Health & Place 70 (2021) 102619

Contents lists available at ScienceDirect

Health and Place

journal homepage: www.elsevier.com/locate/healthplace

Short Communication

Population density predicts youth's physical activity changes during Covid-19 – Results from the MoMo study

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ARTICLE INFO

Keywords:
Children
Adolescents
Rural
Urban
Lockdown
Built environment

ABSTRACT

Children in Germany showed positive physical activity changes during the first Covid-19 lockdown in April 2020, but it is unclear how the changes relate to population density, which we investigated in a longitudinal sample of 1711 youth (4–17 years). For each ten citizens more per km^2, less positive physical activity changes were observed. For example, a child living in an area with 100 citizens/km^2 increased daily life physical activity by 44.50 min/day, whereas a child living in an area with 3000 citizens/km^2 only engaged in an additional 9.70 min/day. Policymakers should ensure that youth in densely populated areas have access to physical activity opportunities during the pandemic.

1. Introduction

During Germany's first Covid-19 lockdown from March to May 2020, important institutions for youth including kindergarten, schools, and leisure facilities such as sports clubs and playgrounds, were closed to reduce the risk of infection. A recent review indicates that these measures decreased physical activity across all age groups (Stockwell et al., 2021), which is problematic due to the multitude of physical activity's physical and mental health benefits (Poitras et al., 2016). However, it is not well understood how youth's Covid-19 related physical activity changes relate to the built environment. In general, environmental characteristics, including infrastructure for walking and cycling, short distances to facilities, better walkability, mixed land use, as well as park and playground equipment relate positively to youth's physical activity (Nordbø et al., 2020; Smith et al., 2017). Several of those features are commonly more prevalent in densely populated areas (e.g., infrastructure for walking and cycling, short distance to facilities), promoting theoretically more physical activity in densely populated areas (Sallis et al., 2016a). Thus, population density has been used as a proxy variable to assess associations between the built environment and physical activity (e.g., Hino and Asami, 2021). Yet, a systematic review including studies before Covid-19 reported inconsistent associations between population density and physical activity in children and adolescents, with most studies reporting no associations (Nordbø et al., 2020). However, the association between population density and physical activity may be different during a pandemic where physical distancing is essential to mitigate the spread of a virus, with densely populated areas having a higher potential for human contact and virus transmission. In addition, amenities in densely populated areas (e.g., short walkable/cyclable distances) that allow engagement in daily life physical activity together with the closure of playgrounds may have reduced the potential for physical activity. During Covid-19, we are only aware of one study that investigated the association between physical activity assessed via step counts and population density in adults (Hino and Asami, 2021). The study showed that step counts decreased more in neighborhoods with higher population density (Hino and Asami, 2021). In adolescents, one study showed that physical activity decreased stronger in urban compared to rural areas (Zenic et al., 2020), however, the study was not nationally representative, did not include children, and the urban-rural dichotomy was only a rough classification of environmental characteristics. In Germany, Covid-19 related physical activity changes in children and adolescents during the first lockdown in

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https://doi.org/10.1016/j.healthplace.2021.102619
Received 24 February 2021; Received in revised form 29 June 2021; Accepted 29 June 2021
Available online 3 July 2021

April 2020 have already been investigated in a longitudinal sample, showing that sports-related physical activity decreased, while daily life physical activity and the number of active days increased (Schmidt et al., 2020a), but it is unknown how those changes relate to population density, which we investigated in our study. We hypothesize that participants living in areas with higher population density demonstrate less positive physical activity changes.

2. Materials and methods

2.1. Participants & procedures

Data was derived from the representative Motorik-Modul study (MoMo), which applies a cohort-sequence design to assess physical activity, physical fitness, and health parameters in children and adolescents aged 4–17 years. Detailed study information is elsewhere available (Woll et al., 2021). For this study, data from Wave 3 (August 2018–March 2020) was used, with Wave 3 being incomplete due to the Covid-19 pandemic. Preceding the lockdown, participants were invited to examination rooms within proximity to their homes and answered the MoMo physical activity questionnaire on laptops. Participants that had taken part in the study before Covid-19 were asked to fill in the questionnaire again online at the end of April 2020, which was during Germany's first Covid-19 lockdown. For details see Schmidt et al. (2020a). Study participation was voluntary, and participants' guardians provided written consent. The study was conducted in accordance with the Declaration of Helsinki. Ethics approval was obtained by the Charité Universitätsmedizin Berlin ethics committee, by the University of Konstanz, and by the ethics committee of the Karlsruhe Institute of Technology. The Federal Commissioner for Data Protection and Freedom of Information was informed about the study and approved it.

2.2. Measures

Sociodemographic data were only assessed before Covid-19. In addition to age and sex, participants' parents were asked for their highest educational degree and were classified as low, medium, and high education based on the CASMIN-classification (Brauns et al., 2003). Children's height and weight were assessed by trained research staff. The body-mass-index (BMI) was calculated and participants were categorized into underweight, normal weight, overweight, and obese based on the cut-off points of the International Obesity Task Force IOTF (Cole et al., 2000). Population density data from 2018 was retrieved from the German Federal Statistics Office's community information system, comprising population density data and geographical center coordinates of communities that are politically independent as well as their sub-communities (destatis, 2018). Using ArcGIS Pro (version 2.8.0), we calculated the closest (sub-)community to the participant's home address and matched the population density data of the corresponding community with the participant.

Physical activity was assessed via the MoMo physical activity questionnaire, consisting of 28 items and assessing sports-related physical activity (including physical activity in sports clubs, leisure sports, and school physical activity) and daily life physical activity (including free outdoor play, gardening, household work, walking, and cycling) (Jekauc et al., 2013). Both sports-related and daily life physical activity components were combined into one index, respectively. In addition, children were asked to report how many days they are physically active for at least 60 min with moderate to vigorous intensity in a typical week prior and during the lockdown, which was reflecting the physical activity guidelines of the World Health Organization when the study was set up (WHO, 2010). Sufficient reliability and validity of the questionnaire have been reported (Jekauc et al., 2013).

2.3. Statistical analysis

Data was analyzed with the software IBM SPSS 27. First, we explored differences between study completers and non-completers using independent sample *t*-test and chi-square tests. As our data had a two-level structure with participants nested within communities, we used a multilevel random intercept model to account for correlation in our data which may otherwise bias standard error estimates. We calculated change scores for the physical activity variables by subtracting pre-Covid physical activity from during-Covid physical activity variables. We centered population density and age on the sample's mean. Following previous procedures, we divided population density by ten so that a one-unit increase represents ten more people within one square kilometer (Beenackers et al., 2018). Sex, parental education, age, and BMI were considered as demographical and individual covariates based on previous findings (Fernández-Alvira et al., 2013; Sallis et al., 2016b; Schmidt et al., 2020a; Sterdt et al., 2014) as well as the respective baseline level variable of our outcome of interest (centered on the sample's mean). We then set up a multilevel model which only included population density and the physical activity baseline variable as predictors. In the next step, we set up a model which included the covariates sex, age, BMI, parental education, and the respective physical activity baseline. As previous research has shown that associations between population density and physical activity show distinct associations by gender and age (Kowaleski-Jones et al., 2017), we additionally calculated interactions between population density and sex as well as population density and age. Finally, we re-ran the analyses excluding outliers +/-2 standard deviations around the mean to explore the robustness of our results.

3. Results

A total of 2843 youth participated in the pre-Covid-19 study, and 1711 of those participated in the assessment during the lockdown, forming the longitudinal sample (M_{age}=10.36 [SD=4.04] years, female=49.8%; healthy weight=76.8%). A detailed description of our sample including baseline physical activity levels can be found in *supplement S1*. Sociodemographic differences between study completers and non-completers were observed regarding sex (p=0.049, ϕ=0.04), BMI (p<0.001, V=0.10), and parental education (p<0.001, V=0.09), but not regarding age (p>0.05). A more detailed description of study completers vs. non-completers is available elsewhere (Wunsch et al., 2021).

The inclusion of the covariates improved the model fit based on Akaike's Information Criterion. We report the results of the multi-level model analysis including covariates in Table 1, the model without covariates can be found in s*upplement S2*. A typical child increased the number of active days from pre-Covid to during-Covid by 0.47 days per week, engaged in 68.33 fewer minutes of sports-related physical activity per week, and engaged in 37.74 more minutes of daily life physical activity. Increased population density was associated with less positive changes regarding active days per week and daily life physical activity. Demonstrating this on an example: A typical child living in an area with a population density of 100 citizens/km^2 which, for example, is the population density of the small town Müssen, increased the number of active days per week by 0.58 and daily life physical activity by 44.50 min per day. In contrast, a typical child living in a densely populated area with 3000 citizens/km^{2,} which is roughly the population density of Frankfurt, did not increase the number of active days per week, while it only engaged in an additional 9.70 min of daily life physical activity per day. No association with sports-related physical activity was observed.

Neither interactions between population density and sex nor population density and age were observed. All results remained stable if outliers (+/- 2 SD around the mean) were excluded.

Table 1
Multilevel models with population density predicting physical activity changes.

	Δ Days active (days/week)			Δ Sports-related physical activity (minutes/week)			Δ Daily life physical activity (minutes/day)		
	B	SE	*p*	B	SE	*p*	B	SE	*p*
Fixed effects									
Intercept	0.47	0.07	<0.001	-68.33	10.32	<0.001	37.74	3.94	<0.001
Population density	-0.002	0.00	<0.001	0.07	0.09	0.444	-0.12	0.03	<0.001
Age	-0.13	0.01	<0.001	3.92	1.70	0.021	-6.95	0.66	<0.001
Sex[a]	0.04	0.09	0.648	3.66	12.69	0.773	1.07	5.07	0.834
Parental education[b]									
Low	-0.23	0.26	0.386	-67.67	38.94	0.082	29.83	15.16	0.049
High	-0.36	0.24	0.136	-76.14	33.61	0.024	-37.06	13.92	0.008
BMI[c]									
Underweight	-0.16	0.15	0.283	-12.27	20.59	0.552	-12.29	8.31	0.140
Overweight	-0.32	0.15	0.031	-27.81	21.25	0.191	-0.24	8.49	0.977
Obese	0.06	0.29	0.849	-42.28	41.53	0.309	4.72	17.21	0.784
Baseline level	-0.63	0.03	<0.001	-0.60	0.04	<0.001	-0.48	0.04	<0.001
Random effects									
Intercept	0.07	0.05	0.124	1627.61	925.24	0.079	18.98	118.93	0.873

Please note: population density, age, and baseline levels were grand-mean centered.
[a] reference category: female.
[b] reference category: parents with medium education.
[c] reference category: normal weight.

4. Discussion

Our study showed that children and adolescents residing in densely populated areas showed less favorable physical activity changes than children and adolescents living in sparsely populated areas, which is in line with our hypothesis.

Our results are supported by previous findings showing that unfavorable changes in adult's physical activity were stronger in densely populated areas (Hino and Asami, 2021), while adolescent's physical activity decreased stronger in urban than in rural areas (Zenic et al., 2020). However, in contrast to the two previous studies, children and adolescents living in densely populated areas did not decrease their physical activity, but only showed less favorable or no changes. A reason for this difference could be that our study comprised a nationwide sample with large variations in population density, whereas two former studies concentrated on one region or city (Hino and Asami, 2021; Zenic et al., 2020), limiting generalizability.

Regarding our findings in the context of the lockdown in Germany, the German lockdown restrictions allowed leaving the house for physical activity, which may have prevented a physical activity decline in youth living in densely populated areas. Specifically, our analysis revealed that youth living in more densely populated areas showed no or fewer increases in daily life physical activity, while sports-related physical activity was not influenced by population density. In Germany, all organized sports institutions (e.g., sports clubs), which are a major contributor to youth's sports-related physical activity (Schmidt et al., 2020b), had to close as part of the lockdown. This probably explains why sports-related physical activity is unrelated to population density as lockdown measures were the same across all areas in Germany.

In contrast, there are several explanations why population density has influenced changes in daily life physical activity. In non-Covid-19 times, densely populated areas benefit from short distances to facilities (e.g., schools, shops) as well as leisure time infrastructure (e.g., playgrounds) in terms of physical activity (Sallis et al., 2016a). As all those facilities were closed during the lockdown, walking or cycling to those facilities was of no use.

Furthermore, our analysis showed that daily life physical activity changes were driven by engagement in outdoor play. In less densely populated areas, children may have had multiple opportunities to engage in outdoor play, such as playing on the street, in a yard, or other open spaces. In more densely populated areas, outdoor play opportunities may have been limited due to the disadvantages of densely populated areas, such as traffic exposure and limited physical activity space (Davison and Lawson, 2006; Taylor et al., 2018). The closure of playgrounds as an important physical activity opportunity (Klinker et al., 2014) may have exacerbated this problem.

Finally, fear of Covid-19 in more densely populated areas may have also contributed to this relationship. In children and adolescents, parental involvement in their children's physical activity, such as co-participation, supervision, and encouragement, has been related to physical activity (Beets et al., 2010; Rhodes et al., 2020), which also applies during Covid-19 (Moore et al., 2020). However, adults in Germany living in metropolitan areas with higher population density showed elevated fear levels of Covid-19 compared to adults living in rural areas (with lower population density), which may be due to the fear of getting into larger crowds and being exposed to the virus (Schweda et al., 2021). Thus, in the context of our study, parents in densely populated areas may have shown less support for their children's physical activity out of fear of Covid-19, which may have contributed to no or little changes in daily life physical activity.

There are some limitations of our study that should be considered. All physical activity data is based on self-report and thus prone to recall bias. Since we do not have a control group, we can only theoretically assume a causal relationship between the lockdown and physical activity changes. As our study was interrupted by Covid-19, representativeness in the pre Covid-19 sample is mitigated. Finally, during the follow-up in April 2020, the weather was untypically warm, which may have influenced the physical activity changes. However, as reported previously, physical activity changes remained stable if only baseline participants from April 2019 were considered (Schmidt et al., 2020a).

These limitations notwithstanding, our study sheds light on the role of population density in Covid-19 related physical activity changes. Policymakers should ensure access to places that provide physical activity opportunities for youth living in densely populated areas in a lockdown situation. For example, one solution could be to temporarily close down streets for road traffic, which has been related to increased physical activity and play in youth (Umstattd Meyer et al., 2019) as well as in the general population (Pandit et al., 2020), thus contributing to youth's health, especially during a pandemic.

Data availability statement

The datasets generated and analyzed during the current study are not publicly available due to the strict ethical standards required by the Federal Office for the Protection of Data with which study investigators are obliged to comply but are available from the corresponding author on reasonable request.

Declaration of competing interest

None.

Acknowledgement/Funding

This work was supported by the by the Federal Ministry of Education and Research (funding reference number: 01ER1503) within the research program 'long-term studies' in public health research and has been developed within the Motorik-Modul Longitudinal Study (MoMo) (2009 – 2021): Physical fitness and physical activity as determinants of health development in children and adolescents.

Carina Nigg receives funding of the German Academic Scholarship Foundation (Studienstiftung des deutschen Volkes).

The funding sources were not involved in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

The authors would like to thank Matthias Limberger and Dr. Markus Reichert for their input regarding the statistical analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2021.102619.

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