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Chronic Stress in Young Adults
Associations between occupation, type of job and greenness exposure with job-related chronic stress in young Germans adults

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Table of Contents

Nomenclature

CI: Confidence interval

GEE: Generalized estimating equations

ISAAC: International study on asthma and allergies in childhood

ISCO: International standard classification of occupations

MICE: Multiple imputations by chained equations

NDVI: Normalized difference vegetation index

NIR: Near-infrared spectral region

OR: Odds ratio

RR: Red reflectance

SOLAR: Studie in ost- und westdeutschland zu beruflichen allergierisiken

TICS: Trier inventory for chronic stress

List of Publications

This cumulative dissertation is a summary of the following two publications.

1) **Herrera R**, Berger U, Genuneit J, et al. Chronic Stress in Young German Adults: Who Is Affected? A Prospective Cohort Study. *International Journal of Environmental Research and Public Health*. 2017;14(11):1325. doi:10.3390/ijerph14111325.

2) **Herrera R**, Markevych I, Berger U, et al. Greenness and job-related chronic stress in young adults: a prospective cohort study in Germany. *BMJ Open*. 2018;8(6):e021599. doi:10.1136/bmjopen-2018-021599.

Summary

Introduction: Job-related chronic stress is a mental health problem that could appear during life. High levels of chronic stress bring different health related complications. Populations like students and young adults are more vulnerable to high levels of job-related chronic stress, specifically those in the transition from school life to university or job life. Moreover, certain professions trend to increase the levels of stress in workers. However, studies comparing types of jobs and job-related chronic stress in young adults are scarce, as are those comparing university students with non-student equals. Environmental factors not directly related to working places could also affect mental health in young adults at early stages during working life. Access to green environments has shown significant benefits in mental health in young people and in workers. There are few prospective studies relating exposure to green environments with job-related chronic stress in young adults. Using a German cohort of young adults transitioning from school to university/job life, we compared job-related chronic stress levels among university students and their non-student counterparts, different occupational groups and different levels of greenness around their homes.

Methods: We used data from a population-based cohort in Munich and Dresden two dimensions of chronic stress at university or job: Work overload and work discontent as outcomes, and job history and type of occupation as exposure variables. Using residential addresses, we calculated residential greenness as the environmental exposure. We considered data on socio-demographics, stress outside the workplace and environmental variables as potential confounders. Ordinal generalized estimating equations models were used to study associations between the two dimensions of job-related chronic stress and occupation, type of job and levels of residential greenness controlling for potential confounders. Missing data were handled using multiple imputation techniques.

Results: At the second follow-up, we used data from 1688 participants. Students, compared to employees, reported a more substantial increase in work overload (adjusted odds ratio (OR): 1.33; 95% confidence interval (95% CI): 1.07, 1.67). We did not find statistically significant differences between work dis-content and the groups. Regarding the environmental exposure, we found an association between higher levels of greenness (quartile 4 vs. quartile 1) as well as less work discontent (OR 0.89; 95% CI 0.80 to 0.99) and less work overload (OR 0.87; 95% CI 0.78 to 0.96).

Conclusions: Young adults could experience more work overload when transitioning from school to university/job life, and university students experienced the most substantial increase. Additionally, residential greenness exposures are inversely associated with two types of job-related chronic stress. We believe that stress-relieving interventions targeted to university students and health professionals, as well as public policies to promote access to greenness, could benefit mental health in young adults transitioning from school to job/university.

Introduction

Job-related chronic stress could appear early in working life and varies across lifespan[1]. Variations of job-related chronic stress perception depend on aspects in daily life activities and interactions with working environments[2]. Research has shown that high levels of chronic stress in workers lead to health issues, e.g., sleep disorders, cardiovascular diseases and several mental health outcomes like anxiety or depression, among other complications[3-5]. Additionally, it is well know that certain professions could lead to higher levels of stress perception compared with others, especially high demand jobs with low reward could deteriorate the mental health in workers[6]. Susceptible populations like students and young adults transitioning from school to university/job life experience increments in job-related chronic stress.

Many young people in training combine studies with part-time jobs[7]. This is especially important in countries like Germany that have a dual training system connecting school-based training with training time at work. German young adults have reported a high prevalence of perceived chronic stress[8]; however, especially university students are more likely to experience high levels of anxiety, depression or stress[9, 10]. German laws to prevent and treat job-related chronic stress at the workplace are well implemented in companies[11], however, similar guidelines are mostly lacking at German universities. In that sense, there is lack of studies comparing stress levels between students and workers or across different types of jobs, using a valid instrument applicable both in school and work settings in a longitudinal design.

Mental health in young adults transitioning from school to job/university is not only affected by working environments at the early life but also by environmental factors outside the working place, like residential places[12, 13]. In particular, major cities have adverse effects on mental health, partially due to excessive commuting times or reductions in social interactions[14-16]. Researchers have shown healthful effects of living in more natural residential places [17, 18]. Adolescents exposed to green environments reported gains in emotional well-being, physical activity and project management capabilities compared to adolescents living in less “green” areas[19]. Similarly, workers exposed to green environments also showed better psychological health compared to unexposed workers[20-22]. Nevertheless, there are not many studies relating exposures to green environments with job-related chronic stress in young adults, especially not using a prospective design.

Aims

Because occupational status, type of job and green spaces are associated to job-related chronic stress in young adults transitioning from school to university/job, this doctoral thesis aimed to:

- Compare job-related chronic stress levels among university students and their non-student counterparts, as well as across different occupational groups.
- Investigate the association between exposure to greenness around homes with job-related chronic stress levels.

Materials and Methods

Study population

We analyzed the population of the SOLAR (Studie in Ost- und Westdeutschland zu beruflichen Allergierisiken) I and SOLAR II studies[23]. Both studies aimed to investigate the course of respiratory diseases and allergies in children and young adults. Additionally, occupational risk factors were assessed to investigate the association between occupational factors, stress and respiratory diseases. SOLAR I and SOLAR II were the first and the second follow-ups of the German branch of Phase II of the International Study on Asthma and Allergies in Childhood (ISAAC Phase II)[24], which was carried out in 1996/97 in Munich and Dresden. SOLAR I was conducted from 2002 to 2003 also in these two cities, and SOLAR II was conducted from 2007 to 2009. Starting in SOLAR I, questionnaires included a detailed employment history and the Trier Inventory for Chronic Stress scale (TICS)[25, 26]. The TICS scale is a well-established instrument that applies to job-related chronic stress as well as stress outside the workplace.

In order to compare occupational groups, type of job and their respective chronic stress levels, a population of 2051 out of the 2904 young adults who had agreed to participate in SOLAR II could be included. We excluded participants who had a previous job history before SOLAR I, had unclear educational status, and those with two or more missing items in the TICS scale. The final study population in this first analysis included 1688 young adults with missing data.

In the second analysis relating exposure to greenness around the homes and job-related chronic stress, we geocoded families' or participants' most recent address and matched them to the individual questionnaire information. We excluded those that moved out of the study areas (n=56). In this second analysis, the study population included 1632 participants.

All participants or their legal guardians provided written informed consent. The Bavarian Chamber of Physicians in Munich, the ethics committees from the University of Ulm and the University of Dresden, respectively, approved the studies (EK 38022007).

Variable definitions

Outcome: *Job-Related Chronic Stress.*

Two of the six dimensions of the TICS scale were used as outcomes for both analyses: work discontent and work overload. All TICS sub-scales were measured on a five-point Likert scale

ranging from "never" (0 points) to "very often" (4 points). Each subscale of the TICS was categorized based on the frequency of stressful situations as: "low" (≤ median), "average" (above median to median + 1 standard deviation) and "high" (≥ one standard deviation above the median). We used medians and standard deviations obtained in SOLAR I to categorize the outcomes in SOLAR I and SOLAR II.

Exposure 1: *Occupation and type of job*

At SOLAR I and SOLAR II, participants reported their occupational status as well as any jobs they had before SOLAR I and between SOLAR I and SOLAR II. We considered the occupational status as a time-varying exposure because at SOLAR I the majority of the participants were students. At SOLAR II, the occupational status was categorized as: employee, university-student, vocational trainee, unemployed, self-employed, and other (i.e., maternal leave or work disability).

All jobs held until two years before SOLAR II were considered and coded according to the International Standard Classification of Occupations (ISCO-88) by two trained coders[27]. We constructed five job groups, each one with at least 90 participants (no vs. yes): clerks (ISCO-88 major group 4), professionals and technicians (ISCO-88 major group 2 and 3), health professions (with direct patient contact), plant machine operators (ISCO-88 major group 8) and elementary occupations (ISCO-88 major group 9). Each participant could hold more than one type of job over the study period. The reference category was "never worked" for each of the job groups.

Exposure 2*: Greenness of the home environment*

Using the geocoded participants' addresses at SOLAR I and SOLAR II, we estimated the greenness around the participant's homes using the Normalized Difference Vegetation Index (NDVI)[28]. NDVI is a satellite-images-based vegetation index that considers the ratio of the difference between near-infrared spectral region (NIR), radiation beyond the visible spectrum and vegetation strongly reflects, and the red reflectance (RR) the light which vegetation absorbs[28]. It ranges between -1.0 (water) to 1.0 (dense green vegetation) with 0 indicating sand, snow or rocks. We used buffers of 500 m radius around the home address to average the NDVI measures. This radius was considered because it approximates better the greenness directly accessible to outside of each home[29]. We treated greenness exposure also as a time-varying exposure because it was measured in SOLAR I and SOLAR II.

Statistical analysis

Given that job-related stress was measured as an ordinal variable in two-time points, we used generalized estimating equations (GEE) models for ordinal outcomes with an exchangeability correlation structure[30]. Using this strategy, we assessed the relationship between exposures and job-related stress, meanwhile controlling for outcomes correlation. Additionally, GEE methods produce population-averaged estimates, i.e., we can describe marginal changes in the population

based on changes in studied covariates. Missing data were imputed using the multiple imputations by chained equations (MICE) approach[31], obtaining five imputed data set. We combined odds ratios and confidence intervals from the five imputed data sets using Rubin's rules[32].

Occupational status, type of job and job-related chronic stress

We added all potential confounders sequentially into the models to study the association between occupational status, type of job and job-related stress. We first examined unadjusted relationships using sequential covariate inclusion into the models as follows:

Model 0: Each individual variable was added to study the relation between them and job-related stress.

Model 1: Simultaneously included occupational status and the sociodemographic variables.

Model 2: All variables in Model 1 and five different type of jobs variables.

Model 3: All variables included in Model 2 and all non-job-related chronic stress variables.

Greenness exposure and job-related chronic stress

In the ordinal GEE model, we included the following covariates: sex, having children, parental socioeconomic status, level of education, occupational status, physical activity, type of job, non-job-related psychological variables and environmental covariates (distance to sport facilities, distance to nearest urban green spaces, distances to nearest lake or river and percentage of tree coverage). We estimated separate models for Munich, Dresden and both cities combined. We calculated quartiles of NDVI using follow-up and city-specific quartiles to account for distributional differences between city and study period[33]. Additionally, given that physical activity could mediate the association between the greenness and the job-related chronic stress[34, 35], we conducted a mediation analysis using the approach in [36] to test this hypothesis.

Results

Descriptive results of the 1688 SOLAR participants are given in table 1[1]. More women than men took part in the study. About two thirds of the participants' parents had high socioeconomic status. At SOLAR II, about half of participants were students and only around 3% had a child. Being professional and technician was the most frequent job group reported two years before to SOLAR II.

Table 1. Descriptive results of the 1688 SOLAR I and II participants included in the first publication[1].

Variables	$N_{missing}$	%	N
Socio-demographics			
Sex‡	0		
Women		59	991
Having children‡	10		
Yes		3	52
Parental socio-economic status‡**	19		
High		64	1063
Education‡	33		
Elementary		<1	8
Secondary		26	432
Advanced technical		12	199
Higher		62	1043
Physical activity†	33		
>2hrs/week		32	511
Chronic stress not related to the job‡			
Social overload	15		
Low		39	659
Average		43	724
High		17	290
Lack of social recognition	15		
Low		45	760
Average		41	682
High		14	231
Chronic worrying	17		
Low		51	853
Average		28	474
High		21	344
Stressful memories	12		
Low		53	882
Average		26	436
High		21	358

†: Measured at 2nd follow-up (SOLAR II) and taken from Herrera et al. (2018)[37].
$N_{missing}$: Missing values.
** High defined as at least one parent having ≥12 years of schooling at SOLAR I.
‡: Measured at 1st follow-up (SOLAR I) and taken from Herrera et al (2017) [38].

[1] Descriptive results for the 2nd publication were almost identical since only 56 participants who moved out the study area had to be excluded from these analyses. See publication 2 for details.

Occupations, type of jobs and job-related chronic stress

After adjustments, work overload increased statistically significantly from SOLAR I to SOLAR II (Table 2). After adjusting for additional covariates (Model 3), students were more likely to report higher levels of work overload than employees (aOR: 1.33, 95% CI: 1.07; 1.67). Similarly, self-employed study participants reported higher levels of work overload compared with employees (aOR: 2.55, 95%CI: 1.16; 5.58). Regarding the job categories, young adults working in the healthcare sector had higher chances of reporting work overload compared to those who never worked in this sector (aOR: 1.17, 95% CI: 1.01; 1.37).

Table 2. Unadjusted (OR) and adjusted odds ratios (aOR) with 95% confidence intervals (95% CI) after multiple imputation for **work overload.** Prospective cohort of 1688 young adults in Germany. Taken from Herrera et al (2017)[38].

	Model 0	**Model 1**	**Model 2**	**Model 3**
	OR (95% CI)	**aOR‡ (95% CI)**	**aOR‡ (95% CI)**	**aOR‡ (95% CI)**
Follow-up				
SOLAR I	1	-	1	1
SOLAR II	1.12 (1.04, 1.20)*	1.51 (1.23, 1.85)*	1.50 (1.23, 1.84)*	1.55 (1.22, 1.95)*
Occupation				
Employed	1	1	1	1
Student	1.01 (0.89, 1.16)	1.30 (1.08, 1.57)*	1.30 (1.08, 1.57)*	1.33 (1.07, 1.67)*
Vocational trainee	0.96 (0.82, 1.13)	1.11 (0.92, 1.33)	1.10 (0.92, 1.33)	1.07 (0.86, 1.34)
Unemployed	0.71 (0.49, 1.03)	0.70 (0.47, 1.05)	0.70 (0.47, 1.05)	0.62 (0.39, 1.00)
Other	1.10 (0.77, 1.57)	1.09 (0.73, 1.62)	1.08 (0.73, 1.61)	1.07 (0.69, 1.67)
Self-employed	2.08 (1.10, 3.94)*	2.32 (1.16, 4.62)*	2.34 (1.16, 4.69)*	2.55 (1.16, 5.58)*
Clerks **	1.04 (0.88, 1.24)	-	0.98 (0.82, 1.16)	1.04 (0.87, 1.25)
Professionals and technicians **	0.99 (0.87, 1.13)	-	0.95 (0.83, 1.09)	0.94 (0.82, 1.08)
Health professions **	1.19 (1.02, 1.38)*	-	1.20 (1.03, 1.41)*	1.17 (1.01, 1.37)*
Plant machine operators **	0.81 (0.70, 0.93)*	-	0.91 (0.79, 1.06)	0.92 (0.79, 1.08)
Elementary occupations **	1.00 (0.83, 1.22)	-	1.07 (0.87, 1.32)	1.01 (0.81, 1.27)

***** Statistically significant. ****** Reference category "Not working in the job". ‡ aOR: Adjusted odds ratios.
Model 0: Each individual variable was added to study the relation between them and job-related stress. **Model 1:** Simultaneously included occupational status and the sociodemographic variables. **Model 2:** All variables in Model 1 and five different type of jobs variables. **Model 3:** All variables included in Model 2 and all non-job-related chronic stress variables.

After adjusting for all covariates in Model 3, work discontent did not statistically significantly change between SOLAR I and SOLAR II, (aOR: 1.08, 95%CI: 0.86; 1.36). Students were equally likely to report work discontent compared with employees (aOR: 1.06, 95%CI: 0.84; 1.34). Unemployed participants had twice the chance of reporting higher levels of work discontent at follow-up than the employees (aOR: 2.15, 95%CI: 1.50; 3.09). In respect to the five studied job categories, workers in the healthcare sector, clerks and plant machine operators were less likely to report work discontent than those who never worked in those sectors (Table 3).

Table 3. Unadjusted (OR) and adjusted odds ratios (aOR) with 95% confidence intervals (95% CI) after multiple imputation for **work discontent** Prospective cohort of 1688 young adults in Germany. Taken from Herrera et al. (2018)[38].

	Model 0	**Model 1**	**Model 2**	**Model 3**
	OR (95% CI)	**aOR‡ (95% CI)**	**aOR‡ (95% CI)**	**aOR‡ (95% CI)**
Follow-Up				
SOLAR I	1	1	1	1
SOLAR II	0.68 (0.63, 0.74)*	1.11 (0.90, 1.38)	1.11 (0.90, 1.38)	1.08 (0.86, 1.36)
Occupation				
Employed	1	1	1	1
Student	1.25 (1.06, 1.46)*	1.08 (0.87, 1.35)	1.10 (0.88, 1.37)	1.06 (0.84, 1.34)
Apprentice	0.97 (0.80, 1.18)	0.98 (0.80, 1.22)	0.99 (0.80, 1.22)	0.91 (0.72, 1.14)
Unemployed	2.04 (1.48, 2.82)*	2.08 (1.50, 2.88)*	2.10 (1.52, 2.91)*	2.15 (1.50, 3.09)*
Other	1.52 (1.07, 2.18)*	1.49 (1.01, 2.19)*	1.50 (1.02, 2.21)*	1.46 (0.95, 2.26)
Self-employed	0.69 (0.21, 2.20)	0.71 (0.24, 2.14)	0.70 (0.24, 2.05)	0.61 (0.19, 1.98)
Clerk**	0.82 (0.69, 0.97)*	-	0.79 (0.66, 0.95)*	0.81 (0.68, 0.98)*
Professionals and technicians**	0.91 (0.80, 1.03)	-	0.90 (0.79, 1.02)	0.90 (0.79, 1.04)
Health professions **	0.86 (0.73, 1.01)	-	0.84 (0.71, 1.00)	0.80 (0.67, 0.95)*
Plant machine operators**	0.84 (0.72, 0.97)*	-	0.81 (0.70, 0.95)*	0.82 (0.70, 0.96)*
Elementary occupations**	0.98 (0.79, 1.21)	-	0.99 (0.80, 1.24)	0.94 (0.74, 1.19)

***** Statistically significant. ****** Reference category "Not working in the job". ‡ aOR: Adjusted odds ratios.
Model 0: Each individual variable was added to study the relation between them and job-related stress. **Model 1:** Simultaneously included occupational status and the sociodemographic variables. **Model 2:** All variables in Model 1 and five different type of jobs variables. **Model 3:** All variables included in Model 2 and all non-job-related chronic stress variables

Greenness of the home environment and job-related chronic stress

Average NDVI values within a 500 m buffer in SOLAR I were higher in Dresden (median: 0.36, interquartile range: 0.31;0.41) than in Munich (0.31; IQR: 0.26; 0.34). In SOLAR II, greenness decreased for participants in Dresden (0.31; IQR = 0.26; 0.34), but not for participants in Munich. In the univariate analysis, the prevalence of high levels of the studied job-related chronic stress decreased by the increment of levels of greenness within a buffer of 500 m around participants' homes. Once we controlled by all covariates, these results were confirmed (Figure 1). When we restricted the study population to participants who did not change residence between ISAAC II and SOLAR II (n=443 in Munich and n=186 in Dresden), we found similar associations as those using the whole study population (Figure 2). Results were more consistent for Munich than Dresden.

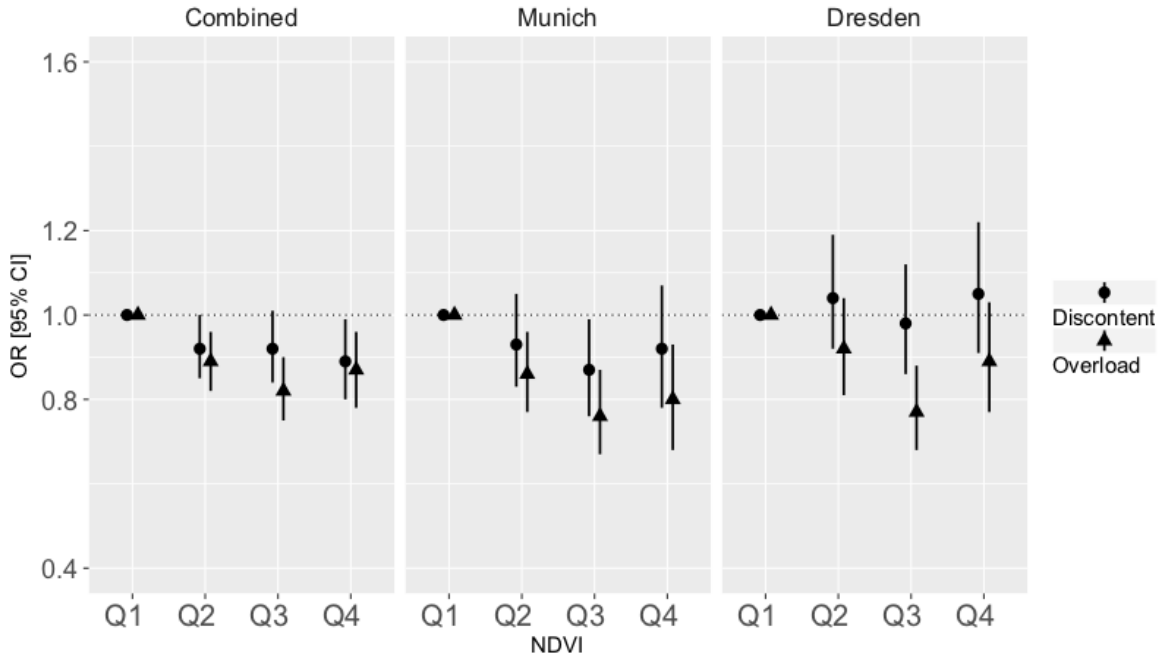

Figure 1. City specific associations between greenness in 500 m buffer around participants' homes and work discontent and work overload. Models adjusted for: sex, having children, physical activity, education, current status, type of job, non-job-related psychological variables and environmental variables using complete cases (n=1430), Munich (n=779) and Dresden (n=651) Taken from Herrera et al. (2018)[37].

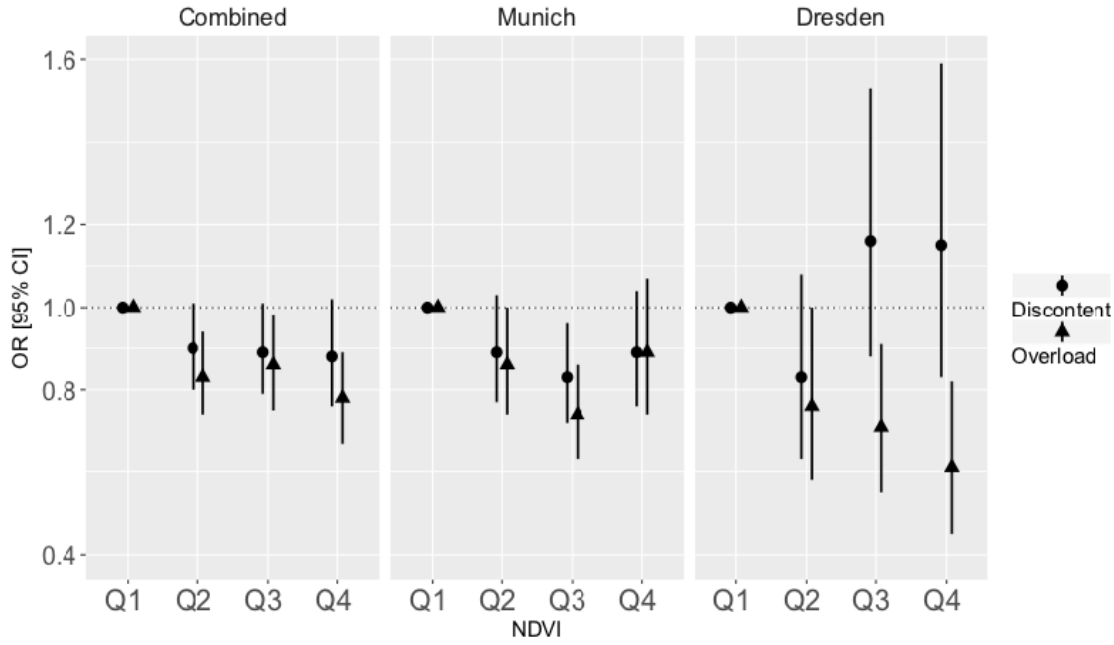

Figure 2. City specific associations between greenness in 500 m buffer and work discontent and work overload. Models adjusted for: sex, having children, physical activity, education, current status, type of job, non-job related psychological variables and environmental variables using complete cases that never moved (n=629), Munich (n=443) and Dresden (n=186). Taken from Herrera et al (2018)[37].

Discussion

In the analyses of data of young adults transitioning from school to university/work life, we showed increased levels of chronic stress compared to school life with higher increments in work overload in university students compared to employees. At the same time, university students reported less work discontent compared to employed participants. Finally, exposure to green spaces around the home environment was associated with reduction of job-related chronic stress perception.

Other studies on stress in young workers also reported changes in chronic stress levels in the transition from school to working life[39]. Psychological conditions of the work environments and less familiar working conditions could lead to an elevated perception of chronic stress and musculoskeletal disorders[40]. Studies involving participants at the university indicated that students feel overwhelmed and that there is not enough time to complete their activities[41, 42].

Likewise, we found increments in levels of job-related chronic stress for specific occupational groups; similar findings were reported in a French cohort[3]. E.g., over time, work discontent decreased statistically significantly in participants working as clerks and machine operators. This could be attributable to the fact that young people can apply their manual skill in direct practice while they felt stressed by intellectual requests at school. In contrast, participants in the healthcare sector were affected by higher work overload while reporting less work discontent. However, the perception of work discontent is likely to change after several years of working in this sector[43]. Other studies

have shown that people working in highly demanding jobs like those in the healthcare sector are at higher risk of developing depression and anxiety disorders[44].

Like in our second analysis, several studies have shown positive mental health benefits of greenspaces[18, 20, 45], and that these benefits could be attributable to increments in physical activities[14, 35, 46]. Nevertheless, in our mediation analysis we did not find that physical activity acted as a mediator. We estimated different patterns in associations between Munich and Dresden, this is expected because both cities have different distributions of several other factors, like socio-economic status, which may affect the impact of greenness exposure and job-related chronic stress[33].

Strengths and limitations

Outcomes in both analyses relied on self-report of job-related chronic stress situations, which can lead to reporting bias influenced by personality. This bias may be influenced additionally by many personal, social or cultural characteristics. Therefore, we controlled for non-job related chronic stress, sex, education, having children and parental socioeconomic status.

In the first analysis, the definition of occupation groups was based on a well-established standardized coding instrument (ISCO-88) and done by trained coders. Moreover, we restricted the analysis to most common professions in the study population. Additionally, because health status could have conditioned the initial jobs participants had. This fact could lead to a healthy worker effect which could lead in biases in our estimates[47].

We could not find enough quality satellite images to calculate greenness at SOLAR I. Nevertheless, we expected that greenness remained stable over several years[35]. Greenness exposure at workplaces was not measured because addresses of the workplace were not obtained for ethical considerations. This fact also made impossible to calculate the commuting green space of participants, which is a common shortcoming in this type of studies, and almost no study has obtained information different than the residential address for NDVI calculations[48, 49].

Females and children of parents with higher education levels were more likely to take part in each follow-up[23], therefore, generalizability might be limited to families with higher SES. To reduce selection bias, we used several strategies to increase the participation in each follow-up.

Among the strengths, we used a prospective design that allowed us to differentiate a temporal sequence between exposures and outcomes. The main focus of the study was asthma and allergies. Therefore, participants were not aware of the hypothesis of both analyses, and we expected a limited differential misclassification of the outcomes.

We used the Trier Inventory for the Assessment of Chronic Stress (TICS) scale[25, 26], which is a well-established and validated instrument in German language that allows valid comparisons of stress

levels among students and non-students. Additionally, this instrument can be applied both to the university and working environments.

For the calculation of exposure to greenness around homes, we used NDVI as a proxy for exposure to green spaces and all kind of vegetation. This index is a standardized and objective assessment based on good satellite resolution images at each follow-up.

Conclusion

Our analyses of data from young adults in transition from school to university /work life provide further knowledge about occupational and environmental factors associated with job-related chronic stress in this population. Besides the contribution we did to the literature on occupational health among young adults transitioning into working life, we also understand better how certain professions, like those working in the health sector, could lead to a higher perception of job-related chronic stress, and also how university students perceived more job-related chronic stress. In this sense, we recommend to implement stress-relieving interventions to university students and health professionals. To the best of our knowledge, our study is among the first indicating that green spaces around the home could lead to a lower perception of job-related chronic stress in young adults. We consider it important that in constantly growing cities policy makers consider access to greenness as a strategy for mental health promotion.

Contributions to the Individual Publications

The present dissertation summarizes two publications studying the association between some occupational and environmental factors and job-related chronic stress. The study population consisted of young adults transitioning from school to university or job life in two German cities, Munich and Dresden. In the first publication, we studied the association of occupation and type of job with job-related chronic stress, and we learned that in this particular cohort, participants experienced higher levels of job-related chronic stress depending on the specific occupational factors. Knowing this, we used participants' home addresses to calculate a proxy of exposure to greenness around their homes (NDVI), controlling for the type of job and other covariates of interest. The aim of this second studied was to study the relation between different levels of greenness and job-related chronic stress, after controlling for occupational factors.

My contribution to each publication will be outlined as follows:

Publication 1: Chronic Stress in Young German Adults: Who Is Affected? A Prospective Cohort Study. ***International Journal of Environmental Research and Public Health*****. 2017;14(11):1325**.

Supervised by Dr. Ursula Berger and Prof. Dr. Katja Radon, I designed and performed the statistical analysis data plan. It included the programming of all routines for the plausibility check of data, univariate analysis, and data preparation. I programmed and executed the R code for the ordinal estimation of the generalized estimating equation models, multiple imputation strategies and production of the figures results. I wrote manuscript supervised by Prof. Dr. Radon. Finally, I was in charge of the paper submission to journal.

Publication 2: Greenness and job-related chronic stress in young adults: a prospective cohort study in Germany. BMJ Open 2018;8:**e021599. doi: 10.1136/bmjopen-2018-021599.**

This paper was a consequence of the first paper, where we already knew that our study population experienced higher levels of job-related chronic stress. Using this knowledge, we aimed to study whether exposure to greenness was related with this specific type of chronic stress. I was in charge of standardized participants' addresses to obtain their geo-coordinates. Using the addresses, Dr. Markevich and Dr. Heinrich produced the primary exposure (NDVI) and the environmental covariates. Jointly with Prof. Dr. Radon and Dr. Berger, we designed the statistical analysis plan. I was in charge of writing and executing the R code for this analysis. Under the supervision of Prof. Dr. Radon, I produced the figures, graphs, and tables of the paper. I wrote the manuscript. Finally, I prepared and submitted the final manuscript to the journal.

Original Publications

Publication 1

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Article

Chronic Stress in Young German Adults: Who Is Affected? A Prospective Cohort Study

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Abstract: We aimed to prospectively assess changes in chronic stress among young adults transitioning from high school to university or working life. A population-based cohort in Munich and Dresden (Germany) was followed from age 16–18 (2002–2003) to age 20–23 (2007–2009) (n = 1688). Using the Trier Inventory for the Assessment of Chronic Stress, two dimensions of stress at university or work were assessed: work overload and work discontent. In the multiple ordinal generalized estimating equations, socio-demographics, stress outside the workplace, and job history were additionally considered. At follow-up, 52% of the population were university students. Work overload increased statistically significantly from first to second follow-up, while work discontent remained constant at the population level. Students, compared to employees, reported a larger increase in work overload (adjusted odds ratio (OR): 1.33; 95% confidence interval (95% CI): 1.07, 1.67), while work discontent did not differ between the groups. In conclusion, work overload increases when young adults transition from school to university/job life, with university students experiencing the largest increase.

Keywords: work stress; longitudinal study; psychological effects; generalized estimation equations

1. Introduction

To promote well-being across an adult's working life, occupational health specialists face the challenge of determining and preventing stress among employees. Work stress is conceptualized as

the interaction of employee characteristics with demands of the personal and work environment [1]. If personal resources of employees are not effective in coping with the demands and pressures of the job, adverse psychological and physiological reactions such as sleeping disorders, cardiovascular effects, chronic pain, and depression may result [2–5]. Previous research has shown that particularly chronic, rather than acute, stress is associated with adverse health effects [6–8]. While acute stress refers to situations that occur only once and begin or end abruptly, chronic stress is related to a daily routine in a constant environment in the absence of effective coping mechanisms [9,10]. Aside from job demands, chronic stress at work includes a persistent lack of need fulfillment (e.g., need for appreciation, autonomy, social support, or meaningful tasks) [10,11].

Chronic stress may already develop early in working life [12] and varies across the lifespan. The current economic crisis in Europe generated investment in training of young people to avoid unemployment and improve job perspectives [13]. In these young people, prevalence of chronic stress might be highest, as recently shown in a German national survey [14]. Many of these young adults are still enrolled at the university or, especially in Germany, in so-called dual training systems where school-based training is combined with training on the job. While the latter are covered by Germany's Occupational Safety Law [15] (which includes stress prevention at the workplace), no such programs are regularly in place at most German universities. At the same time, many university students face a double burden, as they need to work to earn a living in addition to studying. Others need to do mandatory internships to complete their studies. Research has indicated high levels of stress, anxiety, and depression among university students [16,17]. For example, a prospective study among more than 14,000 university students in the UK showed a significant increase in distress in the transition from school to university life [18]. Only few of the existing studies included peers not studying at universities. None of them followed a prospective design [19,20]. The advantage of using such a design is that the difference in personal stress levels before entering university/working life can be controlled for.

In addition, measurement of stress differed across existing studies with most studies using distress as a proxy of stress levels [21]. For a valid comparison of stress levels among students and non-students, it is important to use an instrument applicable to the school, university and working environment alike. In addition, it should include stress factors outside the workplace/university setting like social stress, worries, lack of social recognition, and worrying memories to control for potential sources of non-job-related chronic stress. The Trier Inventory for the Assessment of Chronic Stress (TICS) considers these dimensions and enables the reliable and comprehensive assessment of stress across various domains including training settings such as schools and universities or in unemployment [6,22]. This scale has been successfully implemented in the above-mentioned cross-sectional national survey of German adults [15].

We aimed to prospectively assess the marginal change in chronic stress following a population-based cohort transitioning from high school to university/working life. In addition, our objective was to compare stress levels among university students and their non-student counterparts. Finally, we wanted to examine chronic stress levels by occupational groups.

2. Materials and Methods

2.1. Population

The study population consisted of participants of the Study of Occupational Allergy Risks (SOLAR) II [23]. In brief, SOLAR II was aimed to investigate the course of respiratory diseases and atopy in symptomatic and symptom free persons from childhood to young adulthood. Additionally, occupational risk factors were identified to investigate associations between occupational factors, stress and the course of respiratory diseases. SOLAR II is the 2nd follow-up of the International Study on Asthma and Allergies in Childhood (ISAAC) II [24]. ISAAC II was the German part of a multicenter international study intended to investigate the prevalence of asthma and allergies, the sample was

chosen using schools in Munich and Dresden as sampling units, and participants at age 10 were studied (4th grade, age range: 9–11) in 1995/1996. It included 7498 children. In 2002/2003, SOLAR I (first follow-up) was started. We re-contacted 3785 of the initial ISAAC II participants, of which 3053 adolescents with an average age of 17 (age range: 19–23) agreed to participate. By SOLAR II (the second follow-up), we re-contacted 2904 participants from SOLAR I, and a total of 2051 of 2904 young adults agreed to participate in 2007/2009. During SOLAR I, participants received the questionnaires between August and January 2003. For SOLAR II, fieldwork was distributed between August 2007 and November 2008, and 100 invitation letters per month and per center were sent out.

Starting from SOLAR I in 2002–2003, questionnaires included a detailed school and employment history and the TICS version 1.0 [6]. Analyses were restricted to participants who never worked until SOLAR I, excluding 318 subjects with a previous work history (Figure 1). Moreover, 21 participants with unclear educational status and 24 participants with two or more items missing in one of the TICS questionnaires at SOLAR I or SOLAR II were excluded (Figure 1). All participants or their legal guardians provided written informed consent. The Ethical Committees of the Medical Faculty of the University of Dresden, the University of Ulm, and the Ethical Committee of the Bavarian Chamber of Physicians in Munich approved the study (EK 38022007).

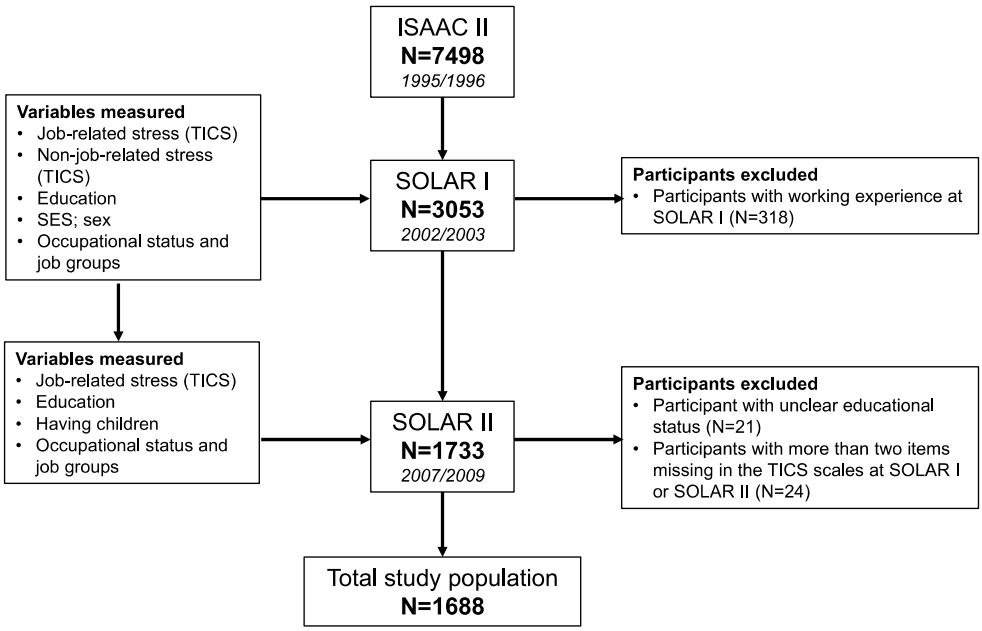

Figure 1. Flow chart of final sample size and the variables measured in each follow-up.

2.2. Occupational Status and Job Groups

At SOLAR I and SOLAR II, participants reported their current occupational status as well as any jobs they had ever held up until SOLAR I and between SOLAR I and SOLAR II. Occupational status at SOLAR II was categorized as: employee, university student, vocational trainee (dual training system), unemployed, self-employed, and other (i.e., in maternity leave or work disability) [23]. Being employed served as the reference category in the analyses.

Jobs held two years prior to SOLAR II were coded according to the International Standard Classification of Occupations (ISCO-88) by two trained coders [25]. The period of two years was chosen because we considered this amount of time as relevant for the development of chronic stress at SOLAR II. Jobs included regular employment, student jobs, and internships. As subjects could change jobs in the period under study, they were eligible for more than one job category. Using the codes, we constructed five job groups each with at least 90 participants (no vs. yes): clerks

(ISCO-88 Major group 4), professionals and technicians (ISCO-88 Major groups 2 and 3), health professions (i.e., with direct patient contact; e.g., medical doctors, physiotherapists, and related associate professionals), plant machine operators (ISCO-88 Major group 8), and elementary occupations (ISCO-88 Major group 9). In each of the job groups, never worked (the no category) in the specific job was used as the reference.

2.3. Sociodemographics Covariates

Sex (male vs. female), having children at SOLAR II (no vs. yes), parental socioeconomic status defining high socioeconomic status as at least one parent having ≥12 years of schooling at SOLAR I (high vs. low), highest educational status reported at SOLAR I and SOLAR II (elementary education vs. secondary education, advanced technical and higher education) were included as sociodemographic covariates.

2.4. Non-Job-Related Chronic Stress

The Trier Inventory for Chronic Stress (TICS) captures chronic stress considering the following dimensions: work overload, work discontent, social overload, a lack of social recognition, chronic worrying, and stressful memories [22]. They were selected using the systemic requirement-resource model of health [6]. The factorial validity of the TICS was shown by confirmatory analysis in a representative sample [22]. In our analyses, the four TICS sub-scales not directly related to work stress at SOLAR I were included as potential confounders:

- social overload (e.g., "Situations in which I cannot resolve conflicts that I have with others".);
- lack of social recognition (e.g., "Times where I get little approval for my work".);
- chronic worrying (e.g., "Times when I worry a lot and cannot stop".);
- stressful memories (e.g., "Intrusive remembrances of an unpleasant experience".).

They were asked only once in SOLAR I because they are considered to be persistent over time, especially over a period as short as the five-year period between SOLAR I and SOLAR II (personal communication with Wolfgang Schlotz).

The TICS sub-scales capture the frequency of self-perceived stressful situations in the last 12 months on a five-point Likert scale from "never" (0 points) to "very often" (4 points). A total score in each sub-scale is calculated by summing all item scores; answers are allowed to be missing for up to 2 items and were imputed. Each subscale score was categorized as "low" (≤median), "average" (above median to median +1 standard deviation), and "high" (≥1 standard deviation from the median) frequency of stressful situations [14].

2.5. Work-/University-Related Chronic Stress as Outcome

The following job-related TICS sub-scales served as outcomes:

- work discontent (e.g., "Times when I have to perform tasks that I am not at all willing to do".);
- work overload (e.g., "I have too many tasks to perform".).

All job-related TICS questions apply to school, university, or job settings alike. As the TICS sub-scales described previously, they were assessed on a five-point Likert scale from "never" to "very often". Outcomes were categorized like the other TICS domains in "low", "average", and "high" using the median and the median +1 standard deviation as cut-off points [14]. Medians and standard deviations of SOLAR I were used for the definition of work discontent and work overload at SOLAR I and SOLAR II.

2.6. Statistical Analysis

As the outcomes were measured at two points in time (SOLAR I and SOLAR II), an ordinal generalized estimating equation (GEE) model with an exchangeable correlation structure was used

in the analysis. Population average models estimated using GEE describe changes in the population mean based on changes in covariates. They then provide a population-averaged interpretation between exposure(s) and outcome(s) and address the temporal correlation between outcome measures [26,27]. GEEs tell us, for every one unit increase in a covariate across the studied population, how much response would change on average [28]. Given that we had time-varying covariates such as occupational status and level of education, GEE models produce more efficient and unbiased regression parameters than ordinary least squares regression (OLS) [27].

Using R version 3.2.4 (R Foundation for Statistical Computing, Vienna, Austria) [29], we first examined the unadjusted relationships between occupational status, potential confounders, and stress in univariate models. In the next step, we simultaneously included occupational status, sex, parental socioeconomic status, having children, level of education, and time into a mutually adjusted GEE model (Model 1). After that, we additionally controlled for the five job groups (Model 2). Our final model (Model 3) additionally included the four non-work-related TICS dimensions.

Missing values were handled using multiple imputations by chained equations (MICE) [30] assuming that missing values were missing at random. Five imputed data sets were obtained. Combined adjusted odds ratios and their respective confidence intervals were derived using Rubin's rules [31].

In the sensitivity analyses, we compared multiply imputed data to complete case analyses. We also stratified by sex to check for differences between women and men. In addition, we restricted Model 3 to students.

3. Results

3.1. Descriptives

The final study population included 1688 participants. Percentage of women was 59% (n = 991). About half of the population were still students at SOLAR II, 52% (n = 879), whereas 22% (n = 376) were employed (Table 1). Considering jobs held during the two years prior to SOLAR II, 19% (n = 328) worked as professionals and technicians, 15% (n = 260) as plant machine operators, 12% (n = 209) in health professions; 10% (n = 163) worked as clerks and 6% (n = 93) in elementary occupations.

Table 1. Descriptive data of outcomes, exposures, and potential confounders at SOLAR I (2002–2003) and II (2007–2009) in 1688 young Germany adults prior to imputation. Where data for SOLAR I and II remained constant, only data for SOLAR I are given.

	SOLAR I		SOLAR II	
	%	(n)	%	(n)
Occupation (NA = 5)				
Employed	0	0	22	376
Student	89	1497	52	879
Apprentice	10	168	19	314
Unemployed	0	0	4	60
Other	1	23	2	42
Self-employed	0	0	1	12
Clerks	-	-	10	163
Professionals and technicians	-	-	19	328
Health professions	-	-	12	209
Plant machine operators	-	-	15	260
Elementary occupations	-	-	6	93
Sex				
Female	59	991	-	-
Having children (NA = 10)				
Yes	-	-	3	52

Table 1. *Cont.*

	SOLAR I		SOLAR II	
	%	(n)	%	(n)
Parental socio economic status ** (NA = 19)				
High	64	1063	-	-
Low	36	606	-	-
Education (NA = 33)				
Elementary	74	1220	0	8
Secondary	26	432	26	432
Advanced technical	0	3	12	199
Higher	0	0	62	1043
Work discontent †† (NA = 17)				
Low	52	872	68	1137
Average	29	483	19	326
High	19	316	13	215
Median (SD)	13	(3.3)	12	(3.4)
Work overload †† (NA = 17)				
Low	55	920	53	882
Average	28	475	27	449
High	17	276	21	348
Median (SD)	20	(5.6)	20	(6.0)
Social overload (NA = 15)				
Low	39	659	-	-
Average	43	724	-	-
High	17	290	-	-
Median (SD)	14	(3.4)	-	-
Lack of social recognition (NA = 11)				
Low	56	943	-	-
Average	30	499	-	-
High	14	231	-	-
Median (SD)	17	(4.1)	-	-
Chronic worrying (NA = 17)				
Low	51	853	-	-
Average	28	474	-	-
High	21	344	-	-
Median (SD)	15	(4.5)	-	-
Stressful memories (NA = 12)				
Low	53	882	-	-
Average	26	436	-	-
High	21	358	-	-
Median (SD)	13	(4.6)	-	-

Note: SD: Standard deviation. ††: Cut-off points were established based on SOLAR I distribution. ** High: at least one parent having ≥12 years of schooling. NA: Missing Values.

Regarding the outcomes, while median work overload scores did not change considerably between SOLAR I and SOLAR II, the relative frequency of subjects in the high work overload category increased from 17% (n = 276) to 21% (n = 348). With respect to work discontent, the median score decreased slightly from 13 at SOLAR I to 12 at SOLAR II and relative frequency of participants with high work discontent decreased from 19% (n = 316) at SOLAR I to 13% (n = 215) at SOLAR II (Table S1).

3.2. GEE Models

Estimating population change over the follow-up, work overload increased statistically significantly from SOLAR I to SOLAR II (crude odds ratio (OR): 1.12, 95% confidence interval (95% CI): 1.04, 1.20). Difference became more pronounced when adjusting for other covariates (Tables 2 and 3).

Table 2. Unadjusted (OR) and adjusted odds ratios (aOR) after multiple imputation with 95% confidence intervals (95% CI) for work overload using ordinal generalized estimating equation (GEE) models in a prospective cohort of 1688 young adults in Germany.

	Univariate	Model 1 #	Model 2 #	Model 3 #
	OR (95% CI)	**aOR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**
Follow-up				
SOLAR I	1	-	1	1
SOLAR II	1.12 (1.04, 1.20) *	1.51 (1.23, 1.85) *	1.50 (1.23, 1.84) *	1.55 (1.22, 1.95) *
Occupation				
Employed	1	1	1	1
Student	1.01 (0.89, 1.16)	1.30 (1.08, 1.57) *	1.30 (1.08, 1.57) *	1.33 (1.07, 1.67) *
Vocational trainee	0.96 (0.82, 1.13)	1.11 (0.92, 1.33)	1.10 (0.92, 1.33)	1.07 (0.86, 1.34)
Unemployed	0.71 (0.49, 1.03)	0.70 (0.47, 1.05)	0.70 (0.47, 1.05)	0.62 (0.39, 1.00)
Other	1.10 (0.77, 1.57)	1.09 (0.73, 1.62)	1.08 (0.73, 1.61)	1.07 (0.69, 1.67)
Self-employed	2.08 (1.10, 3.94) *	2.32 (1.16, 4.62) *	2.34 (1.16, 4.69) *	2.55 (1.16, 5.58) *
Clerk **				
Yes	1.04 (0.88, 1.24)	-	0.98 (0.82, 1.16)	1.04 (0.87, 1.25)
Professionals and technicians **				
Yes	0.99 (0.87, 1.13)	-	0.95 (0.83, 1.09)	0.94 (0.82, 1.08)
Health professions **				
Yes	1.19 (1.02, 1.38) *	-	1.20 (1.03, 1.41) *	1.17 (1.01, 1.37) *
Plant machine operators **				
Yes	0.81 (0.70, 0.93) *	-	0.91 (0.79, 1.06)	0.92 (0.79, 1.08)
Elementary occupations **				
Yes	1.00 (0.83, 1.22)	-	1.07 (0.87, 1.32)	1.01 (0.81, 1.27)
Sex				
Male	1	1	1	1
Female	1.77 (1.59, 1.97) *	1.78 (1.59, 1.99) *	1.77 (1.58, 1.97) *	1.35 (1.22, 1.53) *
Having children **				
Yes	1.54 (1.19, 1.99) *	1.41 (1.08, 1.83) *	1.42 (1.09, 1.86) *	1.46 (1.10, 1.93) *
Parental socio economic status				
High	1	1	1	1
Low	0.93 (0.83, 1.03)	0.93 (0.83, 1.04)	0.94 (0.84, 1.05)	0.88 (0.79, 0.99) *
Education				
Elementary	1	1	1	1
Secondary	0.95 (0.86, 1.06)	0.88 (0.76, 1.01)	0.89 (0.77, 1.03)	0.87 (0.75, 1.01)
Advanced technical	1.17 (0.99, 1.39)	0.87 (0.67, 1.13)	0.88 (0.68, 1.14)	0.86 (0.65, 1.15)
Higher	1.08 (0.99, 1.18)	0.74 (0.60, 0.92) *	0.75 (0.60, 0.93) *	0.77 (0.60, 0.98) *
Social overload ††				
Average	1.50 (1.34, 1.67) *	-	-	1.24 (1.10, 1.41) *
High	2.48 (2.16, 2.85) *	-	-	1.42 (1.20, 1.68) *
Lack of social recognition ††				
Average	1.46 (1.30, 1.64) *	-	-	1.08 (0.96, 1.23)
High	2.10 (1.82, 2.42) *	-	-	1.16 (0.99, 1.40)
Chronic worrying ††				
Average	2.26 (1.99, 2.56) *	-	-	1.82 (1.58, 2.09) *
High	4.04 (3.50, 4.66) *	-	-	2.89 (2.41, 3.46) *
Stressful memories ††				
Average	1.82 (1.61, 2.07) *	-	-	1.20 (1.04, 1.38) *
High	2.59 (2.28, 2.95) *	-	-	1.13 (0.95, 1.35)

Note: # Each model mutually adjusted for all variables given in the column. * Statistically significant. ** Reference category "No". †† Reference category "Low".

Table 3. Unadjusted (OR) and adjusted odds ratios (aOR) after multiple imputation with 95% confidence intervals (95% CI) for work discontent using ordinal GEE models in a prospective cohort of 1688 young adults in Germany.

	Univariate	Model 1 #	Model 2 #	Model 3 #
	OR (95% CI)	**aOR (95% CI)**	**aOR (95% CI)**	**aOR (95% CI)**
Follow-Up				
SOLAR I	1	1	1	1
SOLAR II	0.68 (0.63, 0.74) *	1.11 (0.90, 1.38)	1.11 (0.90, 1.38)	1.08 (0.86, 1.36)
Occupation				
Employed	1	1	1	1
Student	1.25 (1.06, 1.46) *	1.08 (0.87, 1.35)	1.10 (0.88, 1.37)	1.06 (0.84, 1.34)
Apprentice	0.97 (0.80, 1.18)	0.98 (0.80, 1.22)	0.99 (0.80, 1.22)	0.91 (0.72, 1.14)
Unemployed	2.04 (1.48, 2.82) *	2.08 (1.50, 2.88) *	2.10 (1.52, 2.91) *	2.15 (1.50, 3.09) *
Other	1.52 (1.07, 2.18) *	1.49 (1.01, 2.19) *	1.50 (1.02, 2.21) *	1.46 (0.95, 2.26)
Self-employed	0.69 (0.21, 2.20)	0.71 (0.24, 2.14)	0.70 (0.24, 2.05)	0.61 (0.19, 1.98)
Clerk **				
Yes	0.82 (0.69, 0.97) *	-	0.79 (0.66, 0.95) *	0.81 (0.68, 0.98) *
Professionals and technicians **				
Yes	0.91 (0.80, 1.03)	-	0.90 (0.79, 1.02)	0.90 (0.79, 1.04)
Health professions **				
Yes	0.86 (0.73, 1.01)	-	0.84 (0.71, 1.00)	0.80 (0.67, 0.95) *
Plant machine operators **				
Yes	0.84 (0.72, 0.97) *	-	0.81 (0.70, 0.95) *	0.82 (0.70, 0.96) *
Elementary occupations **				
Yes	0.98 (0.79, 1.21)	-	0.99 (0.80, 1.24)	0.94 (0.74, 1.19)
Sex				
Men	1	1	1	1
Women	1.11 (1.01, 1.23) *	1.12 (1.01, 1.25) *	1.11 (1.00, 1.23)	0.89 (0.80, 1.00)
Having children **				
Yes	1.10 (0.86, 1.40)	0.91 (0.70, 1.19)	0.89 (0.68, 1.18)	0.89 (0.67, 1.18)
Parental socioeconomic status				
High	1	1	1	1
Low	1.00 (0.91, 1.11)	0.96 (0.86, 1.07)	0.95 (0.85, 1.06)	0.91 (0.81, 1.02)
Education				
Elementary	1	1	1	1
Secondary	0.75 (0.67, 0.84) *	0.72 (0.62, 0.83) *	0.71 (0.62, 0.82) *	0.70 (0.60, 0.81) *
Advanced technical	0.73 (0.60, 0.88) *	0.64 (0.49, 0.84) *	0.65 (0.49, 0.85) *	0.60 (0.45, 0.81) *
Higher	0.54 (0.48, 0.60) *	0.48 (0.38, 0.61) *	0.48 (0.38, 0.61) *	0.47 (0.37, 0.61) *
Social overload ††				
Average	1.48 (1.33, 1.64) *	-	-	1.09 (0.96, 1.23)
High	2.02 (1.77, 2.31) *	-	-	1.17 (0.98, 1.38)
Lack of social recognition ††				
Average	1.60 (1.43, 1.79) *	-	-	1.38 (1.22, 1.57) *
High	2.53 (2.20, 2.89) *	-	-	1.94 (1.64, 2.30) *
Chronic worrying ††				
Average	1.65 (1.47, 1.86) *	-	-	1.41 (1.23, 1.62) *
High	2.26 (1.99, 2.56) *	-	-	1.72 (1.45, 2.05) *
Stressful memories ††				
Average	1.53 (1.36, 1.72) *	-	-	1.19 (1.04, 1.36) *
High	1.92 (1.70, 2.16) *	-	-	1.11 (0.94, 1.31)

Note: # Each model mutually adjusted for all variables given in the column. * Statistically significant. ** Reference category "No". †† Reference category "Low".

Compared to employees, students were more likely to report higher levels of work overload at follow-up (fully adjusted Model 3: aOR: 1.33, 95% CI: 1.07, 1.67). Likewise, work overload of self-employed increased significantly compared to the reference group (aOR: 2.55, 95% CI: 1.16, 5.58). Looking at the different job categories, those working at some time in the healthcare sector were more

likely to change in a higher work overload category than those never working in this sector (aOR: 1.17, 95% CI: 1.01, 1.37).

Regarding working discontent, it decreased over time (OR: 0.68, 95% CI: 0.63, 0.74) but differences between SOLAR-I and II became none significant after adjustment. In addition, there was no change in work discontent in students compared to employees (aOR: 1.06, 95% CI: 0.84, 1.34), whereas unemployed subjects reported a higher level of work discontent at follow-up than employees (aOR: 2.15, 95% CI: 1.50, 3.09). Of the five job categories studied, working in the healthcare sector (aOR: 0.84, 95% CI: 0.71, 0.99), as a clerk (aOR: 0.83, 95% CI: 0.70, 0.99) or as a plant machine operator (aOR: 0.82, 95% CI: 0.70, 0.96) was inversely associated with work discontent compared to those not working in these sectors (Table 3). Adjustments only marginally changed the results (Tables 2 and 3).

Looking at the non-job-related chronic stress parameters of Model 3, those in the high chronic worrying category were also more likely to change into a higher work overload category (aOR: 2.89, 95% CI: 2.41, 3.46) and work discontent (aOR: 1.72, 95% CI: 1.45, 2.05) category between SOLAR I and SOLAR II. Social overload was associated with work overload only (aOR: 1.42, 95% CI: 1.20, 1.68). In contrast, lack of social recognition increased the chances of reporting work discontent at follow-up (aOR: 1.94, 95% CI: 1.64, 2.30).

The sensitivity analyses confirmed consistency between multiply imputed data and complete cases analyses (Table S2). After stratification for sex, results remained stable with only minor changes in the odds ratios for men and women (Tables S3 and S4). Restricting the analyses to students, those with part-time jobs reported less work discontent than those not working. In addition, students with part-time jobs in the healthcare sector reported higher work overload compared to students not working in this sector (Table S5).

4. Discussion

In this cohort of young adults, we found a substantial increase of work overload from school to working/university life at the population level. Especially affected were university students compared to their employed counterparts. Differences in work overload became even more pronounced for working students. At the same time, university students were more content with what they were doing than at the SOLAR I, which is reflected by less work discontent compared to employees.

Our findings contribute to the current literature on job-related well-being among young adults during their transition into work life. The few existing studies on stress among young workers showed that new psychological work environments and unfamiliar working conditions might lead to an elevated perception of chronic stress and musculoskeletal symptoms among job beginners [32]. Studies among college students indicated that they may become overwhelmed with feelings that there is not enough time to complete all their work adequately. In our study population, this seems particularly true for students who hold part-time jobs attending school at the same time [11,33,34]. Evidence-based interventions for stress reduction should therefore specifically be targeted on the management of work overload among university students [35]. Students with part-time jobs (but not vocational trainees) in the health sector were mostly affected by higher work overload, but also less work discontent compared to full-time students, which is in line with existing literature. However, work discontent perception could change after several years of working in the health sector [36,37].

Work discontent also decreased significantly over time among clerks and machine operators as compared to those not working in such jobs. It might be that young people starting in such jobs can successfully apply their manual skills and capabilities in vocational practice while they were stressed by the intellectual demands at school. For the other occupational groups, we did observe significant associations with chronic job-related stress, which is consistent with previous work by Melchior et al. [5]. Then, participants exposed to high demanding jobs, such as jobs with excessive workload or with extreme high demanding time pressures, had a greater risk of reporting job chronic stress, which in the long term can lead to severe problems such as depression or anxiety disorders. Our findings remained robust after stratifying for gender, which is an indication of lack of effect

modification. This is in line with other studies using the same [14,38] or different instruments to assess stress [39].

Overall, our study expands on previous attempts to determine chronic job-related stress among young adults entering university and to compare them to those entering work life. Due to the prospective design, it is possible to discern the temporal sequence between the exposure and outcome. Using the job-history at SOLAR I, we excluded individuals with previous occupational exposure. Our data were collected as part of an extensive protocol that assessed a wide spectrum of health-related information, and participants were not aware of the main hypothesis addressed in the analyses presented in this paper. Therefore, differential misclassification of exposure or outcome is unlikely. Additionally, as almost half of our study population were students, many of the jobs may have been temporary (e.g., student jobs), which had not been investigated previously.

Our study has some limitations. We used a well-established standardized coding instrument (ISCO-88) to define the occupational groups. However, our analyses were restricted to the most prevalent professions in our cohort. Our data relies on the self-report of work-related chronic stress, which may be biased by personality or other reporting bias. Both the type of job selection and chronic stress may be influenced by several individual, social, and cultural characteristics. Accordingly, all estimates were adjusted for a set of a priori defined potential confounders such as sex, socioeconomic status, education, having children, and non-work related chronic stress. Additionally, we did not assess whether the questionnaires were answered during or after the exam period. However, in SOLAR I, participants received the questionnaires between August 2002 and January 2003, which is a period without main exams in Germany. In SOLAR II, questionnaires were sent between August 2007 and November 2008. It might be therefore that some of our students were in an exam or assessment period. Stress measurement in general underlies a random fluctuation, but we do not believe that our results were largely affected by this non-differential misclassification, as our instrument measures chronic stress rather than study load or work load. Data on contextual features such as ethnic background, cultural conception, and social capital were not collected in our study due to legal and logistical reasons. Health status may have conditioned the beginning of professional life, with participants entering the labor market differentially depending on their health status. This so-called healthy hire effect might have caused unmeasured confounding. SOLAR II was based on a population-based cohort. Several methodologies were used to increase participation as far as possible to decrease selection bias. Generalizability of our results should, however, be interpreted carefully, since females and children of parents with higher parental education level were more likely to take part in each follow-up [23].

5. Conclusions

In summary, our prospective study of young adults transitioning from school to university and working life indicates that university students were especially affected by work overload, especially those who were concurrently working and studying. This indicates that stress-related interventions might be useful for university students as chronic stress may result in poor health over time. Particularly health professionals reported increased chronic job stress in comparison to other professions, which calls for further measures to reduce psychosocial risks in the healthcare sector.

Supplementary Materials: The following are available online at www.mdpi.com/1660-4601/14/11/1325/s1, Table S1: Prevalences in each job-related category in SOLAR I and SOLAR II. Rows represent prevalences at baseline (SOLAR I) and columns are prevalences in SOLAR II, Table S2: Adjusted odds ratios for stress outcomes using complete case (ORCC) and multiple imputation (ORMI) with 95% confidence intervals (95% CI) using the Model 3. Associations obtained using ordinal GEE models in a prospective cohort study of 1688 German young adults, Table S3: Adjusted odds ratios after multiple imputation (aOR) and 95% confidence intervals (95% CI) for work discontent and sex using the Model 3, Table S4: Associations obtained using ordinal GEE models in a prospective cohort study of German young adults. Adjusted odds ratios after multiple imputation (aOR) and 95% confidence intervals (95% CI) for work overload and sex using the Model 3, Table S5: Adjusted odds ratios after multiple imputation (aOR) and 95% confidence intervals (95% CI) for job-related chronic stress outcomes using the Model 3 using only the students.

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Author Contributions: Ronald Herrera was responsible for data preparation, data analysis, interpretation of the data, and the writing of the manuscript. Ursula Berger was contributed to the design of the analyses, interpretation of the data, and drafting of the manuscript. Jon Genuneit made contributions to conception and design and was responsible for data management. Jessica Gerlich was responsible for the acquisition of data and interpretation of the data. Dennis Nowak made contributions to the conception and design of the study. Wolff Schlotz contributed to the conception and design of the study and was also responsible for TICS scale conception. Christian Vogelberg made contributions to the conception and design of the study and data interpretation. Erika von Mutius made contributions to the conception, design, and analyses of the study. Gudrun Weinmayr made contributions to the conception and design of the study and was also responsible for data management. Doris Windstetter contributed to the conception of the study and interpretation of the data. Matthias Weigl was responsible for the interpretation of the data and for drafting the manuscript. Katja Radon made contributions to the conception and design of the study, as well as data analyses and interpretation, and helped draft the manuscript. All authors read and approved the final manuscript.

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Publication 2

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BMJ Open

Greenness and job-related chronic stress in young adults: a prospective cohort study in Germany

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ABSTRACT

Objectives We aimed to prospectively study the association between normalised difference vegetation index (NDVI) as a measure of greenness around homes and occupational stress.

Setting A population-based cohort in Munich and Dresden cities was followed from age 16–18 years to age 20–23 years (n=1632).

Participants At baseline, all participants attended high-school while at follow-up some had started working and others studying at university. At baseline and in each follow-up, we assigned NDVI based on participants' residential geocoded addresses and categorised it by quartiles.

Outcome measures School-related, university-related or job-related self-reported chronic stress was assessed at the two follow-ups by the Trier Scale for Assessment of Chronic Stress using work discontent and work overload as outcomes. We modelled the association employing ordinal generalised estimating equations model accounting for changes in sociodemographics, non-job-related stress, job history and environmental covariates. Stratified analysis by each city was performed.

Results NVDI at baseline was higher for participants from Dresden (median=0.36; IQR 0.31–0.41) than Munich (0.31; 0.26–0.34). At follow-up, it decreased only for participants in Dresden (0.34; 0.30–0.40). Higher greenness (quartile 4 vs quartile 1) was associated with less work discontent (OR 0.89; 95% CI 0.80 to 0.99) and less work overload (OR 0.87; 95% CI 0.78 to 0.96). In stratified analyses, results were more consistent for Munich than for Dresden.

Conclusions Our results suggest that residential green spaces, using the vegetation index as a proxy for exposure, are inversely associated with two types of job-related chronic stress in German young adults transitioning from school to university or working life.

Strengths and limitations of this study

- ► This paper is the first study investigating the association of greenness and job-related chronic stress using a prospective study in young adults.
- ► We used a validated instrument to measure the job-related stress as well as stress dimensions outside the workplace.
- ► Our results remained robust when controlling for a wide range of confounding factors like sociodemographic variables, type of employment and non-job-related chronic stress.
- ► We used satellite images from 2009 for the normalised difference vegetation index calculations, which were not temporally aligned with the survey used.
- ► We did not include participants' commuting times, nor green measurements at work places, making it impossible to control for these covariates.
- ► Some contextual data like ethnic background and social cohesion were not taken into account in our analysis.

INTRODUCTION

Some projections estimate that around 66% of the worldwide population is expected to live in urban areas by 2060; in Germany, this proportion is expected to reach 92% by then.[1] Moreover, the global number of large cities (ie, 5–10 million inhabitants) will be 65 by the year of 2030, housing approximately 400 million people worldwide.[2] Large cities present advantages for economic growth and industrialisation. Also, they promote livability and sustainability and are bringing social and health benefits.[3] However, big cities have adverse impacts on health and well-being of their inhabitants.[4]

Mental health is especially affected in big cities, in part because of reduction of social interaction, excessive commuting and through increments in psychological stressors.[5 6] Psychological distress has been identified as an essential public health and economic problem in large cities because it leads to work absence, lower productivity or early retirement.[7] Susceptible populations like students and young adults in transition from school to job/university life reported

increments in job-related chronic stress.[8] In line with this, evidence has shown significant mental health benefits of residing in cities with more natural environments through restorative effects on psychological health.[9–17]

Mechanisms explaining the restorative effect of a green environment are attributed mainly to physical activity, social contact and deliberately seeking environments to recover from demanding situations and tasks.[10 12 18–21] Restorative niches were associated with emotional well-being, as well as increments of project management capabilities in adolescents transitioning from junior to secondary school.[22] Additionally, few studies have studied associations between the access to green environments and job satisfaction.[23–25] Researchers have shown the restorative effect of greenness mainly at schools or workplaces.[19 26–28] These studies showed that being exposed to a green environment at the workplace/school is beneficial for workers or students. Despite these potential benefits, most of the office workers and students do not go outdoors during the job/study day, mainly because of a perception of having many tasks to do and a job/studying culture that does not include outdoor behaving.[27 29]

So far, there are few studies relating greenness around the home environment to job-related chronic stress, especially in longitudinal settings.[16 30 31] No previous research has analysed the association between greenness at home and job-related stress development in young people in the transition from school to university or working life. Our aim was therefore to investigate the association between normalised difference vegetation index (NDVI) as a measure of greenness around homes and two different job/study-related chronic stress measurements: work discontent and work overload.[32 33] Data were drawn from a population-based cohort in two major German cities, specifically Munich and Dresden, surveying young adults in the transition from high school to university or working life.

METHODS

We analysed data of the SOLAR (Studie in Ost- und Westdeutschland zu beruflichen Allergierisiken) I and SOLAR II studies.[34] These studies were aimed at studying the course of respiratory diseases and atopy in symptomatic and non-symptomatic children and young adults. Also, occupational risk factors were assessed to investigate associations among occupational factors, stress and the course of respiratory diseases. SOLAR II is the second follow-up of the German phase II of the International Study on Asthma and Allergies in Childhood (ISAAC II), a multicentre study planned to assess the prevalence of asthma and allergies with participants from elementary school students.[35] The German branch of the ISAAC II was carried out in 1996/1997 in Munich and Dresden. In these cities, it included 7498 participants at age 10 years (fourth grade, age range 9–11 years). From August to January 2003, 3053 of these participants answered the questionnaire of the first follow-up of the study (SOLAR I; age range 16–18 years). From August 2007 to November 2008, 2051 of the participants agreed to participate in SOLAR II (age range 19–24 years).

In the present analysis, we considered questionnaire data from SOLAR I and II, as only these two surveys contained data on chronic stress (figure 1). Besides chronic stress items, the written questionnaires contained validated items on sociodemographics, type of job, occupational diseases and physical activity. More details on the study methods are given by Heinrich *et al*.[34]

In the current analyses, we excluded participants who had ever worked before SOLAR I (n=318), those without information on educational status (n=21) and those with more than two items missing in one of the Trier Inventory for Chronic Stress (TICS)[32 33] scales (n=24). We geocoded the families' or participants' most recent addresses in SOLAR I and SOLAR II. We then calculated the environmental covariates and matched them to the individual questionnaire information. We excluded 56 participants because they moved out of the study areas (figure 1).

All participants or their legal guardians provided written informed consent.

Variable definition

Job-related stress

For this study, it was essential to use an instrument applicable to the school, university and working environments. TICS is a well-established instrument that includes scales of job-related chronic stress and stress outside the workplace dimensions. These scales were selected using the model of health[33] and validated using confirmatory analysis in a representative sample.[32] Hence, it is well suited to study the change of stress from school life to working or university life. We used two job-related TICS subscales as chronic stress outcomes: work discontent (eg, "Satisfaction from the work that I have to perform daily") and work overload (eg, "Too little time to execute my daily tasks"). Responses were assessed on a 5-point Likert scale from 'never' (0 points) to 'very often' (4 points). Total scores were formed as sum of all particular items in each subscale. Based on the recommendations of the scales' authors,[33] up to two missing items per subscale were accepted otherwise, the subscale was considered as missing. Each subscale was categorised based on the frequency of stressful situations, as 'low' (≤median), 'average' (above median to median+1 SD) and 'high' (≥1 SD from the median).[36] We used the median and SD obtained in SOLAR I to categorise the outcomes in SOLAR I and SOLAR II.

Greenness of the home environment

We geocoded participants' addresses in SOLAR I and SOLAR II. Based on the geocoding, the exposure to natural and green areas around each home address was estimated using NDVI, a satellite image-based vegetation index. $NDVI = \frac{NIR-RR}{NIR+RR}$ is the ratio of differences between the near-infrared region (NIR) and red reflectance (RR) to the sum of these two measures, and it ranges between

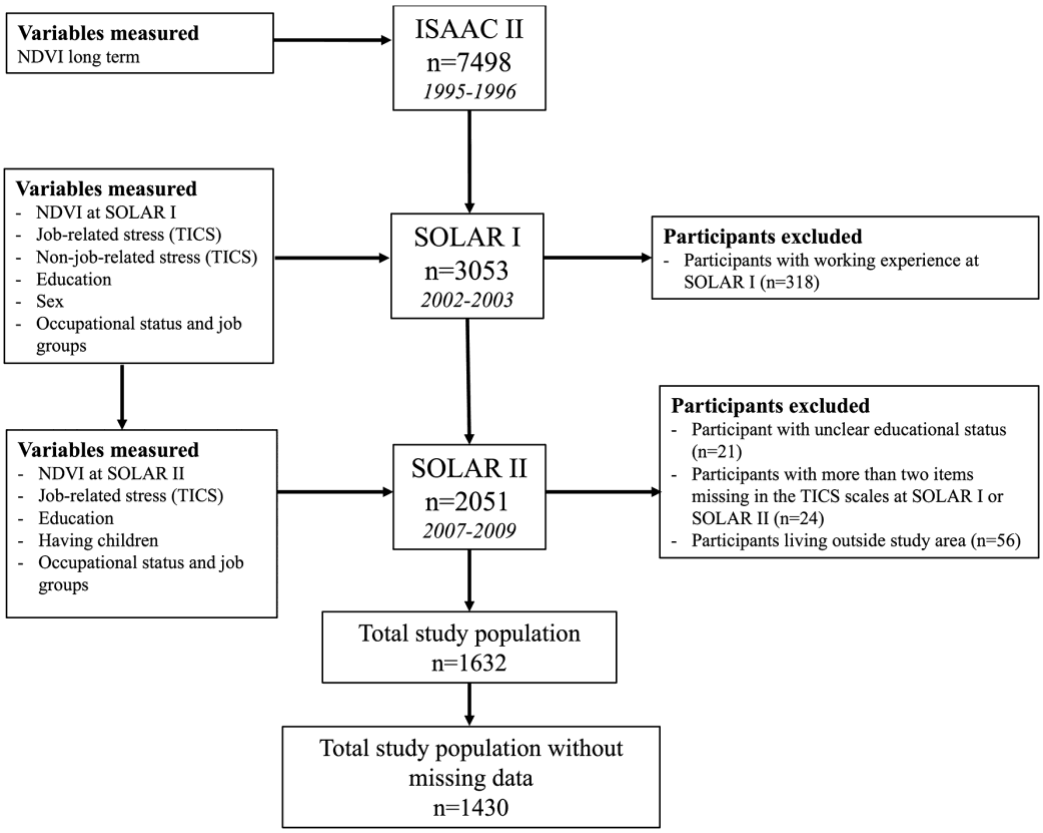

Figure 1 Flow chart of follow-up from International Study on Asthma and Allergies in Childhood (ISAAC) phase II to SOLAR II including normalised difference vegetation index (NDVI) measurements, job-related and non-job-related stress variables and total participants in each follow-up and the current analysis. Excluded participants: n=318 ever worked previously to SOLAR I, n=21 no educational status information, n=24 more than two Trier Scale for Assessment of Chronic Stress (TICS) items missing and n=56 residence out of the study areas.

−1.0 (water) and 1.0 (dense green vegetation), with zero indicating sand, snow or rocks.[37] Choosing Landsat 5 Thematic Mapper (http://earthexplorer.usgs.gov/) cloud-free satellite images, an average NDVI was obtained using a 30 m by 30 m resolution in a 500 m radius around home addresses. The 500 m radius was used because it is considered to reflect better greenness directly accessible outside each home.[38] For the Munich area (including the city of Munich and an adjacent region of Upper Bavaria), we used two images from 31 August in 2009 and merged them to cover the entire study area. In Dresden (including the Saxony area), four images were combined to cover the study area. As no data for a single day were available, we used images from 24 and 31 August in 2009. Finally, the exposure was categorised using survey and city-specific quartiles to account for distributional differences between city and study period.[39]

Covariates

Sociodemographics

As sociodemographic variables, we included: sex (male vs female), highest educational status reported at SOLAR I and SOLAR II (elementary education vs secondary education, advanced technical or higher education) and if the participant had children by SOLAR II (no vs yes). To account for physical activity, we used the WHO recommendations[40] considering the age-specific cut-o point for SOLAR I (≥4 hours/week) and SOLAR II (≥2 hours/week).

Non-job-related chronic stress

TICS also measures the stress outside the workplace/university environment using the following four subscales:

- social overload (eg, "I quarrel with others because I do not behave the way others expect me to");
- lack of social recognition (eg, "The experience that other people have no trust in me");
- chronic worrying (eg, "Times when I am not able to suppress my worries");
- stressful memories (eg, "Recurrent memories of failures").

We measured these non-job-related chronic stress scales in SOLAR I only (figure 1) because they are considered to be persistent over time[8] and used them as covariates to control for self-perceived stressful circumstances outside the work or study environment. Categorisation of the

non-job-related chronic stress scales was done using the same method as for job-related stress.

Current status and job type

At SOLAR II, we categorised the occupational status as follows: employee (reference), university student, vocational trainee (in a dual training programme), unemployed, self-employed and other (ie, on maternity leave or being work disabled).[8 34] In addition, participants reported any jobs they had ever held up until SOLAR I and between SOLAR I and SOLAR II. Two trained persons coded these jobs (including regular employment, student job or internship) according to the International Standard Classification of Occupations (ISCO-88).[41] Following the ISCO classification, we assigned each working participant to one of five job groups: clerks, professionals and technicians, healthcare professionals (ie, with direct patient contact), plant machine operators and elementary occupations (ie, routine tasks using mainly handheld tools and some involving physical effort).

Environmental covariates

We used the European Environmental Agency databases[42] to link participants' residential addresses to the following spatial covariates: distance to sports facilities,[43] distance to nearest urban green space[44] (ie, either a garden, a park, a cemetery or a plant nursery), distance to nearest lake or river[11] and the percentage of tree coverage[45] (ie, the percentage of flat ground covered by woody vegetation over a 5 m height). Additionally, we included the proportion of soil sealing derived in 2000 m buffer for the year 2009 as a measure of urbanisation degree. Finally, we used the NDVI measurement in a 500 m buffer at ISAAC II as a continuous variable to control for long-term greenness exposure.[42]

Statistical analysis

We employed generalised estimating equations (GEE) models for ordinal outcomes with an exchangeability correlation structure.[46] Applying this strategy, we assessed the relationship between greenness and job-related stress, meanwhile controlling for the outcomes temporal correlation.[46 47] GEE methods produce population-averaged estimates, that is, they describe changes in the population mean based on changes in covariates.[47 48] In the present analysis, GEE estimates tell us how much the studied outcomes (work overload or work discontent) would change on average in the population for each NDVI quartile increase controlling for covariates. Positive values thus mean an increase in chronic stress over time.

We included all mentioned covariates in the final models. Given the possible interaction between city and greenness,[39] we stratified the analyses by city (Munich and Dresden). Furthermore, we estimated the final models using only participants who never changed their home addresses during the whole study period (n=675). Additionally, we restricted the analyses to only students (n=845) and only workers, that is, participants that reported being employees or vocational trainees (n=670). Finally, we performed a mediation analysis using the approach suggested by Schluchter[49] to test the hypothesis that physical activity could mediate the association between greenness and job-related stress.

Using complete-case analyses in the presence of missing data might bias the results.[50] Therefore, we constructed five imputed datasets using multiple imputations by chained equations.[51] Using Rubin's rules,[52] we obtained the combined adjusted ORs and CIs. We presented the comparison between complete cases and multiply-imputed estimates in the online supplementary material.

Statistical analyses were performed in R V.3.3.1[53] and the geographical calculations using ArcGIS 10.0 (Environmental Systems Research Institute, 2012) joint with the Geospatial Modelling Environment software (Spatial Ecology).

Patient and public involvement

Patients and public were not involved in the design of the study.

RESULTS

The number of participants in both cities was similar (869 in Munich and 763 in Dresden). Surrounding average greenness in a 500 m buffer for SOLAR I was higher in Dresden (median=0.36; IQR 0.31–0.41) than Munich (0.31; IQR 0.26–0.34). In SOLAR II, NVDI decreased for participants in Dresden (0.34; IQR 0.30–0.40) while it remained the same for participants living in Munich (0.31; IQR 0.26–0.34) (see online supplementary table S1 and figure S1).

Comparing the covariates across the greenness quartiles, we found small difference between quartiles (table 1): participants with children tended to live in places with greenness values in the lower quartiles of the greenness distribution, and those with higher education and students in the upper quartiles. Likewise, the percentage of physically active people was higher with increasing level of greenness around the participants' houses. Based on the p values, we did not find statistically significant differences in Munich between the distance to sports facilities or distance to the nearest urban green space and NDVI quartiles; however, all other environmental covariates showed statistically significant differences with respect to NDVI quartiles. In Dresden, all environmental covariates were associated with NDVI (table 1).

Prevalence of high levels of work discontent and work overload decreased by increasing level of greenness in a buffer of 500 m around the home, especially for SOLAR II (table 2). Results were confirmed when we took changes over time into account as shown by ORs <1 for work discontent (adjusted OR comparing the fourth to the first quartile of greenness: OR 0.89; 95% CI 0.80 to 0.99) and work overload (OR 0.87; 95% CI 0.78 to 0.96) (figure 2A).

Restricting the study population to participants who did not move between ISAAC II and SOLAR II did not affect the results (figure 2B). Stratifying by city, results were more consistent for Munich than for Dresden. In

Table 1 Sociodemographic characteristics, type of job, psychological scores, environmental variables at baseline by city-specific NDVI quartile and city

		Munich, n=869					Dresden, n=763				
		Centre-specific NDVI quartile					Centre-specific NDVI quartile				
	Total	Q1	Q2	Q3	Q4	P values	Q1	Q2	Q3	Q4	P values
Individual characteristics, n (%)											
Sex, woman	961 (58.9)	127 (59.1)	122 (56.7)	32 (61.7)	119 (55.3)	0.56	111 (60.3)	110 (59.8)	111 (60.7)	112 (60.9)	0.99
Having children* (NA=20), yes	51 (3.1)	5 (2.4)	6 (2.8)	2 (<1)	3 (1.4)	0.26	12 (6.8)	6 (3.4)	7 (4.0)	6 (3.4)	0.17
Education* (NA=6)											
Elementary	8 (<1)	1 (<1)	2 (<1)	2 (<1)	1 (<1)	<0.01	0	1 (<1)	0	1 (<1)	0.08
Secondary	419 (25.8)	73 (34.3)	55 (25.9)	53 (25.2)	47 (22.4)		54 (30.7)	41 (23.4)	48 (27.3)	33 (18.9)	
Advanced technical	194 (11.9)	31 (14.6)	32 (15.1)	32 (15.2)	21 (10.0)		17 (9.7)	14 (8.0)	18 (10.2)	21 (12.0)	
Higher	1005 (61.8)	108 (50.7)	123 (58.0)	123 (58.6)	141 (67.1)		105 (59.7)	119 (68.0)	110 (62.5)	120 (68.6)	
Physical activity* (NA=33), >2 hours/ week	511 (32.0)	55 (26.1)	76 (35.7)	74 (35.1)	70 (32.9)	0.69	48 (27.4)	57 (31.7)	50 (27.8)	64 (35.6)	0.05
Current status* (NA=5)											
Employed	365 (22.4)	52 (24.5)	44 (20.8)	42 (20.0)	43 (20.4)	0.35	49 (27.8)	35 (20)	43 (24.4)	38 (21.6)	0.10
Students	845 (51.9)	97 (45.8)	110 (51.9)	118 (56.2)	124 (58.8)		74 (42.0)	97 (55.4)	82 (46.6)	96 (54.5)	
Apprentice	305 (18.7)	47 (22.2)	49 (23.1)	41 (19.5)	35 (16.6)		32 (18.2)	23 (13.1)	39 (22.2)	31 (17.6)	
Unemployed	59 (3.6)	8 (3.8)	4 (1.9)	5 (2.4)	2 (<1)		10 (5.7)	12 (6.9)	7 (4.0)	8 (4.5)	
Other	53 (3.3)	8 (3.8)	5 (2.4)	4 (1.9)	7 (3.3)		11 (6.2)	8 (4.6)	5 (2.8)	3 (1.7)	
Type of job, n (%)											
Clerks	159 (9.7)	19 (8.8)	16 (7.4)	21 (9.8)	25 (11.6)	0.24	18 (9.8)	20 (10.9)	14 (7.7)	21 (11.4)	0.64
Professionals and technicians	318 (19.5)	41 (19.1)	48 (22.3)	39 (18.2)	40 (18.6)	0.74	41 (22.3)	32 (17.4)	31 (16.9)	37 (20.1)	0.92
Health professionals	202 (12.4)	18 (8.4)	22 (10.2)	27 (12.6)	31 (14.4)	0.24	23 (12.5)	21 (11.4)	30 (16.4)	26 (14.1)	0.80
Plant machine operators	248 (15.2)	31 (14.4)	36 (16.7)	34 (15.9)	22 (10.2)	0.38	34 (18.5)	29 (15.8)	21 (11.5)	37 (20.1)	0.30
Elementary occupations	90 (5.5)	10 (4.7)	10 (4.7)	8 (3.7)	5 (2.3)	0.65	14 (7.6)	14 (7.6)	10 (5.5)	17 (9.2)	0.85
Psychological variables, n (%)											
Lack of social recognition (NA=14)											
Low	739 (45.7)	91 (42.9)	102 (47.4)	112 (53.1)	98 (46.0)	0.09	85 (46.7)	73 (40.1)	82 (44.8)	76 (41.5)	0.35
Average	656 (40.5)	84 (39.6)	85 (39.5)	78 (37.0)	90 (42.3)		69 (37.9)	84 (46.2)	74 (40.4)	79 (43.2)	
High	223 (13.8)	37 (17.5)	28 (13.0)	21 (10.0)	25 (11.7)		28 (15.4)	25 (13.7)	27 (14.8)	28 (15.3)	
Social overload (NA=14)											
Low	638 (39.4)	76 (35.8)	73 (34.4)	89 (42.2)	76 (35.7)	0.25	78 (42.4)	80 (43.5)	74 (40.7)	73 (39.9)	0.49
Average	697 (43.1)	88 (41.5)	99 (46.7)	79 (37.4)	93 (43.7)		76 (41.3)	77 (41.8)	79 (43.4)	90 (49.2)	
High	283 (17.5)	48 (22.6)	40 (18.9)	43 (20.4)	44 (20.7)		30 (16.3)	27 (14.7)	29 (15.9)	20 (10.9)	

Continued

Table 1 Continued

	Total	Munich, n=869				P values	Dresden, n=763				P values
		Centre-specific NDVI quartile					Centre-specific NDVI quartile				
		Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4	
Chronic worrying (NA=16)											
Low	822 (50.9)	109 (50.9)	106 (50.2)	99 (46.9)	104 (48.8)	0.29	100 (54.9)	97 (53.0)	92 (50.5)	92 (50.3)	0.40
Average	461 (28.5)	70 (32.7)	55 (26.1)	50 (23.7)	61 (28.6)		48 (26.4)	58 (31.7)	55 (30.2)	56 (30.6)	
High	333 (20.6)	35 (16.4)	50 (23.7)	62 (29.4)	48 (22.5)		34 (18.7)	28 (15.3)	35 (19.2)	35 (19.1)	
Stressful memories (NA=12)											
Low	852 (52.6)	111 (52.1)	112 (52.1)	101 (47.6)	99 (46.3)	0.81	106 (58.2)	105 (57.7)	101 (55.8)	93 (50.8)	0.30
Average	423 (26.1)	56 (26.3)	51 (23.7)	56 (26.4)	65 (30.4)		42 (23.1)	44 (24.2)	43 (23.8)	55 (30.1)	
High	345 (21.3)	46 (21.6)	52 (24.2)	55 (25.9)	50 (23.4)		34 (18.7)	33 (18.1)	37 (20.4)	35 (19.1)	
Environmental variables, mean (SD)*											
Distance to sports facilities (km)	0.34 (0.26)	0.37 (0.25)	0.36 (0.21)	0.33 (0.19)	0.35 (0.26)	0.31	0.45 (0.34)	0.24 (0.20)	0.26 (0.23)	0.38 (0.33)	<0.01
Distance to nearest urban green space (km)	0.28 (0.27)	0.25 (0.18)	0.25 (0.19)	0.27 (0.39)	0.23 (0.22)	0.15	0.36 (0.27)	0.35 (0.21)	0.25 (0.22)	0.34 (0.40)	<0.01
Distance to nearest lake or river (km)	1.43 (0.91)	1.26 (0.52)	1.58 (0.90)	1.69 (1.02)	1.82 (1.15)	<0.01	0.82 (0.60)	1.28 (0.75)	1.32 (0.78)	1.55 (0.99)	<0.01
Proportion of tree coverage in 500 m	2.5 (4.1)	0.75 (0.61)	1.09 (1.24)	1.48 (1.86)	4.54 (5.90)	<0.01	1.60 (1.02)	1.50 (1.12)	2.23 (1.96)	7.30 (7.45)	<0.01
Proportion of soil sealing	49.1 (18.6)	67.7 (10.1)	53.7 (11.7)	46.7 (11.8)	40.2 (14.2)	<0.01	60.8 (15.0)	53.1 (15.1)	43.5 (14.7)	24.5 (14.5)	<0.01
Greenness at ISAAC II (500 m buffer)	0.31 (0.08)	0.30 (0.06)	0.32 (0.06)	0.35 (0.06)	0.37 (0.08)	<0.01	0.22 (0.05)	0.28 (0.05)	0.32 (0.04)	0.35 (0.07)	<0.01

Total sample, n=1632.
*Calculated in the second follow-up (SOLAR II).
ISAAC, International Study on Asthma and Allergies in Childhood; NDVI, normalised difference vegetation index; NA, missing data; Q, quartile.

Table 2 Prevalence of job-related chronic stress outcomes by city-specific NDVI quartile in SOLAR I and SOLAR II

	Munich, n=869				Dresden, n=763			
	Centre-specific NDVI quartile				Centre-specific NDVI quartile			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
SOLAR I								
Work discontent (NA = 14)								
Low	103 (48.4)	108 (50.9)	108 (50.7)	102 (48.1)	111 (61.0)	95 (52.2)	100 (55.2)	103 (56.3)
Average	56 (26.3)	60 (28.3)	62 (29.1)	69 (32.5)	46 (25.3)	57 (31.3)	55 (30.4)	51 (27.9)
High	54 (25.4)	44 (20.8)	43 (20.2)	41 (19.3)	25 (13.7)	30 (16.5)	26 (14.4)	29 (15.8)
Work overload (NA=13)								
Low	116 (55.8)	114 (53.5)	125 (58.7)	118 (55.4)	104 (57.1)	97 (52.7)	102 (56.0)	92 (50.5)
Average	56 (26.9)	63 (29.6)	53 (24.9)	55 (25.8)	50 (27.5)	54 (29.3)	54 (29.7)	60 (33.0)
High	36 (17.3)	36 (16.9)	35 (16.4)	40 (18.8)	28 (15.4)	33 (17.9)	26 (14.3)	30 (16.5)
SOLAR II								
Work discontent (NA=14)								
Low	126 (59.4)	135 (64.0)	152 (71.7)	141 (66.8)	108 (62.4)	126 (72.4)	125 (71.4)	127 (72.2)
Average	47 (22.2)	43 (20.4)	34 (16.0)	46 (21.8)	40 (23.1)	27 (15.5)	33 (18.9)	30 (17.0)
High	39 (18.4)	33 (15.6)	26 (12.3)	24 (11.4)	25 (14.5)	21 (12.1)	17 (9.7)	19 (10.8)
Work overload (NA=13)								
Low	99 (46.7)	110 (52.1)	114 (53.8)	105 (50.0)	90 (51.4)	100 (56.8)	101 (58.0)	98 (56.0)
Average	59 (27.8)	50 (23.7)	56 (26.4)	64 (30.5)	48 (27.4)	48 (27.3)	38 (21.8)	47 (26.9)
High	54 (25.5)	51 (24.2)	42 (19.8)	41 (19.5)	37 (21.1)	28 (15.9)	35 (20.1)	30 (17.1)

Total sample, n=1632.
NA, missing data; NDVI, normalised difference vegetation index; Q, quartile.

students (figure 3A), the OR for work overload was <1 for all quartiles compared with the first quartile of NDVI. For workers (figure 3B), no statistically significant difference for work overload and work discontent was seen by NDVI quartiles. Stratifying results for city, results for students followed the same pattern when restricting the analyses for Munich while for work discontent they did not reach the level of statistical significance for students from Dresden. For workers, we did not see any statistically significant associations for participants from Munich while work overload decreased with increasing NDVI quartile in Dresden (figure 3B).

In the mediation analysis, we found a mediated proportion of physical activity on stress of 1.46% (95% CI −10.2% to 5.6%) for work discontent, and a 0.13% (95% CI −0.6% to 3%) for work overload. Unadjusted results were similar to the adjusted ones (see online supplementary table S2). Likewise, complete-case analyses were not different from imputed results (see online supplementary table S3).

DISCUSSION

In our cohort of young adults in the transition from school to working/university life, we found that more greenness around the place of living corresponds to lower levels of job-related stress. For work discontent, our results suggest a linear, inverse dose-response pattern across quartiles while for work overload we observed a 'J-shape' association. Our results remained robust when controlling for a wide range of confounding factors and with only small differences when stratifying for various subpopulations. These findings thus contribute to an improved understanding of the mental health benefits of green environments, especially in young adults transitioning from school to the university or working life. Our results expand and corroborate the finding of previous studies on the benefits of being exposed to greenness on mental health among different populations.[17 29 31 54 55]

Greenness exposure brings benefits on mental health. It could operate through increasing opportunities for physical activity and enhanced access to recreational and sports facilities.[56–58] Therefore, we controlled for physical activity and distance to sports facilities which did not change the results. Some researchers suggested that physical activity may act as a mediator between greenness and mental health.[6 17] However, this was not confirmed in our mediation analysis. Therefore, we hypothesise that the described associations between greenness and stress might be attributed to mechanisms beyond physical activity, which is in line with other studies.[18 54]

In our study, higher exposure to NDVI levels was inversely related to reporting stress at school, university or workplace, indicating that a favourable environment is an essential resource for recreation and recovery, setting off or balancing out stress related to school,

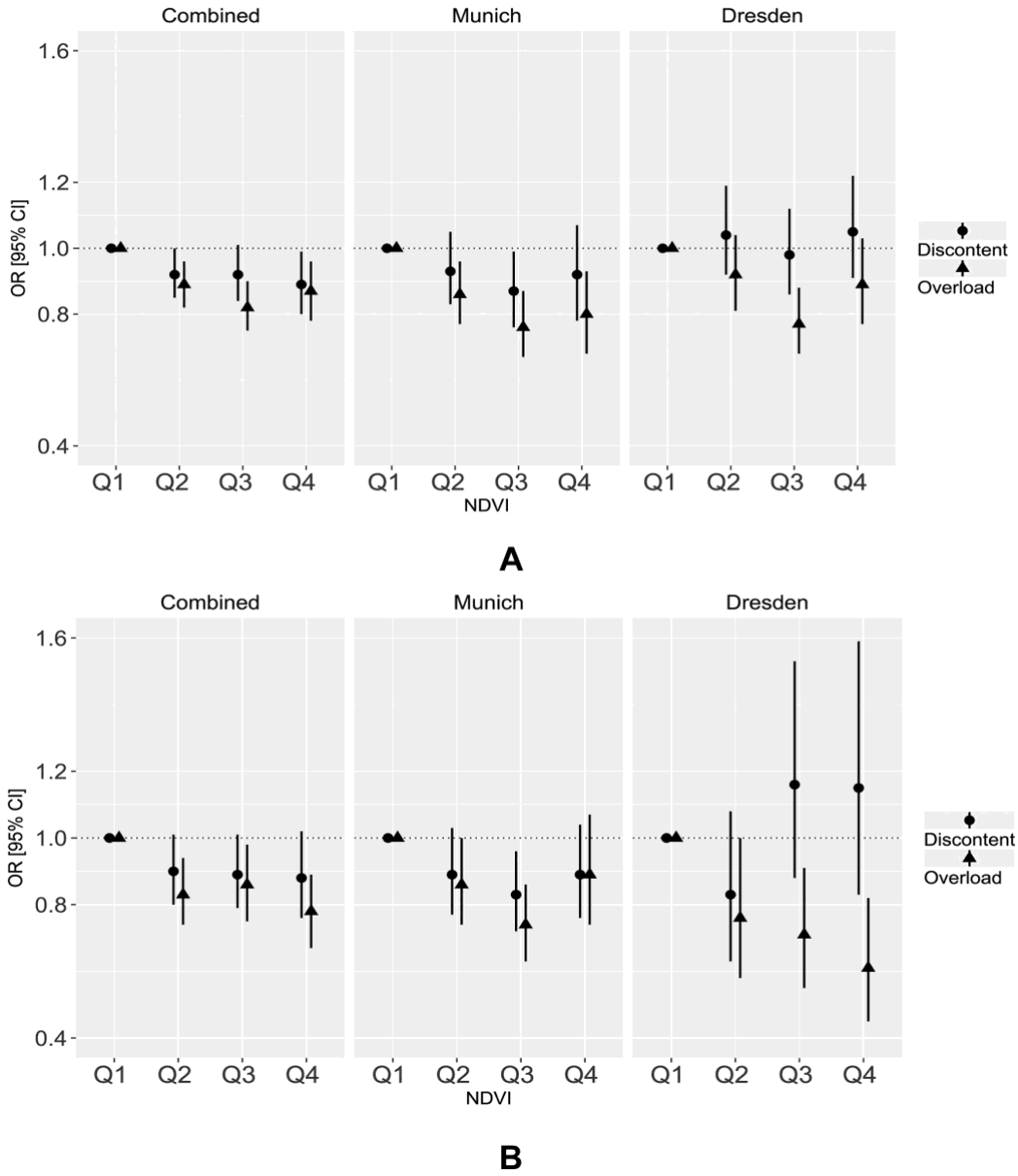

Figure 2 City-specific associations between greenness in a 500 m buffer and work discontent and work overload. Ordinal generalised estimating equation models adjusted for sex, having children, physical activity, education, current status, type of job, psychological variables and environmental variables using complete cases in selected subpopulations: (A) complete cases for the combined population (n=1430), Munich (n=779) and Dresden (n=651). (B) Complete cases that never moved in the combined population (n=629), Munich (n=443) and Dresden (n=186). NDVI, normalised difference vegetation index; Q, quartile.

university or workplace. The association remained stable when adjusting for type of job/being a student/being employed so that such potential differences do not explain the observed associations. Differences in the estimated associations between Munich and Dresden may result from different distributions of other factors, like socioeconomic status among both cities, which could affect the susceptibility to greenness exposure and job-related chronic stress.[17 39 59]

The 'J-shape' observed for work overload in our study was also seen in an Australian life-course study using GHQ-12 as a mental health outcome.[31] We believe that participants in our cohort who were living in the highest greenness quartile have the most extended commuting times between their homes and place of study or work. Commuting plus work/studying may result in increased mental burden measured by work overload. Unfortunately, we did not ask participants for their commuting times. Future studies on this subject should include commuting times as a potential confounder. As suggested by other authors,[18 29 30 58 60] we included environmental variables such as tree coverage, distance to sports facilities,

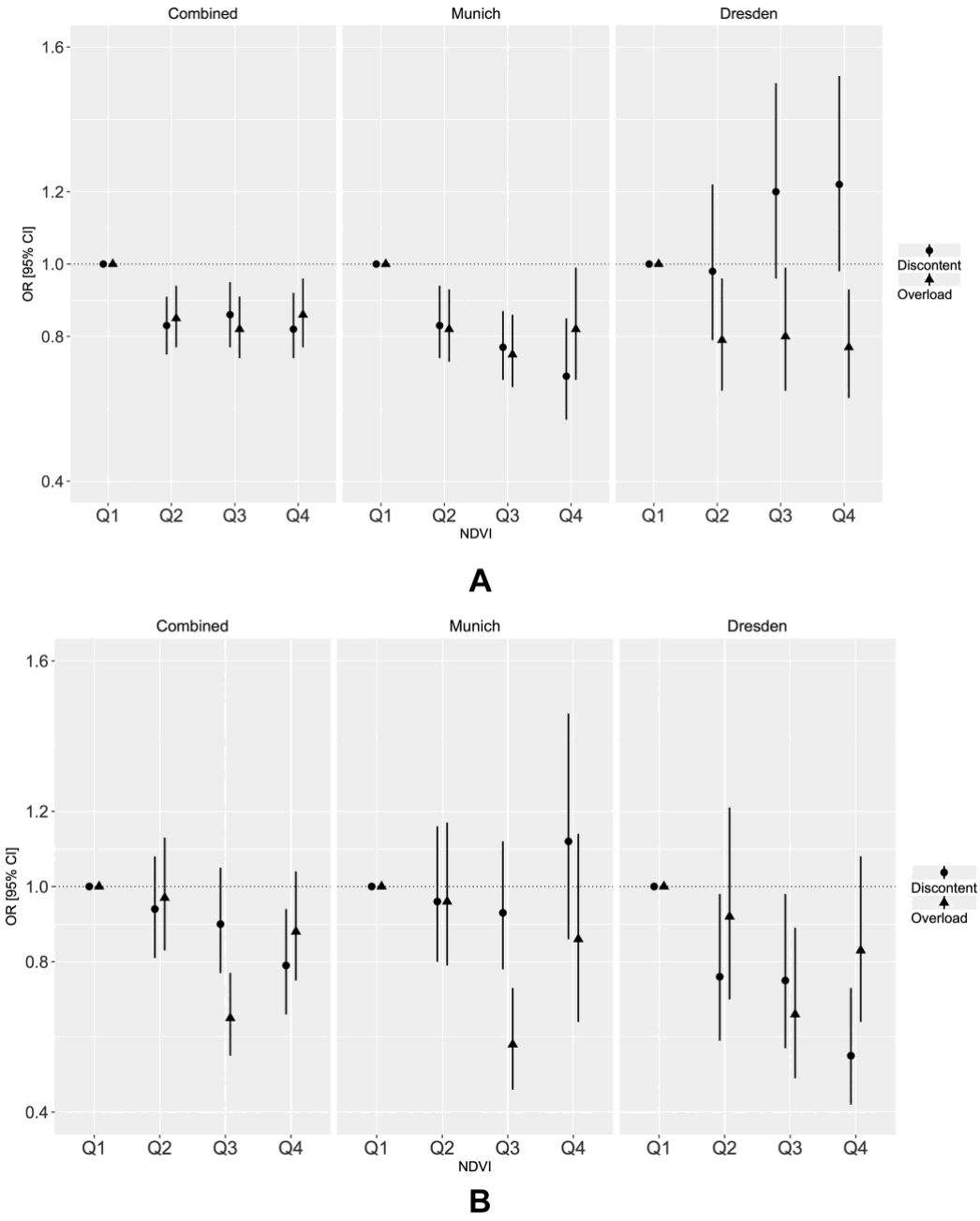

Figure 3 City-specific associations between greenness in a 500 m buffer and work discontent and work overload. Ordinal generalised estimating equation models adjusted for sex, having children, physical activity, education, current status, type of job, psychological variables and environmental variables using complete cases in selected subpopulations: (A) complete cases students only for the combined population (n=845), Munich (n=463) and Dresden (n=382). (B) Complete cases workers only in the combined population (n=670), Munich (n=359) and Dresden (n=311). NDVI, normalised difference vegetation index; Q, quartile.

distance to rivers, etc as potential confounders. However, removing those from the adjusted models did not change the results (data not shown).

Among the strengths of our study is its prospective design, which allows to differentiate the temporal sequence between the exposure to greenness and job-related chronic stress. Our questionnaire focused on asthma and allergies so that participants were not aware of the hypotheses of the current paper. Therefore, we expect differential misclassification of the outcomes to be limited. Standardised, objective and blinded assessments of greenness at each follow-up point, from good satellite

resolution images are further strengths of our study. Using NDVI as a proxy for exposure to green spaces accounts for all kinds of vegetation, and it can promote greener landscape views and leisure activities, which has shown stress recovering benefits in workers.[13 28 56]

Among the limitations of our study are the use of satellite images for the NDVI calculations, which were not temporally aligned with the SOLAR I surveys. Nevertheless, we expected spatial greenness to remain stable over several years.[58] We could not measure exposure to greenness at work because for ethical issues we could not assess the address of the workplace. This made it also impossible to calculate the commuting greenspace of participants. The shortcomings of our study are common, and almost no study in the field has obtained information other than the residential address for greenspace assessment.[60 61] A distinctive feature of our study compared with similar ones is that job-related stress was assessed using a validated scale, instead of using general stress and mental health. Residential greenspaces could improve coping mechanisms to job-related chronic stress in different ways, through viewing, physical activity and social interaction.[12 18] Inclusion of additional sources of greenness deserves more attention in future studies on greenness and job-related chronic stress. Our data draw on self-reports of job-related chronic stress, which may be biased by personality or other reporting bias. Moreover, we did not consider whether the participants answered during or after the exam period. Nevertheless, in SOLAR I, participants received the questionnaires between August 2002 and January 2003, which is a period without a high academic load in Germany. In SOLAR II, we sent the questionnaires between August 2007 and November 2008, this means, over a more than a 1 year period. Therefore, SOLAR II also included periods of higher academic load for students. We expected random fluctuations in stress measurement in general, but we do not believe that our results were influenced by this non-differential misclassification because our instrument measures chronic stress rather than study load or workload.[33] Job-related chronic stress may be influenced by several personal, social and cultural characteristics. Accordingly, we adjusted all estimates for a set of predefined variables such as sex, education, having children and non-job-related chronic stress measurements. In our study, we did not collect contextual data such as ethnic background, cultural conceptions and social cohesion due to legal and logistical reasons. Those suffering from job-related stress at follow-up might have been less likely to participate. However, we do not assume that this depended on our exposure, so potential selection bias should be limited.

CONCLUSION

Our findings suggest that residential green spaces, measured using the vegetation index, is inversely associated with job-related chronic stress in German young adults transitioning from school to university or working life. Further studies on this topic could further contribute to improve urban planning or to develop recommendations for health promotion through favourable living and working spaces.

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