnaire (CTQ) was used for the retrospective self-report of child maltreatment [43,44]. It is a brief, reliable and valid screening device for histories of childhood trauma including emotional, sexual, and physical abuse as well as emotional and physical neglect. Each of these dimensions is captured by five items each which are endorsed on a 5-point Likert scale ranging from "never true" (1) to "very often true" (5) with higher scores indicating a higher degree of CM. In addition to a dimensional scoring procedure, the manual provides threshold values to determine the severity of abuse and neglect (none, mild, moderate, and severe). Dichotomized variables (none to mild versus moderate to severe) were created for each trauma type. From these, three composite variables were computed indicating threat (defined as experience of one or more types of abuse of at least moderate severity), deprivation (exposure to at least one category of moderate to severe neglect), and emotional maltreatment (endorsing either emotional abuse or neglect of at least moderate degree) [37]. Moreover, the number of moderate or severe CM types was counted. The CTQ is considered one of the most widely used instruments to assess CM, and it was reported to show good reliability and validity in independent studies [45]. Additionally, the five-factor model (i.e. the 5 subscales reflecting the different types of childhood trauma) was empirically confirmed [43,45]. The psychometric properties of the German version of the CTQ were found to be similar to the original [44]. In this study, the CTQ's internal consistency according to Cronbach was $\alpha = 0.88$.

The PHQ-9 represents the depression module of the Patient Health Questionnaire (PHQ) and is a brief self-administered measure for screening, diagnosing, monitoring, and measuring the severity of depression [46]. It scores each of the nine DSM-IV criteria for depression as "0" (not at all) to "3" (nearly every day) and is a reliable and valid tool [46,47]. Cronbach's α was calculated to be 0.84 for our sample.

Relevant covariates were derived from the self-report measures, the personal interview, and the core medical examination. The waist-height

ratio was defined as the subject's waist circumference divided by the subject's height. The presence of a metabolic syndrome was assumed if three out of the following five criteria were present: (i) waist-circumference ≥ 94 cm in males and ≥ 80 cm in females; (ii) self-reported intake of antidiabetic medication (ATC: A10) or a blood sugar level of ≥144 mg/dl if fasting <8 h or ≥ 110 mg/dl if fasting >8 h; (iii) HDL-cholesterol <40 mg/dl in males and < 50 mg/dl in females; (iv) self-reported intake of lipid-lowering medication (ATC: C10AB) or Niacine (ATC: C10AD) or a triglyceride concentration of >204 mg/dl if fasting for <8 h and > 150 mg/dl if fasting for >8 h; (v) blood pressure ≥ 130/85 mmHg or a self-reported intake of antihypertensive medication (ATC: C02). Smoking packyears and current smoking status were assessed based on the subjects' self-reported disclosures of smoking habits. Average daily alcohol consumption was calculated according to the self-reported consumption of various alcoholic beverages in the last 30 days [48]. Partner status was defined based on the self-reported disclosures, equivalent income was defined as the self-reported net income of the subjects' household divided by the square root of the number of individuals living in the household, and education years was defined as the theoretical number of years required to gain the highest school or vocational qualification; subjects with no degree were given a default value of 8 years.

2.4. Statistical analysis

All statistical analyses were performed with R Version 4.1 [49]. Missing covariates were imputed in the whole SHIP-Trend dataset using the "missForest" R package [50]. Ordinary least square regression was used to assess the impact of CM (exposure), both the CTQ total score as well as the five CTQ subscale scores) on sleep apnea severity (outcome). In the first step, we used both the dimensional CTQ total score as well as the five dimensional CTQ subscale scores as predictors; the CTQ subscales reflecting the different CM types were entered both separately and simultaneously as predictor variables into the regression equations; regarding the latter, there was no evidence of collinearity between the predictor variables as indicated by variance inflation factors (VIF), which were below 2 in all cases. In the second step, the number of CM types and specific combinations of CM representing threat, deprivation, and emotional maltreatment [37] were entered as independent variables into the regression equation. To normalize their distribution, both AHI and ODI were log-transformed after the addition of a pseudo count of one. In the initial stage (model 0), all models were adjusted for age, sex, age×sex, and total sleep time (TST), with age and TST being modeled non-linearly using restricted cubic splines to account for non-linear dependencies [41]. Furthermore, to account for overly influential subjects, each model was calculated twice: First, the entire study population was used to identify outliers, i.e. those whose cook's distance was greater than four times the mean distance or if any dfbeta was >0.3. Then, the re-analysis was performed without the outliers, the results of which are presented [51]. As we present the analyses of the data without outliers, the number of subjects included in the different regression equations differs slightly. In the next step, significant models were re-analyzed while adjusting for sets of additional factors using a one-at-a-time approach to investigate the robustness of the models and the effect of mediating factors. The investigated sets were obesity (model 1) assessed using the waist-height ratio as well as its interaction with sex, depression severity (model 2), assessed using the PHQ-9 score, metabolic factors (model 3) assessed via the presence of the metabolic syndrome, risky behaviors (model 4) assessed using smoking pack years as well as its interaction with the current smoking status and alcohol consumption as well as its interaction with sex and finally socio-economic factors (model 5) assessed via partnership status, education level and equivalent income. To account for multiple testing, we applied the false discovery rate (FDR) approach. For all models, effects were considered significant if the FDR was <0.05 in the base models and if the *p*-value was <0.05 in the expanded models.

3. Results

3.1. Baseline characteristics of the study sample

Of all PSG volunteers ($N = 1264$), 962 individuals (76.1% of those undergoing PSG; 21.8% of all SHIP-TREND participants) had complete data for the CTQ and the PSG-based outcomes and spent >4 h sleeping during the PSG (cf. STROBE flow chart in Supplementary Fig. 1). The mean age of the study population was 52.1 ± 13.7 years, and it comprised 433 women (44.7%). The mean AHI score was 9.54 ± 14.1 events per hour which lies within the mild sleep apnea interval (5 ≤ AHI < 15); the mean ODI score was 6.84 ± 11.7 and the mean ESS sum score was 7.10 ± 3.33. Compared to the remaining SHIP-Trend sample, the analyzed sample had a slightly lower proportion of females but was otherwise comparable. Further details on exposure variables and covariates as well as the corresponding values from the remaining SHIP-Trend sample are illustrated in Table 1. A complete set of covariates

Table 1
Characteristics of the study sample and the remaining SHIP-Trend population.

	Study sample [mean ± sd/ N (%)]	Missing N (%)	SHIP sample [mean ± sd/ N (%)]	Missing N (%)
	N = 962		*N* = 3458	
Age, years	52.1 ± 13.7		51.9 ± 15.9	
Sex, female	433 (45.0%)		1842 (53.3%)	
TST, hours	6.31 ± 0.95		5.13 ± 1.62	3311 (95.7)
Sleep Apnea factors:				
AHI	9.54 ± 14.1		9.45 ± 13.8	3311 (95.7)
ODI	6.84 ± 11.7		6.54 ± 10.6	3311 (95.7)
ESS score	7.10 ± 3.33		6.49 ± 3.26	3195 (92.4)
CTQ – dimensional scores				
Total score	33.40 ± 9.30		33.30 ± 9.80	324 (9.4)
Emotional Abuse	6.64 ± 2.49		6.21 ± 2.46	257 (7.4)
Physical Abuse	5.75 ± 1.89		5.66 ± 1.92	246 (7.1)
Sexual Abuse	5.27 ± 1.47		5.21 ± 1.26	240 (6.9)
Emotional Neglect	9.09 ± 4.23		9.05 ± 4.47	295 (8.5)
Physical Neglect	6.95 ± 2.39		7.19 ± 2.68	289 (8.4)
CTQ – types				
Number of CM types	0.36 ± 82		0.37 ± 0.83	220 (6.4%)
Threat	80 (8.3%)		229 (7.2%)	277 (8.0%)
Deprivation	176 (18.3%)		648 (20.7%)	317 (9.2%)
Emotional Maltreatment	118 (12.3%)		385 (12.3%)	310 (9.0%)
Covariates				
Whtr	0.54 ± 0.08	3 (0.3)	0.54 ± 0.09	13 (0.4)
PHQ-9	8.36 ± 5.92		7.75 ± 5.33	202 (5.8)
Smoking Packyears	7.75 ± 14.6		8.81 ± 14.6	
Current Smoking	196 (20.4%)	3 (0.3)	987 (28.5%)	19 (0.5)
Alcohol, g of Ethanol/day	9.27 ± 12.8	8 (0.8)	8.22 ± 13.6	43 (1.2)
Partner, yes	763 (79.3%)	3 (0.8)	2655 (76.8%)	67 (1.9)
Equivalent Income	1450 ± 764	38 (4.0)	1340 ± 682	10 (0.3)
Education years	12.9 ± 2.42	3 (0.8)	12.1 ± 2.31	60 (1.7)
Metabolic Syndrome	265 (27.5%)	17 (1.8)	969 (28.0%)	67 (1.9)

Abbreviations: AHI: apnea-hypopnea index; CTQ: Childhood Trauma Questionnaire; Threat: experience of one or more types of abuse of at least moderate severity; Deprivation: exposure to at least one category of moderate to severe neglect; Emotional maltreatment: endorsing either emotional abuse or neglect of at least moderate degree; ESS: Epworth Sleepiness Scale; ODI: oxygen desaturation index; PHQ-9: Patient Health Questionnaire-9; sd: standard deviation; TST: total sleep time; Whtr: waist-height ratio.

was seen in 93.7% of the study sample, with equivalent income exhibiting the highest missingness rate (cf. Table 1 and Supplementary Fig. 2). The (locally) optimal imputation was reached after the 7th iteration with an estimated normalized root mean square error of 0.41 and an estimated proportion of falsely classified of 0.12 (see Supplementary Figs. 3 and 4). Participants who slept less than four hours during the PSG and thus were excluded from the analyses ($N = 38$) did not differ in their CTQ total and subscale scores from the study population (data not presented). The bivariate correlation matrix of all study variables is presented in Supplementary Fig. 5.

3.2. Associations between childhood maltreatment and sleep-based markers

Looking at CM in general and after correcting for multiple testing, both AHI and ESS scores were positively associated with the dimensional CTQ total score, while we did not observe an association between ODI and CM (cf. Table 2).

The significant CM-AHI link remained stable when additionally controlling for depression (model 2) or socioeconomic factors (model 5). The association was slightly attenuated, with metabolic factors (model 3) reducing the effect estimate by 20.2% and risky health behaviors (model 4) by 16.9%. Controlling for obesity (model 1) resolved the significant association between CM and AHI possibly suggesting a partial mediation. Similarly, the relation between CM and EDS (measured by the ESS) remained stable when accounting for obesity, metabolic factors, risky health behaviors, and socioeconomic factors, but not when current depression (assessed by the PHQ-9) was controlled for.

Table 2
Associations between CM (assessed by the dimensional CTQ total score) and objective and subjective indicators of sleep apnea (in case of significant effects, the findings of the sensitivity analyses are also provided).

Model	Estimate [95%-CI]	p [FDR]	N
log AHI			
Base (model 0) [a]	0.0089 [0.0024; 0.015]	0.0074 [0.011] *	915
Obesity (model 1) [b]	0.0052 [−0.00094; 0.011]	0.097	916
Depression (model 2) [c]	0.0091 [0.0024; 0.016]	0.0078 **	913
Metabolic (model 3) [d]	0.0071 [0.00051; 0.014]	0.035 *	926
Risky Behavior (model 4) [e]	0.0074 [0.00063; 0.014]	0.032 *	922
Socioeconomic (model 5) [f]	0.0085 [0.0023; 0.015]	0.0078 **	920
log ODI			
Base (model 0) [a]	0.0056 [−0.00083; 0.012]	0.087 [0.087]	915
ESS			
Base (model 0) [a]	0.044 [0.021; 0.067]	2e-04 [0.00061] ***	918
Obesity (model 1) [b]	0.043 [0.02; 0.065]	0.00022 ***	916
Depression (model 2) [c]	0.017 [−0.0061; 0.04]	0.15	915
Metabolic (model 3) [d]	0.046 [0.024; 0.069]	7.10E-05 ***	914
Risky Behavior (model 4) [e]	0.042 [0.018; 0.065]	0.00057 ***	918
Socioeconomic (model 5) [f]	0.042 [0.018; 0.065]	0.00047 ***	920

* p- or FDR-value <0.05; ** p- or FDR-value <0.01; *** p- or FDR-value <0.001.
Abbreviations: AHI: apnea-hypopnea index; CI: confidence interval; ESS: Epworth Sleepiness Scale; FDR: false discovery rate; PHQ-9: Patient Health Questionnaire-9; ODI: oxygen desaturation index; Whtr: waist-height ratio.

[a] Model was adjusted for age [non-linear], sex, age [non-linear] × sex and total sleep time [non-linear].

[b] Model was adjusted for the base covariates (see a) as well as for Whtr and Whtr×sex.

[c] Model was adjusted for the base covariates (see a) as well as for PHQ-9.

[d] Model was adjusted for the base covariates (see a) as well as for the presence of the metabolic syndrome.

[e] Model was adjusted for the base covariates (see a) as well as for smoking packyears, current smoking status, smoking packyears×current smoking status, alcohol consumption and alcohol consumption×sex.

[f] Model was adjusted for the base covariates (see a) as well as for partnership status, equivalent income and education years.

3.3. Individual and differential associations between CM types and sleep-based markers

Investigating the dimensional scores of the five CM types separately revealed that AHI and ODI were associated with the CTQ subscales measuring physical abuse, physical neglect, and sexual abuse (AHI only); in contrast, we did not find a relation with emotional abuse or emotional neglect (cf. Table 3). As with the sum score, the effects remained stable except when controlling for obesity. Conversely, emotional abuse and neglect were significantly related to ESS score. The magnitude of these associations was decreased but remained stable when controlling for obesity, metabolic conditions, risky health behaviors, or socioeconomic factors. However, when considering depression as a covariate neither emotional abuse nor emotional neglect were significantly associated with EDS. Table 3 presents a detailed overview of the results.

Considering all CM types simultaneously to determine their differential associations with sleep-based markers revealed that only physical neglect, but not emotional neglect nor any of the abuse dimensions was significantly related to AHI. This association was attenuated, but not resolved when accounting for obesity, depression, metabolic conditions, risky health behaviors, or socioeconomic factors (cf. Table 4). Similarly, ODI was linked to both physical abuse and physical neglect, but not to any other CM type. Again, controlling for covariates resulted in attenuation, but not resolution of the relation except for the physical neglect-ODI link when additionally taking obesity into account. EDS was not associated with any CM types apart from emotional neglect, but this association just reached significance and vanished when depression or socioeconomic factors were controlled for.

3.4. Associations between number and specific combinations of CM types and sleep-based markers

The number of CM types was positively and significantly related to AHI, but neither to ODI nor ESS scores (cf. Table 5). Accounting for obesity, depression, metabolic factors, risky health behaviors, or socioeconomic factors attenuated the association but did not resolve it. Likewise, deprivation (defined as exposure to childhood physical and/or emotional neglect) was found to be associated with AHI, but not with ODI or ESS. Again, controlling for potential covariates resulted in attenuation, but not resolution of the association. Neither threat (i.e. childhood experience of physical, sexual, and/or emotional abuse) nor emotional maltreatment were significantly related to any of the objective or subjective sleep-based markers.

4. Discussion

Given that both CM and sleep apnea represent major public health issues, their association has gained increasing attention with the majority of studies using subjective indicators of sleep problems [4–13]. In contrast, and to the best of our knowledge, this is the first general population study relating CM to objective (i.e. PSG-based) markers of sleep apnea. Our main results can be summarized as follows: CM in general and physical as well as sexual abuse and physical neglect were significantly associated with AHI; these associations were partly mediated by obesity, risky health behaviors, and metabolic syndrome. In contrast, only physical abuse and physical neglect were related to ODI. We also found significant associations between CM in general as well as emotional maltreatment (i.e. emotional abuse and emotional neglect) and self-reported EDS, which were partly mediated by depression.

Table 3
Associations between different types of CM (assessed by the dimensional CTQ subscales) and objective and subjective indicators of sleep apnea (in case of significant effects, the findings of the sensitivity analyses are also provided).

Outcome	Model	Estimate [95%-CI]	p [FDR]	N
	Emotional Abuse			
log **AHI**	Base (model 0)[a]	0.013 [−0.013; 0.039]	0.32 [0.39]	912
log ODI	Base (model 0)[a]	0.0045 [−0.021; 0.03]	0.73 [0.78]	914
ESS	Base (model 0)[a]	0.120 [0.033; 0.210]	0.008 [0.028] *	915
	Obesity (model 1)[b]	0.130 [0.046; 0.220]	0.0028 **	916
	Depression (model 2)[c]	0.002 [−0.092; 0.096]	0.97	914
	Metabolic (model 3)[d]	0.100 [0.015; 0.190]	0.022 *	916
	Risky Behavior (model 4)[e]	0.140 [0.048; 0.230]	0.0029 **	916
	Socioeconomic (model 5)[f]	0.110 [0.018; 0.200]	0.019 *	919
	Physical Abuse			
log AHI	Base (model 0) [a]	0.046 [0.013; 0.080]	0.007 [0.028] *	915
	Obesity (model 1)[b]	0.039 [0.0079; 0.07]	0.014 *	916
	Depression (model 2)[c]	0.051 [0.016; 0.085]	0.004 **	911
	Metabolic (model 3)[d]	0.043 [0.011; 0.075]	0.008 **	923
	Risky Behavior (model 4)[e]	0.042 [0.009;0.076]	0.014 *	920
	Socioeconomic (model 5)[f]	0.044 [0.009;0.079]	0.015 *	912
log ODI	Base (model 0) [a]	0.038 [0.0075; 0.069]	0.015 [0.032] *	919
	Obesity (model 1)[b]	0.021 [−0.0072; 0.05]	0.14	914
	Depression (model 2)[c]	0.037 [0.0051; 0.069]	0.023 *	919
	Metabolic (model 3)[d]	0.032 [0.0018; 0.062]	0.038 *	913
	Risky Behavior (model 4)[e]	0.042 [0.011; 0.072]	0.0082 **	923
	Socioeconomic (model 5)[f]	0.038 [0.0068; 0.068]	0.017 *	923
ESS	Base (model 0) [a]	0.061 [−0.064; 0.19]	0.340 [0.39]	915
	Sexual Abuse			
log AHI	Base (model 0) [a]	0.057 [0.012; 0.100]	0.012 [0.031] *	920
	Obesity (model 1)[b]	0.049 [0.006; 0.092]	0.026 *	922
	Depression (model 2)[c]	0.048 [0.003; 0.093]	0.035 *	917
	Metabolic (model 3)[d]	0.060 [0.014; 0.110]	0.01 *	928
	Risky Behavior (model 4)[e]	0.059 [0.014; 0.100]	0.01 *	928
	Socioeconomic (model 5)[f]	0.066 [0.004; 0.130]	0.038 *	918
log ODI	Base (model 0)[a]	0.046 [−0.0052; 0.098]	0.078 [0.13]	919
ESS	Base (model 0) [a]	0.250 [0.008; 0.480]	0.043 [0.08]	928
	Emotional Neglect			
log AHI	Base (model 0) [a]	0.011 [−0.003; 0.025]	0.12 [0.18]	915
log ODI	Base (model 0)[a]	0.0017 [−0.012; 0.015]	0.81 [0.81]	914
ESS	Base (model 0) [a]	0.078 [0.033; 0.120]	8e-4 [0.006] **	918
	Obesity (model 1)[b]	0.078 [0.033; 0.120]	0.001 ***	919
	Depression (model 2)[c]	0.029 [−0.016; 0.074]	0.210	915
	Metabolic (model 3)[d]	0.068 [0.023; 0.110]	0.003 **	912
	Risky Behavior (model 4)[e]	0.065 [0.018; 0.110]	0.007 **	920
	Socioeconomic (model 5)[f]	0.076 [0.030; 0.120]	0.001 **	919
	Physical Neglect			
log AHI	Base (model 0) [a]	0.048 [0.022; 0.073]	0.00022 [0.0034]**	910
	Obesity (model 1)[b]	0.028 [0.0049;0.052]	0.018 *	914
	Depression (model 2)[c]	0.046 [0.02; 0.072]	0.00045 ***	908
	Metabolic (model 3)[d]	0.041 [0.016; 0.066]	0.0015 **	926
	Risky Behavior (model 4)[e]	0.044 [0.019; 0.07]	0.00073 ***	924
	Socioeconomic (model 5)[f]	0.045 [0.021; 0.069]	0.00026 ***	919
log ODI	Base (model 0) [a]	0.033 [0.0078; 0.058]	0.01 [0.031] *	916
	Obesity (model 1)[b]	−0.0016 [−0.024;0.021]	0.89	911
	Depression (model 2)[c]	0.035 [0.0089; 0.06]	0.0084 **	913
	Metabolic (model 3)[d]	0.026 [0.00042; 0.051]	0.046 *	924
	Risky Behavior (model 4)[e]	0.028 [0.0027; 0.054]	0.030 *	918
	Socioeconomic (model 5)[f]	0.028 [0.0049; 0.052]	0.018 *	915
ESS	Base (model 0) [a]	0.05 [−0.034; 0.14]	0.24 [0.33]	920

Abbreviations: AHI: apnea-hypopnea index; CI: confidence interval; ESS: Epworth Sleepiness Scale; FDR: false discovery rate; PHQ-9: Patient Health Questionnaire-9; ODI: oxygen desaturation index; Whtr: waist-height ratio.
* p- or FDR-value <0.05; ** p- or FDR-value <0.01; *** p- or FDR-value <0.001.
[a] Model was adjusted for age [non-linear], sex, age [non-linear] × sex and total sleep time [non-linear].
[b] Model was adjusted for the base covariates (see a) as well as for Whtr and Whtr×sex.
[c] Model was adjusted for the base covariates (see a) as well as for PHQ-9.
[d] Model was adjusted for the base covariates (see a) as well as for the presence of the metabolic syndrome.
[e] Model was adjusted for the base covariates (see a) as well as for smoking packyears, current smoking status, smoking packyears×current smoking status, alcohol consumption and alcohol consumption×sex.
[f] Model was adjusted for the base covariates (see a) as well as for partnership status, equivalent income and education years.

Numerous investigations have found relevant associations between childhood trauma and subjective indicators of sleep apnea such as daytime sleepiness, lower subjective sleep quality, or trouble staying asleep throughout the night (reviewed by [4,5]). However, self-reported outcomes are heavily influenced by individual differences in self-presentation styles impacting the accuracy of symptom reporting which is of primary importance in health-related research [52]. Biases in symptom reporting can be attributed to sensory-perceptual or affective-motivational aspects [52,53]. For sleep disturbances and sleep apnea, mood-dependent (i.e. depressive) attentional processing may distort symptom perception resulting in both under- and over-reporting [54]. Although it is unknown whether or not adult victims of CM are more liable to symptom over-reporting than adults without exposure to CM, it may well be that the association between childhood trauma and self-reported sleep disturbances can partially be attributed to mood-dependent health bias and symptom over-reporting. These considerations are underscored by our finding of an association between self-reported depression and EDS resulting in the resolution of the CM-EDS link when depression was accounted for. Therefore, PSG as an

Table 4
Differential associations between all types of CM (dimensional CTQ subscale scores) and objective and subjective indicators of sleep apnea.

	Exposure	Emotional Abuse		Physical Abuse		Sexual Abuse		Emotional Neglect		Physical Neglect		
	Model	Estimate	p	Estimate	p	Estimate	p	Estimate	p	Estimate	p	N
log AHI	Base model[a]	−0.022 [−0.057; 0.014]	0.23	0.032 [−0.008; 0.073]	0.12	0.044 [−0.006; 0.093]	0.08	−0.009 [−0.028; 0.01]	0.36	0.052 [0.020; 0.084]	0.0016	917
	Obesity (model 1)[b]	−0.016 [−0.049; 0.018]	0.36	0.036 [−0.006; 0.077]	0.09	0.025 [−0.022; 0.071]	0.30	−0.013 [−0.031; 0.005]	0.15	0.04 [0.010; 0.07]	0.0092	915
	Depression (model 2)[c]	−0.021 [−0.056; 0.015]	0.25	0.042 [−0.001; 0.084]	0.05	0.025 [−0.024; 0.074]	0.32	−0.0083 [−0.028; 0.011]	0.40	0.048 [0.016; 0.081]	0.0035	916
	Metabolic (model 3)[d]	−0.015 [−0.048; 0.019]	0.40	0.038 [−0.007; 0.082]	0.10	0.057 [−0.006; 0.120]	0.08	−0.011 [−0.029; 0.008]	0.26	0.052 [0.022; 0.083]	0.0008	910
	Risky Behavior (model 4)[e]	−0.018 [−0.053; 0.017]	0.31	0.035 [−0.006; 0.077]	0.09	0.04 [−0.011; 0.091]	0.12	−0.019 [−0.039; 0.001]	0.06	0.059 [0.026; 0.092]	0.0004	930
	Socioeconomic (model 5)[f]	−0.013 [−0.049; 0.022]	0.46	0.028 [−0.013; 0.069]	0.18	0.038 [−0.012; 0.088]	0.13	−0.018 [−0.038; 0.001]	0.07	0.058 [0.025; 0.091]	6.00E-04	927
log ODI	Base model[a]	−0.023 [−0.058; 0.013]	0.21	0.044 [0.002; 0.085]	0.038	0.053 [−0.013; 0.12]	0.12	−0.013 [−0.032; 0.007]	0.20	0.043 [0.011; 0.076]	0.0088	913
	Obesity (model 1)[b]	−0.021 [−0.053; 0.011]	0.19	0.041 [0.005; 0.077]	0.027	0.02 [−0.029; 0.069]	0.42	−0.014 [−0.031; 0.003]	0.10	0.02 [−0.009; 0.048]	0.18	910
	Depression (model 2)[c]	−0.024 [−0.061; 0.013]	0.21	0.051 [0.007; 0.095]	0.022	0.036 [−0.031; 0.100]	0.29	−0.015 [−0.035; 0.005]	0.14	0.04 [0.008; 0.073]	0.016	912
	Metabolic (model 3)[d]	−0.027 [−0.061; 0.008]	0.13	0.05 [0.010; 0.090]	0.016	0.029 [−0.038; 0.096]	0.39	−0.013 [−0.031; 0.006]	0.18	0.039 [0.0077; 0.07]	0.014	916
	Risky Behavior (model 4)[e]	−0.025 [−0.061; 0.011]	0.17	0.057 [0.016; 0.098]	0.0062	0.053 [−0.016; 0.120]	0.13	−0.02 [−0.04; −0.001]	0.04	0.045 [0.012; 0.078]	0.0072	920
	Socioeconomic (model 5)[f]	−0.022 [−0.058; 0.014]	0.23	0.053 [0.012; 0.093]	0.011	0.046 [−0.021; 0.110]	0.18	−0.018 [−0.038; 0.002]	0.08	0.041 [0.0076; 0.074]	0.016	923
ESS Sum	Base model[a]	0.044 [−0.08; 0.17]	0.49	−0.056 [−0.220; 0.110]	0.5	0.16 [−0.060; 0.370]	0.16	0.067 [0.002; 0.130]	0.04	−0.0072 [−0.11; 0.10]	0.89	923
	Obesity (model 1)[b]	0.037 [−0.086; 0.160]	0.56	−0.043 [−0.200; 0.120]	0.6	0.059 [−0.170; 0.280]	0.6	0.066 [0.001; 0.130]	0.05	−0.0087 [−0.11; 0.097]	0.87	921
	Depression (model 2)[c]	−0.055 [−0.18; 0.067]	0.38	−0.095 [−0.250; 0.057]	0.22	0.087 [−0.120; 0.300]	0.41	0.061 [−0.002; 0.120]	0.06	−0.011 [−0.11; 0.094]	0.84	927
	Metabolic (model 3)[d]	0.032 [−0.094; 0.160]	0.62	−0.048 [−0.220; 0.120]	0.57	0.13 [−0.092; 0.360]	0.25	0.07 [0.004; 0.140]	0.04	−0.016 [−0.12; 0.092]	0.77	925
	Risky Behavior (model 4)[e]	0.032 [−0.091; 0.160]	0.61	−0.11 [−0.270; 0.057]	0.2	0.17 [−0.060; 0.390]	0.15	0.076 [0.011; 0.140]	0.02	−0.023 [−0.13; 0.085]	0.67	922
	Socioeconomic (model 5)[f]	0.027 [−0.099; 0.150]	0.68	−0.01 [−0.180; 0.160]	0.91	0.12 [−0.095; 0.340]	0.27	0.063 [−0.002; 0.130]	0.06	−0.011 [−0.12; 0.097]	0.84	920

Abbreviations: AHI: apnea-hypopnea index; CI: confidence interval; ESS: Epworth Sleepiness Scale; FDR: false discovery rate; PHQ-9: Patient Health Questionnaire-9; ODI: oxygen desaturation index; Whtr: waist-height ratio.

[a] Model was adjusted for age [non-linear], sex, age [non-linear] × sex and total sleep time [non-linear].

[b] Model was adjusted for the base covariates (see a) as well as for Whtr and Whtr×sex.

[c] Model was adjusted for the base covariates (see a) as well as for PHQ-9.

[d] Model was adjusted for the base covariates (see a) as well as for the presence of the metabolic syndrome.

[e] Model was adjusted for the base covariates (see a) as well as for smoking packyears, current smoking status, smoking packyears×current smoking status, alcohol consumption and alcohol consumption×sex.

[f] Model was adjusted for the base covariates (see a) as well as for partnership status, equivalent income and education years.

objective method is an important complement when analyzing the relation between CM and sleep apnea or sleep abnormalities, respectively [9–13].

Because prior research focussed on either specific types of CM (e.g. sexual abuse [36,55,56]) or CM in general [8], the differential impact of the various CM types on sleep disturbances remains to be determined. Given that maltreatment types are significantly interrelated and often co-occur [1,37], a failure to consider all forms of CM simultaneously or specific combinations may result in an overestimation of effects attributed to individual CM types [35]. Analyzing CM types separately as opposed to simultaneously [8] does not allow disentangling whether effects are driven by what is common to all forms of CM versus what is

Table 5
Associations between numbers of CM types and specific combinations of CM types indicating threat, deprivation and emotional deprivation with AHI, ODI and ESS.

Model	Number of CM types		Threat		Deprivation		Emotional maltreatment	
	Estimate [95%-CI]	p [FDR]	Estimate [95%-CI]	p [FDR]	Estimate [95%-CI]	p [FDR]	Estimate [95%-CI]	P [FDR]
log AHI								
Base (model 0) [a]	0.11 [0.032; 0.18]	0.0048 [0.041]	0.26 [0.035; 0.48]	0.023 [0.093]	0.20 [0.056; 0.35]	0.0069 [0.041]	0.095 [−0.083; 0.27]	0.30 [0.44]
Obesity (model 1) [b]	0.073 [0.0027; 0.14]	0.042			0.15 [0.0097; 0.29]	0.036		
Depression (model 2) [c]	0.11 [0.033; 0.18]	0.005			0.21 [0.059; 0.36]	0.0062		
Metabolic (model 3) [d]	0.10 [0.033; 0.17]	0.0042			0.19 [0.052; 0.34]	0.0073		
Risky Behavior (model 4) [e]	0.12 [0.05; 0.20]	0.0011			0.20 [0.054; 0.35]	0.0076		
Socioeconomic (model 5) [f]	0.092 [0.017; 0.17]	0.017			0.17 [0.014; 0.32]	0.033		
log ODI								
Base (model 0) [a]	0.056 [−0.018; 0.13]	0.14 [0.33]	0.20 [−0.024; 0.42]	0.08 [0.24]	0.088 [−0.059; 0.24]	0.24 [0.44]	−0.054 [−0.23; 0.12]	0.55 [0.62]
ESS								
Base (model 0) [a]	0.14 [−0.11; 0.40]	0.27 [0.44]	0.22 [−0.54; 0.99]	0.57 [0.62]	0.21 [−0.28; 0.71]	0.40 [0.53]	0.15 [−0.46; 0.75]	0.64 [0.64]

Threat: experience of one or more types of abuse of at least moderate severity; Deprivation: exposure to at least one category of moderate to severe neglect; Emotional maltreatment: endorsing either emotional abuse or neglect of at least moderate degree.

[a] Model was adjusted for age [non-linear], sex, age [non-linear] × sex and total sleep time [non-linear].

[b] Model was adjusted for the base covariates (see a) as well as for Whtr and Whtr×sex.

[c] Model was adjusted for the base covariates (see a) as well as for PHQ-9.

[d] Model was adjusted for the base covariates (see a) as well as for the presence of the metabolic syndrome.

[e] Model was adjusted for the base covariates (see a) as well as for smoking packyears, current smoking status, smoking packyears×current smoking status, alcohol consumption and alcohol consumption×sex.

[f] Model was adjusted for the base covariates (see a) as well as for partnership status, equivalent income and education years.

specific to a particular type [35]. Concerning AHI, our findings suggest that deprivation, particularly physical neglect has the strongest impact above and beyond other types of CM. This is in good keeping with a study about predictors of insomnia among 4101 active duty service members of the US Army before deployment identifying physical neglect as the only significant contributor of all CTQ subscales [57]. Thus, our result in concert with the finding mentioned above [57] calls into question whether the extensively documented association between childhood sexual abuse and sleep problems [36,55,56] is unique. Regarding ODI, our results are equivocal because it was neither associated with CM in general as indicated by the dimensional CTQ total score as well as the number of CM types nor with specific combinations of CM types representing threat, deprivation, or emotional maltreatment. In contrast, physical abuse and physical neglect were related to ODI. Of note, we used ODI3% and it might well be that the use of ODI4% leads to clearer results. Findings on the association between CM and EDS remain inconclusive, too: There were significant relations between the dimensional CTQ total score, the subscales capturing emotional abuse and emotional neglect when analyzed separately, but only emotional neglect emerged as a significant predictor of ESS when all CM types were considered simultaneously. Of note, emotional maltreatment as a specific combination was not associated with EDS. Further research is needed to clarify these discrepancies.

The differential associations of childhood adversity with AHI and ODI, respectively, deserve some consideration as these metrics are highly correlated (> 0.95) with one another [14]. However, there is significant heterogeneity in studies comparing ODI and AHI [58], and studies using in-lab PSG have shown that these indicators behave differently, depending on age, BMI, and sex [59]. Specifically, growing evidence suggests that agreement between AHI and ODI disappears progressively with the increase of obesity [59], which also influences their association with CM. Moreover, AHI covers a wider range of sleep apnea-related signs (e.g. sleep fragmentation) compared to ODI exclusively capturing oxygen desaturation [14]. Thus, it might be speculated that CM is associated with sleep apnea as a whole, but not with oxygen desaturation.

Although our study holds some strengths including the population-based design, the use of a psychometrically sound and well-established questionnaire to assess CM [45], and the adjustment for relevant confounders, some methodological limitations need to be discussed. First, the exclusive reliance on self-report to capture CM may have compromised validity; future research might want to apply an interview to overcome this drawback. Moreover, the retrospective assessment of childhood trauma may have introduced a recall bias. However, the comparison between data based either on a longitudinal cohort study or on a retrospective approach did not show any bias in the retrospective assessment [60]. Moreover, it was shown that the use of retrospective versus prospective reports of CM yields comparable relations with psychopathological outcomes [61]. Second, the cross-sectional design does not allow any causal inferences: Given that the CTQ inquires about traumatic experiences before the age of 18, it seems very reasonable to consider CM as an exposure or predictor variable. Nevertheless, we cannot rule out reverse causation, that is, patients with signs and symptoms of sleep apnea are more likely to endorse items of childhood trauma. Third, although our study sample was drawn from the general population it might not be representative as PSG was carried out on a random subsample of volunteers [40] possibly introducing a self-selection bias. However, this issue was investigated by Fietze and co-workers [62] in the same sample, who concluded that no critical selection bias was present. Finally, because it was not recorded whether participants were receiving treatment for sleep apnea, it was not possible to account for treatment status.

In closing, the findings of this general population study suggest an association between CM, particularly physical neglect, and AHI as an objective, PSG-based indicator of sleep apnea. Sleep apnea itself is an important risk factor for a plethora of ill conditions like cardiovascular

[17], metabolic [18,19], neurodegenerative [20,21], and mental disorders [22]; thus, it may play a decisive role in the complex pathways leading from CM to poor physical and mental health later in life [2,3,23]. Replication of our results is warranted in independent studies as well as longitudinal approaches investigating the mechanisms by which CM has deleterious effects on health in general and sleep health in particular. Finally, our results corroborate the body of evidence for an association between CM and poor sleep in adulthood with important implications for clinical practice and public health issues.

Disclosure statement

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CRediT authorship contribution statement

Carsten Spitzer: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Antoine Weihs:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Ralf Ewert:** Writing – review & editing, Resources, Project administration, Methodology, Data curation, Conceptualization. **Beate Stubbe:** Writing – review & editing, Resources, Project administration, Methodology, Data curation. **Thomas Penzel:** Writing – review & editing, Validation, Software, Resources, Methodology, Formal analysis, Data curation. **Ingo Fietze:** Writing – review & editing, Validation, Software, Resources, Methodology, Formal analysis, Data curation. **Henry Völzke:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization. **Hans J. Grabe:** Writing – review & editing, Project administration, Methodology, Data curation, Conceptualization.

Declaration of competing interest

None.

Data availability statement

For data protection issues, data from "Study of Health in Pomerania" (SHIP) are not open for public use, but are available upon request (https://www2.medizin.uni-greifswald.de/cm/fv/ship/daten-beantragen/).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychores.2024.111600.

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