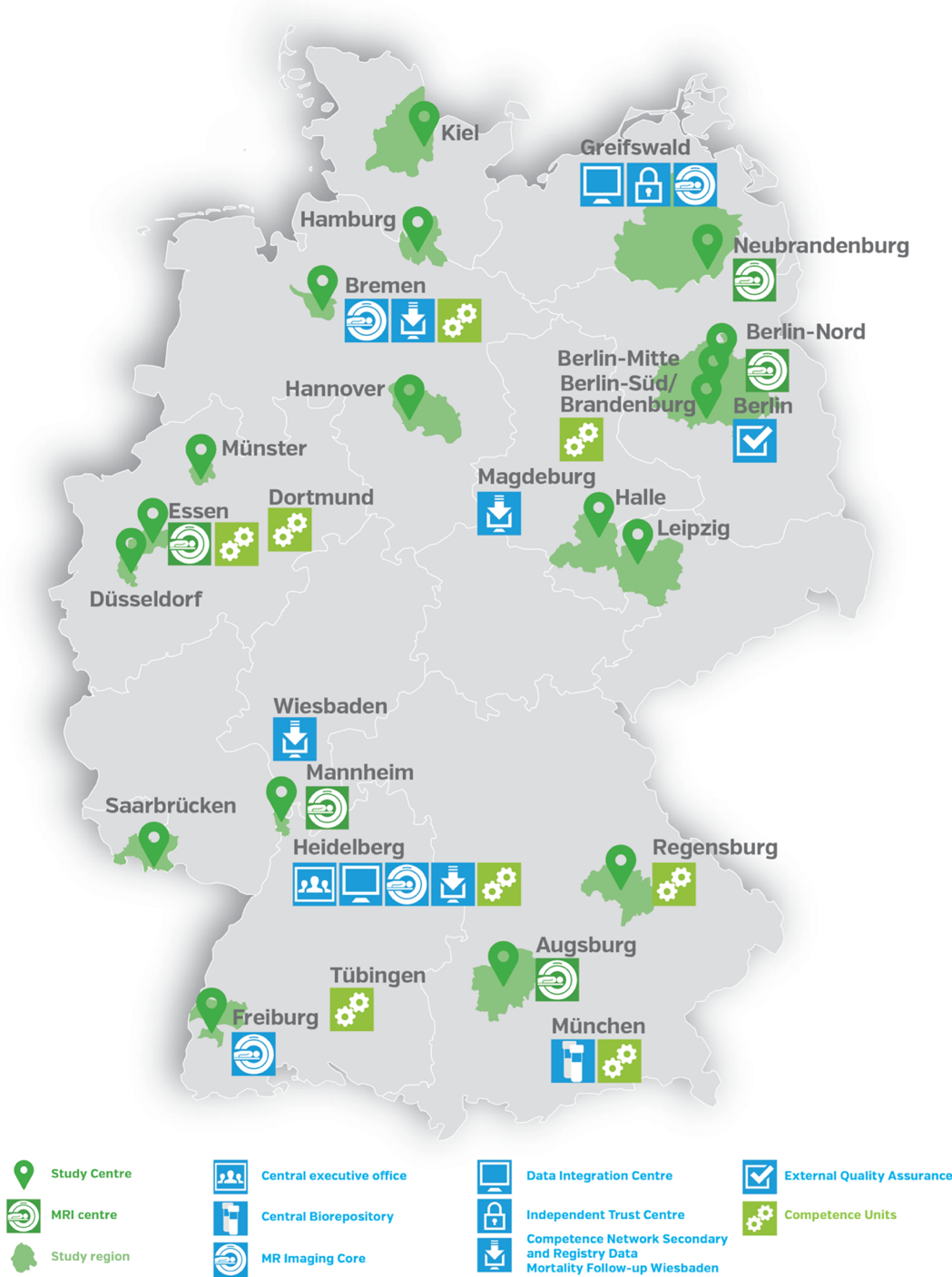
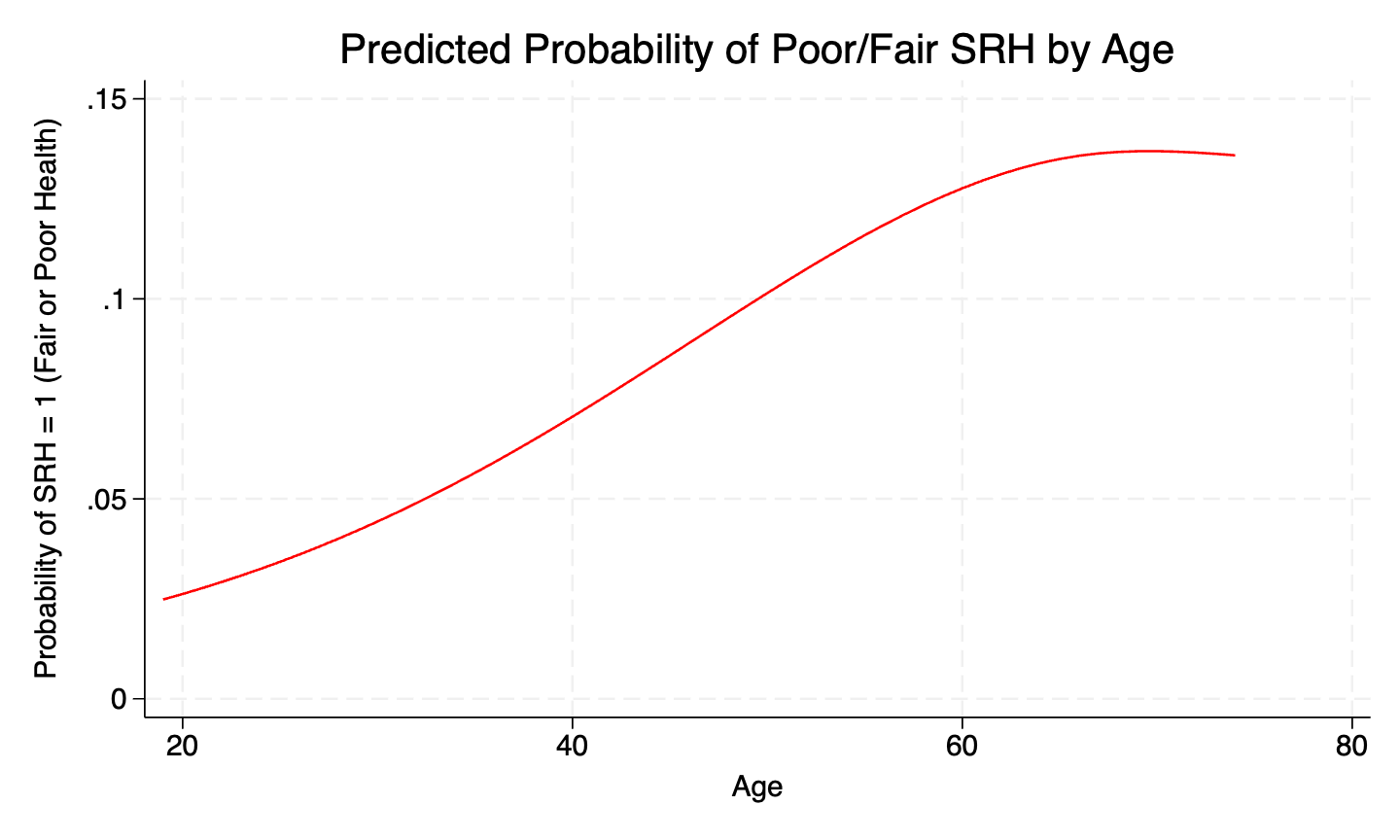
Supplementary materials

*Figure S1: Map of German National Cohort (NAKO) study sites and regions. From Peters, A., German National Cohort (NAKO) Consortium., et al. Framework and baseline examination of the German National Cohort (NAKO). Eur J Epidemiol****37****, 1107–1124 (2022).* [*https://doi.org/10.1007/s10654-022-00890-5*](https://doi.org/10.1007/s10654-022-00890-5)



*Figure S2: Predicted probabilities of fair or poor SRH by continuous age.*



*Figure S3: Directed Acyclic Graph (DAG) of the exposure variables, covariates, and outcome variable, created using Dagitty. Green-colored circles are exposures, and the blue-colored circle is the outcome. Grey-colored circles are unobserved variables, while white circles are covariates and confounders that are included in the analyses.*

A diagram of a network

AI-generated content may be incorrect.

*Table S1: Characteristics of participants excluded from analyses. Statistics are presented for all participants for which at least the outcome or one exposure included missing data.*

|  |  |
| --- | --- |
|  | N (%) or mean (SD) |
| Total number of excluded participants | 29,931 (14.6) |
| SRH  Good or better  Fair or poor | 17,127 (80.0)  4,277 (20.0) |
| Age in years | 55.8 (11.2) |
| Sex  Male  Female | 13,313 (44.5)  16,618 (55.5) |
| Marital status  Single  Married and cohabitating  Married and living separately  Divorced  Widowed | 4,785 (16.0)  18,806 (62.8)  622 (2.1)  4,069 (13.6)  1,649 (5.5) |
| Level of education  Doctorate  Master’s or equivalent  Bachelor’s or equivalent  Post-secondary, non-tertiary  Secondary level 2  Secondary level 1  Primary  Still in general education  Still in vocational training | 531 (1.8)  3,196 (10.7)  7,490 (25.0)  1,723 (5.8)  13,666 (45.7)  2,063 (6.9)  1,027 (3.4)  15 (0.1)  220 (0.7) |
| Migration background  No  Yes | 20,465 (68.4)  9,466 (31.6) |
| Nighttime transportation noise annoyance  Not at all annoyed  Slightly/moderately annoyed  Strongly/extremely annoyed | 176 (64.2)  74 (27.0)  24 (8.8) |
| Annual mean road traffic noise  Low noise (<55 dB(A))  High noise (≥ 55 dB(A)) | 22,907 (76.8)  6,907 (23.2) |
| PM2.5 | 12.6 (1.8) |
| NO2 | 24.9 (8.7) |
| Vegetation period NDVI | 0.54 (0.1) |

*Table S2: Measures of correlation or association between all variables.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | SRH1 | Age2 | Sex1 | Marital3 | Edu3 | Migr1 | Urb.3 | GISD2 | Site1 | PM2.5 | NO2 | NDVI | Noise1 |
| Age2 | 0.12\* | - |  |  |  |  |  |  |  |  |  |  |  |
| Sex1 | 0.01 | -0.02\* | - |  |  |  |  |  |  |  |  |  |  |
| Marital3 | 0.08 | **0.28^** | 0.11 | - |  |  |  |  |  |  |  |  |  |
| Education3 | 0.12 | 0.11^ | 0.11 | 0.13 | - |  |  |  |  |  |  |  |  |
| Migration1 | 0.01 | -0.07\* | 0.00 | 0.02 | 0.11 | - |  |  |  |  |  |  |  |
| Urbanization3 | 0.00 | 0.00^ | 0.00 | 0.09 | 0.13 | 0.11 | - |  |  |  |  |  |  |
| GISD2 | 0.01\* | -0.01\* | 0.01\* | 0.00^ | 0.00^ | -0.09\* | 0.01^ | - |  |  |  |  |  |
| Site1 | 0.03 | 0.00^ | 0.02 | 0.05 | 0.08 | 0.16 | **0.46** | **0.92^** | - |  |  |  |  |
| PM2.5 | 0.01\* | 0.06\* | 0.02\* | 0.00^ | 0.00^ | -0.01\* | 0.00^ | 0.03\* | 0.01^ | - |  |  |  |
| NO2 | 0.00\* | 0.02\* | 0.01\* | 0.00^ | 0.00^ | -0.01\* | 0.00^ | 0.01\* | 0.00^ | 0.44\* | - |  |  |
| NDVI | 0.00\* | 0.11\* | 0.00\* | 0.04^ | 0.02^ | -0.09\* | **0.14^** | -0.01\* | **0.17^** | -0.01\* | 0.00\* | - |  |
| Noise1 | 0.01 | -0.06\* | 0.00 | 0.10 | 0.07 | 0.07 | 0.24 | -0.04\* | 0.32 | 0.00\* | 0.00\* | -0.19\* | - |
| Annoyance3 | 0.06 | 0.00^ | 0.04 | 0.05 | 0.02 | 0.01 | 0.06 | 0.00^ | 0.08 | 0.00^ | 0.00^ | 0.02^ | 0.17 |

*Variables marked with superscript “1” are binary, with “2” are continuous, and with “3” are multi-category. Unmarked statistics represent the Cramer’s V (representing the strength of association) of the corresponding Chi-Squared statistic for the correlation between two categorical variables. Statistics marked with “\*” represent Spearman correlation coefficients between continuous and binary variables. Statistics marked with “^” represent the Eta-squared value, which explains the proportion of the variance of the dependent variable in a linear model (between continuous and multi-category variables) that is explained by the model. Statistics indicating strong correlations or associations are marked in* ***bold****.*

**Note:**  
We had initially intended to also include both degree of urbanization and the German Index of Socioeconomic Deprivation as covariates in our main model covariate set. Degree of urbanization was based on data from Eurostat for the year 2020, categorizing the municipality of residence of each participant into one of three categories: cities (densely populated areas), towns and suburbs (intermediate density areas), and rural areas (thinly populated areas). Municipality-level German Index of Socioeconomic Deprivation (GISD) scores developed by the Robert Koch Institute were also included as covariates (Kroll et al. 2017; Michalski, Reis, Tetzlaff, Herber, et al. 2022; Michalski, Reis, Tetzlaff, Nowossadeck, et al. 2022). GISD scores range from 0 to 1, with 0 representing the lowest level of deprivation and 1 representing the highest level of deprivation. In our assessment of correlation and association across all variables, we found a very strong association between GISD and study site (η² = 0.92), and a moderate correlation between the degree of urbanization and study site (Cramer’s V = 0.46) (Table S2, above). To avoid multicollinearity and over-adjustment, we therefore excluded GISD and the degree of urbanization from our models, as including the NAKO study site as a covariate is considered best practice to account for differences in recruitment and sampling (Kuss et al. 2022).

**References:**

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*Table S3: Results of two multi-exposure models stratified by study site and including 1) objectively assessed road traffic noise (reference group: low noise) and 2) nighttime transportation noise annoyance (reference group: not at all annoyed). Odds ratios and 95% confidence intervals are presented. Study sites are ordered by the proportion of participants residing in areas that are covered by the European Noise Directive (END)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | **Multi-exposure main model including objectively assessed road traffic noise** | **Multi-exposure main model including nighttime transportation noise annoyance** | |
| **Study site** | **% covered by END** | **N** | **High noise**  **OR (95% CI)** | **Slight/moderate annoyance**  **OR (95% CI)** | **Strong/extreme annoyance**  **OR (95% CI)** |
| Neubrandenburg | 6.5 | 16,419 | 1.02 (0.83; 1.25) | 1.30 (1.16; 1.46) | 1.75 (1.50; 2.04) |
| Augsburg | 36.6 | 17,570 | 0.95 (0.79; 1.15) | 1.47 (1.31; 1.65) | 1.98 (1.67; 2.34) |
| Regensburg | 39.4 | 8,639 | 0.95 (0.77; 1.17) | 1.17 (0.99; 1.38) | 1.81 (1.44; 2.27) |
| Saarbrücken | 42.7 | 8,014 | 1.20 (0.98; 1.46) | 1.44 (1.21; 1.70) | 1.48 (1.15; 1.92) |
| Kiel | 56.5 | 8,265 | 1.08 (0.88; 1.33) | 1.39 (1.16; 1.65) | 2.05 (1.62; 2.59) |
| Freiburg | 61.4 | 8,882 | 1.17 (0.97 1.40) | 1.29 (1.09; 1.52) | 1.82 (1.45; 2.28) |
| Halle | 75.6 | 8,482 | 1.09 (0.92; 1.30) | 1.13 (0.95; 1.33) | 2.06 (1.68; 2.53) |
| Berlin | 81.5 | 27,418 | 1.05 (0.96; 1.15) | 1.25 (1.14; 1.37) | 1.72 (1.54; 1.93) |
| Leipzig | 82.5 | 10,161 | 1.08 (0.93; 1.26) | 1.00 (0.86; 1.15) | 1.43 (1.21; 1.71) |
| Münster | 99.4 | 9.055 | 1.05 (0.88; 1.26) | 1.17 (0.98; 1.40) | 1.51 (1.18; 1.93) |
| Mannheim | 99.4 | 9,122 | 0.97 (0.82; 1.13) | 1.36 (1.16; 1.58) | 1.75 (1.42; 2.15) |
| Bremen | 99.4 | 8,925 | 0.88 (0.75; 1.03) | 1.26 (1.08; 1.47) | 1.56 (1.27; 1.92) |
| Düsseldorf | 99.5 | 7,180 | 1.05 (0.88; 1.26) | 1.35 (1.13; 1.62) | 1.48 (1.18; 1.86) |
| Hannover | 99.6 | 8,228 | 1.34 (1.13; 1.58) | 1.22 (1.03; 1.46) | 1.70 (1.36; 2.12) |
| Hamburg | 99.8 | 9,199 | 1.11 (0.90; 1.38) | 1.32 (1.13; 1.55) | 1.69 (1.39; 2.06) |
| Essen | 99.8 | 9,397 | 1.02 (0.89; 1.16) | 1.37 (1.19; 1.57) | 1.89 (1.58; 2.27) |

Note: All models were adjusted for age, marital status, level of education, migration background, and study site. PM2.5, NO2, and vegetation period NDVI were also included as co-exposures.

*Table S4: Complete results of all three multi-exposure main models stratified by sex. Odds ratios and 95% confidence intervals are presented.*

|  |  |  |
| --- | --- | --- |
| **Noise variables and co-exposures** | **Males**  Odds ratios and 95% confidence intervals | **Females**  Odds ratios and 95% confidence intervals |
| Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.04 (0.98, 1.11)  1.02 (0.99; 1.05)  1.03 (0.99; 1.06)  1.07 (1.03; 1.11) | REF  1.07 (1.01, 1.13)  1.04 (1.01; 1.07)  0.97 (0.94; 1.00)  1.04 (1.00; 1.08) |
| Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.30 (1.24, 1.37)  1.72 (1.60, 1.84)  1.02 (0.99; 1.05)  1.02 (0.99; 1.06)  1.05 (1.01; 1.09) | REF  1.25 (1.19, 1.31)  1.74 (1.63, 1.85)  1.04 (1.01; 1.07)  0.97 (0.93; 1.00)  1.02 (0.98; 1.06) |
| Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  0.97 (0.92, 1.03)  REF  1.30 (1.24, 1.37)  1.72 (1.60, 1.85)  1.02 (0.99; 1.05)  1.02 (0.99; 1.06)  1.05 (1.01; 1.09) | REF  1.00 (0.94, 1.05)  REF  1.25 (1.19, 1.32)  1.74 (1.63, 1.85)  1.04 (1.01; 1.07)  0.97 (0.93; 1.00)  1.02 (0.98; 1.06) |

Note: All models were adjusted for age, marital status, level of education, migration background, and study site.

Table S5: Results of three multi-exposure main models that also include multiplicative interaction terms for sex in combination with both noise variables. Odds ratios and 95% confidence intervals are shown.

|  |  |
| --- | --- |
| Model | ORs and 95% CIs |
| Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  High noise (≥ 55 dB(A)) x Female  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.04 (0.98, 1.10)  1.04 (0.96, 1.12)  1.03 (1.01; 1.05)  1.00 (0.97; 1.02)  1.05 (1.03; 1.08) |
| Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Slightly or moderately annoyed x Female  Strongly or extremely annoyed x Female  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.29 (1.23, 1.36)  1.71 (1.59, 1.83)  0.97 (0.90, 1.04)  1.03 (0.93, 1.13)  1.03 (1.01; 1.05)  0.99 (0.97; 1.02)  1.03 (1.00; 1.06) |
| Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  High noise (≥ 55 dB(A)) x Female  Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Slightly or moderately annoyed x Female  Strongly or extremely annoyed x Female  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  0.97 (0.92, 1.03)  1.03 (0.96, 1.12)  REF  1.30 (1.23, 1.36)  1.72 (1.60, 1.84)  0.97 (0.90, 1.04)  1.02 (0.93, 1.12)  1.03 (1.01; 1.05)  0.99 (0.97; 1.02)  1.03 (1.01; 1.06) |

Note: All models were adjusted for age, marital status, level of education, migration background, and study site.

*Table S6: Full results of the path analysis, including direct, indirect, and total effects. Coefficients are presented as unstandardized probit estimates, representing changes in the underlying latent response variables, with 95% confidence intervals. Model fit statistics are reported at the bottom of the table.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Effect type** | **Exposure** | **Mediator** | **Outcome** | **Coefficient (b) (95% CI)** |
| a | Direct | Annual mean road traffic noise ≥ 55 dB(A) | - | Nighttime transportation noise annoyance – one category increase on 5-point Likert scale | 0.43 (0.41; 0.44) |
| b | Direct | Nighttime transportation noise annoyance – one category increase on 5-point Likert scale | - | Poor SRH | 0.12 (0.11; 0.13) |
| c’ | Direct | Annual mean road traffic noise ≥ 55 dB(A) | - | Poor SRH | -0.02 (-0.04; 0.00) |
| a x b | Indirect | Annual mean road traffic noise ≥ 55 dB(A) | Nighttime transportation noise annoyance – one category increase on 5-point Likert scale | Poor SRH | 0.05 (0.045; 0.054) |
| c’ + (a x b) | Total | Annual mean road traffic noise ≥ 55 dB(A) | Nighttime transportation noise annoyance – one category increase on 5-point Likert scale  + direct effect | Poor SRH | 0.03 (0.01; 0.05) |
|  | Model fit\* | χ²(0)=0.00, CFI=1.00, TLI=1.00, RMSEA=0.000, SRMR=0.000 | | | |

Notes:   
Analyses were adjusted for age, marital status, level of education, migration background, study site. PM2.5, NO2, and vegetation period NDVI were also included as co-exposures.   
\* Just-identified DWLS model (df=0); fit indices reflect saturation (non-testable).

*Table S7: Results of sensitivity analyses only including participants who have lived at least five years in their current residence. Results are presented as odds ratios and 95% confidence intervals.*

|  |  |
| --- | --- |
| Model | At least 5 years at residence  (N = 128,843) |
| *Multi-exposure main model*  Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.04 (0.99; 1.09)  1.01 (0.99; 1.04)  1.00 (0.97; 1.03)  1.07 (1.04; 1.10) |
| *Multi-exposure main model*  Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.30 (1.24; 1.35)  1.72 (1.63; 1.82)  1.01 (0.99; 1.04)  1.00 (0.97; 1.02)  1.05 (1.02; 1.08) |

Note: Analyses were adjusted for age, sex, marital status, education, migration background, and study site.

*Table S8: Results of sensitivity analyses only including participants who live in areas where noise measurements are mandated by the END. Results are presented as odds ratios and 95% confidence intervals.*

|  |  |
| --- | --- |
| Model | Participants missing objective noise measurements are dropped (N = 122,442) |
| *Multi-exposure main model*  Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  1.06 (1.01; 1.10)  1.05 (1.02; 1.07)  1.00 (0.97; 1.03)  1.06 (1.03; 1.10) |
| *Multi-exposure main model*  Annual mean road traffic noise  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A))  Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed  Environmental co-exposures  PM2.5  NO2  Vegetation period NDVI | REF  0.99 (0.95; 1.03)  REF  1.26 (1.21; 1.31)  1.72 (1.63; 1.82)  1.05 (1.02; 1.07)  1.00 (0.97; 1.03)  1.05 (1.01; 1.08) |

Note: Analyses were adjusted for age, sex, marital status, education, migration background, and study site.

*Table S9: Results of sensitivity analysis using alternative exposure variables. Results are presented as odds ratios and 95% confidence intervals.*

|  |  |
| --- | --- |
| Model | Results for alternative variables |
| *Multi-exposure main model*  Annual mean road traffic noise (Lden)  < 55 dB(A)  ≥ 55 dB(A) and < 60 dB(A)  ≥ 60 dB(A) and < 65 dB(A)  ≥ 65 dB(A) and < 70 dB(A)  ≥ 70 dB(A) and < 75 dB(A)  ≥ 75 dB(A) | REF  1.08 (1.02; 1.14)  1.06 (0.99; 1.13)  0.99 (0.92; 1.08)  1.07 (0.95; 1.19)  1.17 (0.92; 1.48) |
| *Multi-exposure main model*  Nighttime transportation noise annoyance  Not at all or slightly annoyed  Moderately or strongly annoyed  Extremely annoyed | REF  1.42 (1.36; 1.48)  1.75 (1.64; 1.86) |

Note: Analyses were adjusted for age, sex, marital status, education, migration background, and study site. PM2.5, NO2, and vegetation period NDVI were also included as co-exposures.

*Table S10: Results of sensitivity analysis using multinomial logistic regression and an alternative 3-category outcome variable. Results are presented as relative risk ratios and 95% confidence intervals.*

|  |  |  |
| --- | --- | --- |
| **Noise variable** | **Good SRH**  **(reference: Excellent or very good SRH)** | **Fair or poor SRH**  **(reference: Excellent or very good SRH)** |
| Annual mean road traffic noise (Lden)  Low noise (< 55 dB(A))  High noise (≥ 55 dB(A)) | REF  1.02 (0.99; 1.05) | REF  1.07 (1.03, 1.12) |
| Nighttime transportation noise annoyance  Not at all annoyed  Slightly or moderately annoyed  Strongly or extremely annoyed | REF  1.24 (1.21, 1.27)  1.32 (1.27, 1.37) | REF  1.47 (1.42, 1.53)  2.10 (1.99, 2.21) |

Note: Analyses were adjusted for age, sex, marital status, education, migration background, and study site. PM2.5, NO2, and vegetation period NDVI were also included as co-exposures.

*Table S11: Results of sensitivity analysis assessing additive interaction through the calculation of relative excess risk due to interaction (RERI) using a binary annoyance variable and the binary road traffic noise variable. Results are presented as Excess Risk Ratios (ERR), RERI, attributable proportion, and synergy index, and their 95% confidence intervals.*

|  |  |
| --- | --- |
| **Metric** | **Result** |
| *Excess risk ratios (ERRs)*  Low noise + any annoyance  High noise + no annoyance  High noise + any annoyance | 0.41 (0.36; 0.47)  0.03 (-0.03; 0.09)  0.39 (0.32; 0.46) |
| RERI  Attributable proportion  Synergy index | -0.06 (-0.15; 0.03)  -0.04 (-0.11; 0.03)  0.87 (0.70; 1.08) |

Note: Analyses were adjusted for age, sex, marital status, education, migration background, and study site. PM2.5, NO2, and vegetation period NDVI were also included as co-exposures.