Residential road traffic noise and general mental health in youth: The role of noise annoyance, neighborhood restorative quality, physical activity, and social cohesion as potential mediators

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ABSTRACT

Given the ubiquitous nature of both noise pollution and mental disorders, their alleged association has not escaped the spotlight of public health research. The effect of traffic noise on mental health is probably mediated by other factors, which have not been elucidated sufficiently. Herein, we aimed to disentangle the pathways linking road traffic noise to general mental health in Bulgarian youth, with a focus on several candidate mediators – noise annoyance, perceived restorative quality of the living environment, physical activity, and neighborhood social cohesion. A cross-sectional sample was collected in October – December 2016 in the city of Plovdiv, Bulgaria. It consisted of 399 students aged 15–25 years, recruited from two high schools and three universities. Road traffic noise exposure (L_{den}) was derived from the strategic noise map of Plovdiv. Mental health was measured with the 12-item form of the General Health Questionnaire (GHQ-12). Noise annoyance, perceived restorative quality of the living environment, commuting and leisure time physical activity, and neighborhood social cohesion were assessed using validated questionnaires. Analyses were based on linear regression mediation models and a structural equation modeling (SEM) to account for the hypothesized interdependencies between candidate mediators. Results showed that higher noise exposure was associated with worse mental health only indirectly. More specifically, tests of the single and parallel mediation models indicated independent indirect paths through noise annoyance, social cohesion, and physical activity. In addition, the SEM revealed that more noise annoyance was associated with less social cohesion, and in turn with worse mental health; noise annoyance was also associated with lower neighborhood restorative quality, thereby with less social cohesion and physical activity, and in turn with worse mental health. However, causality could not be established. Further research is warranted to expand our still limited understanding of these person-environment interactions.

1. Introduction

Approximately 30% of the population has experienced a common mental disorder at some point in their life (Steel et al., 2014). Poor mental health accounts for 13% of disability-adjusted life-years of the global burden of disease (Vigo et al., 2016), which is substantial in young age (Whiteford et al., 2013), when most disorders begin (Patel et al., 2007). In Europe, 47 million residents of major agglomerations are exposed to hazardous nighttime noise ≥ 55 dB, 21 million are highly noise-annoyed, and 14 million are severely sleep-disturbed

(Houthuijs et al., 2015). Given the ubiquitous nature of both noise pollution and mental ill-health, their potential association has not escaped the spotlight of public health research. Traffic noise has been linked to self-reported mental health and psychological symptoms (Van Kamp and Davies, 2008) and might be considered detrimental in young age due to the still developing and immature coping mechanisms of children (van Kamp and Davies, 2013). However, compared to other, biomedical outcomes (Basner et al., 2014), mental health has received modest attention (Van Kamp and Davies, 2008). In their review of the pertinent literature, Stansfeld and Clark (2015) concluded that the

evidence base in children was only sufficient for the association between traffic noise and annoyance, stress (increase in catecholamines), and lower cognitive performance, but it was limited regarding well-being, hyperactivity, anxiety and depression.

The effect of traffic noise on mental health is probably mediated by other factors, which have not been elucidated sufficiently (Van Kamp and Davies, 2008). Noise annoyance is a well-documented mediator (van Kamp et al., 2013), being a correlate of both traffic noise (Guski and Schuemer, 2016) and psychological symptoms in children (Dreger et al., 2015; Stansfeld and Clark, 2015). Still, its interaction with other indirect pathways linking noise to mental health has not been formally tested and remains poorly understood. Traffic noise may act as a constraint on psychological restoration and render the residential environment unappealing as a venue for outdoor activities (von Lindern et al., 2016), thereby impeding physical activity (cf. Hartig, 2008; Barton et al., 2016) and diminishing the sense of community (cf. Kuo et al., 1998). Empirical research lends some support to this hypothesis. For example, Foraster et al. (2016) found negative associations between noise annoyance and physical activity levels, and traffic noise might affect physical activity through other, still not confirmed pathways such as sleep deprivation and stress (Roswall et al., 2017). There is also evidence that traffic noise may negatively impinge on neighborhood social cohesion (e.g., reduce social contacts, willingness to help others, processing of social cues, place attachment) (Cohen and Spacapan, 1984; Honold et al., 2014; Jones et al., 1981). In turn, low social cohesion (Cramm et al., 2013; Fone et al., 2014; Erdem et al., 2015) and sedentary behavior (Biddle and Asare, 2011) may be detrimental for mental health.

In this study, we surveyed a sample of Bulgarians aged 15–25 years. To our knowledge, no research on the subject matter has been done in youth. We aimed to disentangle the pathways linking road traffic noise to general mental health, with a focus on several candidate mediators – noise annoyance, perceived restorative quality of the living environment, physical activity, and neighborhood social cohesion. To achieve this, first we assumed that the candidate mediators worked independently (as single or parallel mediators); then, we specified a more complex theoretically-indicated model taking into account the interdependencies between the mediators.

2. Material and methods

2.1. Study design

This secondary research is based on a cross-sectional sample collected in October – December 2016 in the city of Plovdiv. Plovdiv is the second largest city in Bulgaria, with a population of 341,625 and a territory of around 102 km^2 (See Supplementary Fig. S1 for location of the study area). Originally, we collected data to examine the association between urban greenspace and quality of life in youth. The source population consisted of students aged 15–25 years, recruited from two polytechnic high schools and three universities (one medical, one polytechnic, and one general). Trained members of the research team informed the students about the objectives of the study and asked them to take the questionnaire home and to return it within a week.

We included only students who resided in Plovdiv for at least one year. Supplementary Fig. S2 depicts the sampling process. One hundred fifty questionnaires were distributed in each of the six institutions we initially contacted, but one of the schools declined participation due to confidentiality concerns. Overall, 688 students participated (91.73%). After excluding questionnaires with low quality (not completed or with implausible answers) or no addresses (as addresses were needed for noise exposure assignment), the analysis sample comprised 399 participants aged 15–25 years. Participants who reported their address were somewhat older (17.89 ± 2.27 vs 17.38 ± 2.13), reported less social cohesion (28.83 ± 8.67 vs 30.67 ± 9.39), and worse mental health (10.80 ± 6.01 vs 9.06 ± 5.76) compared to those who did not report

their address. Given the high number of scams and burglaries in Bulgarian cities, participants were apprehensive about revealing where they lived, especially since we also asked them about family income, time spent at home, and orientation of rooms.

The study was approved by the school directors, the Regional Inspectorate of Education in Plovdiv, and the Ethics Committee at the Medical University of Plovdiv. Participants or their parents have signed informed consent forms. No incentives were offered.

2.2. Residential road traffic noise

Geocoding of the addresses was conducted with the help of *ggmap* package in the program R 3.2.4 (R Foundation for Statistical Computing, Vienna, Austria) (Supplementary Fig. S3). As participants living in one of the neighborhoods of Plovdiv did not report the street number but rather the number of their residential block, the automatic geocoding was incorrect. This subset of addresses (n = 29, 7.3%) was manually geocoded with http://www.bgmaps.com/map/plovdiv and checked with Google Street View.

Road traffic noise exposure was derived from the strategic noise map of Plovdiv, prepared according to the European Noise Directive 2002/49/EC. Municipality consultants made the noise calculations with LimA v. 5 according to the French national method "NMPB-Routes-96" and the standard "XPS 31-133". The model was calibrated through field measurements according to ISO 1996-1/2005 and ISO 1996-2/1987 (Spectri, 2009; Dzhambov et al., 2014). The noise map has a resolution of 10 × 10 m (4 m above the ground level) and contains exposure data for the 5-dB contours in the range 50–80 dB. Thus, one-unit increase in the day-evening-night noise level (L$_{den}$) variable corresponds to 5 dB.

We overlaid the map of geocoded addresses with the noise map. Each address was also visually inspected using Google Street View. L$_{den}$ was determined at the living room façade (participants were asked to report the orientation of rooms in their dwelling). The exposure of some buildings located on side streets (the data from the noise map was less accurate for those) was manually corrected based on expert judgement and principles of sound propagation – an approach that has been used previously to improve exposure assessment and account for the limitations of noise mapping (Babisch et al., 2006).

2.3. General mental health

General mental health (henceforward referred to simply as "mental health") during "the past few weeks" was measured with the General Health Questionnaire (GHQ) (Goldberg and Blackwell, 1970). We used the Bulgarian translation of the 12-item form of the questionnaire (GHQ-12) (Georgieva, 2010; Mutafova and Maleshkov, 2001). GHQ-12 is a valid and reliable measure of common psychiatric disorders (i.e., depression, anxiety) in youth (Tait et al., 2003; Baksheev et al., 2011). GHQ summary score is usually dichotomized, but since this comes at the expense of lower statistical power, we used it as a continuous variable instead. Example items read: "*Have you recently lost much sleep over worry*?", "*Have you recently been feeling content and happy*?", "*Do you think you are playing a useful part in life*?", "*Have you recently been losing confidence in yourself*?". Each item was scored from "0" to "3" (e.g., response options to the first example question: "0 = No", "1 = No more than usual", "2 = More than usual", "3 = Much more than usual"), with a higher summary score indicating worse mental health. Cronbach's α for the whole GHQ-12 was 0.85.

2.4. Candidate mediators

The following candidate mediators were considered: road traffic noise annoyance, restorative quality of the living environment, physical activity, and neighborhood social cohesion. This choice was guided by theory and the variables available in the dataset.

Noise annoyance was defined as a "multifaceted concept that chiefly