Preprint

This is the authors' version before the revision

A Cohort Analysis of the Correlates of Body Mass Index of Children9 to 12 Years in eight European Cities before and during COVID-19

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Abstract

Background

Obesity has risen as a global disease, particularly among children. Although, the high prevalence of obesity among schoolchildren has been reported in the different parts of the world, the socioeconomic and built environment correlates of the obesity among schoolchildren are not clear in the different countries, particularly in CPVID-19 pandemic.

Methods

The objective of the current paper is to determine the correlates of the Body Mass Index (BMI) among schoolchildren in the pandemic times and also to compare the changes of BMI before and after COVID-19 in eight cities of six European countries. An Ordinary Least Square regression model was employed to determine the relationship of BMI with socioeconomic and built environment features.

Results

The BMI of schoolchildren has correlation with age, income, the number of intersections to school, commuting distance, street connectivity, accessibility to public transport, and open/green space in eight European cities. The BMI of children in Italy and Croatia has decreased during the COVID-19 times, while some increases in BMI have been documented in Turkey and Greece.

Conclusion

The built environment characteristics of areas are associated with the BMI of children aged 9-12 in COVID-19 pandemic. There are no significant changes of BMI schoolchildren during COVID-19 in six European countries.

Keywords: Obesity, schoolchildren, BMI, built environment characteristics, European cities, COVID-19.

1. Introduction

The benefits of physical activity have been indicated in adults with a negative association between physical activity and disease in the existing literature (Ridgers, Stratton, & Fairclough, 2006). Schools can contribute to physical activity by suitable settings for intervention programmes for promoting physical activity and attending school can provide opportunities for active commuting (walking and cycling) for children. Attending preschool is a significant variable for vigorous physical activity among American preschool-aged children, particularly boys (Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004). Socioeconomic profiles of children and perceptions of families play an important role in the level of children's physical activity. Ridgers et al. (2006) discussed that the level of physical activity has increased by physical education and playtime during the school day. However, boys participate in playtime and sports more than girls do (Ridgers et al., 2006). In another study on American children's weight, perceptions and attitudes of children and parents have important influence on physical health of children. For example, there is an association between negative attitudes of parents toward sports and report reduced physical activity levels and obesity in children (Faith, Leone, Ayers, Heo, & Pietrobelli, 2002). Also, the school environment is one of important issue regarding physical activity. A novel school environment named "The Neighborhood" is a designed concept for school to encourage an active learning space. While the children were in school and in the classroom, they were moving in dynamic and fun space that promoted physical activity (Lanningham-Foster et al., 2008). The results of this study regarding impact of school environment on physical activity showed that children had a higher level of physical activity and movement while attending school in the activity-permissive environment compared to the amount of activities of children that went to the traditional school environments (Lanningham-Foster et al., 2008). Active mobility to school is potential way for increasing physical activity in children and reducing disease such as obesity among school-aged children and adolescent. A study on the relationship between active travel and physical activity in children aged 11-12 years in the U.K. showed the active journey to and from schools is a significant correlate for moderate-to-vigorous physical activity (MVPA) (Southward, Page, Wheeler, & Cooper, 2012). Although, the overall association between active mobility and Body Mass Index (BMI) are not consistent, positive correlation between active transportation and BMI were proved for some contexts such as the British primary schoolchildren (McDonald, 2007). Regarding active travel, the built environment characteristics of neighborhoods are important factors to promote walking and biking in traveling to schools. An investigation on the association of physical activity and active travel on American students showed that boys who walked to school have higher level of physical activity after school in comparison with the girls (Cooper, Page, Foster, & Qahwaji, 2003). According to the study on impacts of active transportation on physical activities, boys selected walking and biking as the dominant of mode choice if the school neighborhood had high connectivity and low traffic more than girls did (Trapp et al., 2012).

Coronavirus disease 2019 (COVID-19) has infected the lifestyle of millions worldwide. One and half billion children and adolescents have been changed their lifestyle by remote learning following school closures (Bates et al., 2020). In addition to school closure, social distancing, quarantining has increased sedentary behavior among children and adolescents. Physical activity and mental health of children and adolescents are linked to healthy behaviors including cardiometabolic health, motor skill improvement, psychological health, social interaction, bone density, and BMI. COVID-19 restriction including social distancing and remote learning caused reducing in physical education, sports, and physical activities related to school such as active mobility. Secondary behavior is determined as risk factor for cardiometabolic disease in adults (Santos et al., 2012). Guerrero et al. studied sedentary behavior among children and adolescents (5-17 years old) during the COVID-19 and the perceived capability of parents to restrict their children's screen time was determined as the most predictive factor regarding sedentary behavior (Guerrero et al., 2020). Pombo et al. (2020) studied the impacts of socioeconomic variables on children's percentage of physical activity (%PA) during COVID restrictions. According to that study, there is no difference of %PA between girls and boys, but children with outdoor space and those who had other children in household were active. While children who were with adults working from home illustrated low level if physical activity (Pombo, Luz, Rodrigues, Ferreira, & Cordovil, 2020). (Hemphill, Kuan, & Harris, 2020) analyzed the role of the COVID-19 in the PA of children with congenital heart disease by measuring Fitbit step counts. This study confirmed that physical activity (steps counts) were significantly lower in late March and early April 2020 (quarantining period) compared with 2019 (Hemphill et al., 2020). (Dunton, Do, & Wang, 2020) investigated early effect of the COVID-19 pandemic on the physical activity and sedentary behavior (SE) of American children based on parents' reports. According to this study, parents of older children (ages 9-13) reported that their children had a greater level of decrease on physical activity and increase in sedentary behavior compared with younger children (ages 5-8) in early of pandemic (Dunton et al., 2020). Age, gender, socioeconomic profile, and the built environment characteristics are the main determinants of children's PA during the COVID-19 pandemic (Rossi, Behme, & Breuer, 2021). Another study on assessing the PA of German children and adolescents (aged 4-17) during the pandemic indicated that the PA declined whereas recreational screen time increased (Schmidt et al., 2020). A study on the impacts of COVID-19 restrictions on obesity of children, adolescent, and young adults showed there is an association between gained weight and changes in eating behavior and physical activity during the COVID-19 pandemic (Stavridou et al., 2021).(Jenssen et al., 2021) analyzed the obesity among children during the COVID-19, according to their investigation, the overall obesity increased from 13.7% to 15.4% during June to December 2020. While this increase has been seen more in Hispanic, non-Hispanic Black publicly insured, low-income group, and the patients (ages 13-17). The investigation on determinants of obesity among children in the COVID-19 pandemic confirmed that the COVID-19 pandemic is associated with obesity epidemic in school children by psychological, physical, and nutritional factors (Storz, 2020). The psychological factors are new and unfamiliar stressors for children and parents, lack of social interaction with classmates, friends, and teachers, frustration and boredom, and a lack of personal space at home (Storz, 2020). Also, another study on the assessing the relationship between obesity and pandemic in American children school showed that the level of obesity has increased and the levels of BMI have doubled during the pandemic compared with pre-COVID period (Lange et al., 2021). (Tsenoli, Moverley Smith, & Khan, 2021) discussed the causes and determinants of obesity in children during COVID-19 pandemic including behavioral changes such as changes regarding school closures, screen and media time. In addition, physical inactivity factors, psychological, health inequality and income factors are the determinants of obesity in the pandemic period among British children (Tsenoli et al., 2021).

Although, there is a rich body of literature related the impacts of COVID-19 on the obesity and physical activity of children, our understanding about socioeconomic and behavioral determinants of obesity during COVID-19 is limited. Therefore, there is a need for more studies to analyze different aspects of COVID-19 restrictions on the different socioeconomic and age groups in different context to provide consistent and enough literatures regarding impacts of epidemic disease. Policymakers and strategists need to enough and deep knowledge on psychological and physical impacts of restrictions in the different parts of world with considering the differences in social, cultural and economic issues to address pandemic disadvantages. Socioeconomic status, perceptual and attitudinal behavior of people hypothetically have impacts on the level of physical activity, nutrition diet, and obesity, so, considering various parameters and factors in different parts of the world can provide a deeper understanding of influential factors on physical and psychological health during pandemic. An appealing but underworked topic is the effects of the pandemic on not only the PA and BMI, but also their correlates and determinants. Moreover, there is a shortcoming on determinants of schoolchildren BMI during COVID-19 pandemic among Eastern and Southern European countries. Therefore, this study aims to study correlates of BMI of children of ages 9 to 12 years in European cities during COVID-19 to determine the correlates of changes in BMI during the pandemic.

In addition to influence of COVID-19 on the BMI of schoolchildren, the socioeconomic and built environment determinants of BMI before and during COVID-19 can help to clarify our understanding of different correlates and determinants of physical health in different age groups. (Feng, Glass, Curriero, Stewart, & Schwartz, 2010) studied the impacts of built environment features on the physical activity and obesity in different contexts. Density, diversity, design, connectivity, centering, and walkability are correlates of physical health in different contexts (Feng et al., 2010). (Salois, 2012) discussed adult obesity is highly correlated with built environment characteristics. The positive association of density, diversity, design, distance to transit, and accessibility of destination were confirmed for the American cities (Zhang & Yin, 2019). Thus, another focus on this study has been finding the built environment correlates of BMI among European schoolchildren.

Methodology

1.1. Research Questions and Hypothesis

The current paper seeks to answer the following research questions: (1) what factors determine the BMI of children of 9 to 12 years of age in European cities during the pandemic and after the lockdowns? (2) Are the determinants of BMI during or after COVID-19 times the same as before the pandemic? And (3) has the BMI of the children of this age range changed during the pandemic (2022) compared to the post-pandemic times (2016)?

This paper is based on one main hypothesis, i.e., the determinants and levels of the BMI of schoolchildren in European cities have significantly changed during the pandemic times, and however considering the inconsistency in different countries, it is not possible to predict if COVID-19 has caused an increase or decrease in the BMI of the children. The pandemic and the related changes in lifestyle may have increased or decreased the BMI of children in different European countries. Nevertheless, there is evidence that the pandemic and the change in lifestyles have had influences on children's BMI.

Data and Variables

The data used to answer the research questions of this study are twofold, related to two European projects related to 2016 representing the situation before the outbreak of Covid-19 and 2022 representing the times during the pandemic but when the lockdowns in almost all the European countries were removed. Both data collections and projects were funded by European Commission, the first of which were titled "Multisport against Physical Sedentary", and the latter was named "Promotion of Physical Activity of the Youth through Active Mobility to School".

The data of the year 2016 was undertaken in nine European cities, namely Foggia, Italy; Berlin, Germany; Thessaloniki, Greece; Rijeka, Croatia; Utrecht, Netherlands; Łódź, Poland, Konstantynow Lodzki, Poland; Malatya, Turkey, and Doğanşehir, Turkey. The respondents of the survey were pairs of children and parents (of course the parents answered all of the questions). The overall sample included 1304 pairs, who answered questions 26 questions about household socioeconomics, mobility habits of the child and the parents, perceptions about safety and security. The survey was conducted in 2016 and led to a response rate of 52 percent considering all countries. The survey was collected about the students of 21 schools in seven European countries. The complete details of the survey including the technical points and the results have already been published as an open access research paper by (Masoumi et al., 2017).

In the spring of 2022, the follow-up survey was undertaken in the same schools to define a cohort, leading to forming a dataset including all the schools excluding the schools in the Netherlands. Because of the difficulties of the pandemic, collecting data in the Dutch schools was not possible in 2022, thus the sample size of the 2022 survey was reduced to 1012 students. The structure of the data collection including the questionnaire and the data collection method was similar to the preliminary survey in 2016. The descriptive statistics of both surveys can be seen in Table 1. The target variable of this study is the BMI of the children in the continuous form, which has been used for the analyses of this study without transformation. As shown in table 1, the both surveys were conducted among schoolchildren between 9 and 12 years old the average age of participants in surveys were 10 and 11 years old in 2016 and 2022 respectively. The mean of monthly income for a household was 2203.26 Euros among seven European cities in 2016, while the mean of monthly income per household in same six European cities except Utrecht (Netherlands) was 3878 Euros. The changes regarding Body Mass Index (BMI) is considerable. The minimum and maximum of BMI has changed from 12.17 to 10.57 for minimum and from 21.75 to 35.84 for maximum BMI during 2016-2022.

Table 1. The Descriptive Statistics of some continuous variables in both surveys 2016 and 2022

	MAPS (2016)					PAYAMOS (2022)				
Variable	N	Minimum	Maximum	Mean	Std. Deviation	N	Minimum	Maximum	Mean	Std. Deviation
Age	1154	9	12	10.6	0.9	1005	9	12	11	1
Household Size	1214	0	12	4	1.19	1011	1	10	4	1
Monthly income	954	0	80000.00	2203.26	3211.91	847	0	61538	3878	5974.4
Car Ownership	1184	0	5	1	0.71	991	0	4	1	0.63
No. of driving licenses per household	1189	0	6	1.56	0.689	1000	0	10	1.64	0.72
No .of pepole work in oustside of houes	1189	0	5	2	0.64	996	0	4	2	0.6
Number of Childern	1215	0	10	2	0.98	1011	1	8	2	0.88
Body Mass Index	1103	12.17	218.75	19.35	6.86	967	10.57	35.84	19.2	19.2
Steet Connectivity	1222	0.0400	1.3130	0.53	0.39	1012	0.04	1.31	0.56	0.40
Accessibity to public transportation	1222	0.00	0.09	0.03	0.02	1012	0.01	0.10	0.03	0.02
Pupulation density	1222	3.01	263.09	39.58	65.74	1012	3.01	263.09	39.19	71.90
Green/open space	1222	0.00	0.05	0.01	0.01	1012	0.00	0.05	0.01	0.01

In both surveys, the urban form traits of the surroundings of the schools were collected by surveyors in different countries as well as Google Maps. These land use characteristics consisted of aggregate data about school commuting distance, the number of street crossings, street connectivity, accessibility to public transportation (PT), population density, and finally number of public open/green spaces. These data were gathered for catchment areas of 3 by 3 km rectangles centered around the schools.

1.2. Analysis Methods

In order to answer the first research question of this study, multivariate Ordinary Least Squares (OLS) modeling was applied to the BMI of the subjects the follow-up survey in 2022. The thirteen variables introduced in Table 1 were taken as the independent variables of the model and after 8 iterations, the best possible model with the highest R^2 was generated. The predictors with the P-values of less than 0.1 were taken as significant variables, whereas P-values of less than 0.05 represented significant predictors and those of between 0.05 and 0.10 indicated marginally significant variables. The seven insignificant variables that were omitted from the model were household size, the number of children in the household, the number of household members who work outside of the house, household car ownership, the number of driving licenses in the household, the number of street crossings on the way to school, and population density in the catchment area of the school.

For answering the second research question, the structure of the 2022 model was applied to the dataset of 2016, and no efforts was made to improve the quality of the OLS model. The aim was to find out if the same model can explain the BMI of the children who were studying in the same schools back in 2016. In such a case, if the model could explain the dependent variable, it would indicate no change in the determinant of BMI after the outbreak of COVID-19.

Finally, for answering the third research question of the study regarding occurrence of change in the BMI of the children studying in the same city and the same school, T-tests were conducted to find significant changes between the overall sample of 2022 compared to 2016 as well as between the sub-samples of each city related to 2022 and 2016. Of course, the results of the Kolmokorov-Smirnova and Sharipo-Wilks tests of normality showed that the independent variables of this study are non-normal (P<0.05), so usually non-parametric tests like Mann-Whitney U or Kruskal-Wallis tests should have been applied, but due to the fact that the sample size for each variable was large enough, it was preferred not to test the mean ranks, but to test the null hypothesis of presence of difference between the samples by directly testing the means. Thus, T-tests were applied the overall and city-wide samples.

Findings

The results of the final multivariate Ordinary Least Squares model of 2022 include seven significant explanatory variables (six significant and one marginally significant). The significant explanatory variables of the model (P<0.05) are age, gross household monthly income, the number of intersections (junctions) between home and school places, school commuting distance, street connectivity, accessibility to public transportation, and accessibility to green/open spaces. The only marginally significant variable in the model is accessibility to public transportation (P=0.053) and all others were significant (p<0.05).

The model indicates that a one-year increase in the age of the schoolchildren is correlated with 18% increase in their BMI, which seems natural, having in mind that the age range of the study is only four years (9, 10, 11, and 12 years). As an important socioeconomic predictor, gross monthly household income is negatively correlated with children's BMI; 1000€ increase in the household income is leads to a 19% decrease in the BMI. This means wealthier families may have children with lower BMI. Another negative correlation exists between the number of intersections between the home and school places and the BMI of the children in the sample. When the number of the street crossings increase by one, the BMI will decrease by 33%. However, the same is not true about the school commuting distance, as commuting distance and BMI have a positive significant relation. A one-kilometer increase in school commuting distance is correlated with a 35% increase in the BMI. There are three significant land use variables in the model: street connectivity, accessibility to public transport, and accessibility to green/open spaces. The former two are negatively correlated with BMI (β=12.5% and 10.9% respectively) and the latter is positively correlated (β=13.8%). As seen here, land use can have significant effects on the body configuration of the children, in the form of connected street networks or access to public amenities. These results have been summarized in Table 2.

Table 2. OLS model for BMI schoolchildren 9-12 years old in Six European cities

	Unstandardized Coefcient	standardized Coefcient	
	B	Beta	P
Constant	14.43		<0.001
Age	0.56	0.18	0.002
Montly income per household	-9.84	-0.18	0.005

The number of intersection to school	-0.33	-0.33	0.002		
Commuting distance	0.001	0.35	0.001		
Street connectivity	-0.96	-0.12	0.038		
Accessibility to public transportation	-12.86	-0.1	0.053		
Green/open space	30.85	0.13	0.016		
Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the estimation	
1	0.36	0.13	0.11	2.95	
Model Validation					
Model	Sum of Squares	df	Mean Squares	F	P
Regression	400.43	7	57.2	6.54	<0.001
Residual	2551.17	292	8.73		
Total	2951.6	292			

The validity of the model was tested by F-test, where the P-value of less than 0.001, indicated a correct model. However, the R^2 is not as high as expected; it predicts 13% of the variability of the BMI of the children in the sample. The model validity test results and also the R^2 can be observed in Table 2.

As mentioned in the methodology section, for answering the second research question of this study, the same model structure as the output model taken for 2022 was applied to the dataset of 2016 related to the pre-pandemic times. The results of the model have been summarized in Table 3, whereas the independent variables are non-significant. This indicates a change in the correlates of the BMI of children in the case cities.

Table 3. OLS model for BMI schoolchildren 9-12 years old in Seven European cities

	Unstandardized Coefcient	standardized Coefcient			
	B	Beta	P		
Constant	11.690		<0.001		
Age	0.63	0.08	0.018		
Montly income per household	9.22	0.004	0.9		
The number of intersection to school	0.1	0.07	0.04		
Commuting distance	-0.001	-0.08	0.02		
Street connectivity	1.96	0.11	0.002		
Accessibility to public transportation	-9.81	-0.03	0.3		
Green/open space	17.7	0.034	0.33		
Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the estimation	
1	0.16	0.02	0.02	6.79	
Model Validation					
Model	Sum of Squares	df	Mean Squares	F	P
Regression	1084.68	7	154.99	3.35	0.002

Residual	36921.7	800	8.7346.15		
Total	38006.38	807			

Finally, as seen in Table 4, the results of the T-tests for the overall sample does not reflect any significant change in the BMI between 2016 and 2022, while the tests undertaken individually for each city shows that some of the children of some of the pilot cities have experienced change in their BMI during these six years. The mean of the BMI of the children in the overall sample increased from 19.016 to 19.196, which is a non-significant change (two-sided P=0.207). The cities that show a change in BMI are Foggia, Italy; Malatya, Turkey; Rijeka, Croatia; and Thessaloniki, Greece. In Foggia, the BMI has highly significantly decreased from 21.42 to 18.973 (P<0.001). The sub-sample of Malatya shows a highly significant increase from 18.695 to 20.073 (P<0.001). Like Foggia, children's BMI in Rijeka has highly significantly increased (from 19.268 to 18.005; P<0.001). Finally, similar to Malatya, the BMIs in Thessaloniki have highly significantly increased (from 19.741 to 20.817; P<0.001). The rest of the cities, including Berlin, Konstantinow Lodzki, Lodz, and Dogansehir did not show any significant change between the baseline and the follow-up survey.

Table 4: The T-test results comparing the children's BMI of 2016 (before the pandemic) and 2022 (during or after the pandemic) of the eight cities of the study.

City-Year	N	Mean	Variance	t value	df	Two-sided P
Overall-2016	1182	19.016	11.563	-1.263	2144	0.207
Overall-2022	964	19.196	9.929			
Berlin-2016	130	16.912	10.962	0.643	177	0.520
Berlin-2022	49	16.571	7.394			
Doğanşehir-2016	70	18.204	10.082	-1.051	141	0.295
Doğanşehir-2022	73	18.783	11.603			
Foggia-2016	156	21.420	10.169	6.902	313	<0.001
Foggia-2022	159	18.973	9.636			
Konstantynów Łódzki-2016	98	18.271	10.684	-1.179	130	0.240
Konstantynów Łódzki-2022	34	19.001	6.743			
Łódz-2016	33	18.225	11.370	0.071	69	0.943
Łódz-2022	38	18.175	6.618			
Malatya-2016	144	18.695	8.213	-3.352	229	<0.001
Malatya-2022	87	20.073	10.731			
Rijeka-2016	210	19.268	10.005	4.289	452	<0.001
Rijeka-2022	244	18.005	9.579			
Thessaloniki-2016	261	19.741	10.526	-4.417	539	<0.001
Thessaloniki-2022	280	20.817	5.675			

Discussion

Overweight and obesity are related to serious disease and public health problems. Obesity comes from complex interactions between various factors including diet, physical activity, and psychological health, social and cultural issues and the built environment. This paper confirms that there is an association between built environment characteristics and obesity among schoolchildren. So, this study is in line with study on the relationship between obesity and built environment in the U.S. whereas Booth et al. (2005) discussed urban design factors, land use structures, and availability of public transportation can influence on obesity. According to their study, there is a correlation between neighborhood recourses, sedentary activities, walkability, land use structures, sprawling patterns, and the level of deprivation and obesity in American cities (Booth, Pinkston, & Poston, 2005). Also, this paper is in an agreement with the result of study on a negative association between the street connectivity and obesity in Australian cities (Saelens, Sallis, & Frank, 2003). An investigation that on the relationship of characteristics of built environment with obesity among adults in Queensland, Australia in 2021 showed that there is a positive correlation between characteristics of sprawled neighborhood including low level of street connectivity and obesity in Queensland (Wang, Liu, Lam, & Kwan, 2021). That finding of this paper confirms the result of this study on negatively correlation of high street connectivity and BMI. However, the results of this paper on the positive association of accessibility to green/open space with the BMI of schoolchildren is in contrast with the finding of Wang et al. (2021) in Queensland. Ewing et al. (2014) discussed there is a positive association between characteristics of sprawled areas including low density, low level of street connectivity and the high level of BMI in the U.S. Therefore, the findings of the current paper confirm the results of (Ewing, Meakins, Hamidi, & Nelson, 2014) for the post-pandemic times. In addition, this paper confirms the results of another study in American city regarding the positive association between poor connectivity and the obesity (Xu & Wang, 2015).

According to this paper, there is a positive and highly significant relationship between neighborhoods with open and green space and the schoolchildren's BMI in eight European cities. It is in opposite with results of study on the association of obesity among children and neighborhoods with green spaces in Lisbon, Portugal (Pereira, Nogueira, & Padez, 2019). Probably, this contrast is related to COVID-19 restrictions including encouraging people to stay at home. However, green space was not significant variable before COVID-19 for eight European cities.

The results of this paper show that there is a negative correlation between accessibility to public transportation and the schoolchildren's BMI. This finding related to the accessibility to public transportation is in line with a pre-pandemic study that indicated a negative association between density of bus stops and BMI in American cities in 2007 (Rundle et al., 2007). (Parise, 2020) studied built environment determinants of obesity in Australian cities. According to his study, more time commuting, using car, less active mobility mode choice, less accessibility to public transportation, amount of green space, footpath, less street connectivity, cycling infrastructure are associated with weight gain. Therefore, the results of this paper on negative correlation of BMI and street connectivity and accessibility to public transportation accept the findings of (Parise, 2020). However, Praise's study is in contrast with the current paper regarding the relationship of green space and BMI.

The findings of this paper confirm that the land use structure, street network confirmation, and built environment characteristics of neighborhoods play an important role on the BMI, and physical health of children particularly, during pandemic. Neighborhoods with high street connectivity, mixed land use structures and transportation facilities are associated with the less BMI and better physical health statues in schoolchildren in six European countries. Therefore, decision makers and urban planners can consider compact neighborhoods with more intersections in streets and combination of residential areas with other land use including schools to promote active mobility among children. In addition, the accessibility of public transportation is one of determinants of BMI during the pandemic. Transportation planners and strategists should consider this issue for guarantying physical and psychological health of people during and after pandemics.

Regarding the changes in BMI before and in COVID-19 times, a study investigated the changes in the weights of Polish adults to understand the impacts of nutrition habits in COVID-19. According to that study, two-thirds of the participants in the survey experienced body weight changes, and 45% of respondents became overweight in COVID-19 in Poland (Błaszczyk-Bębenek et al., 2020). The overall results of our study are in contrast with that study in Poland. Also, the results on two Polish cities Łódz and Konstantynów Łódzki are not in line with Błaszczyk-Bębenek et al. (2020). It can be the result of different age groups on two surveys; children of ages 9-12 years in this paper and the adolescents and adults of ages 15-65 years in the study of Błaszczyk-Bębenek et al. (2020). This highlights the different correlates of BMI for different age ranges.

The changes of body weight was measured also in Spain during lockdown (López-Moreno, López, Miguel, & Garcés-Rimón, 2020). Almost 40% of participants in Spanish online survey reported gaining weight during lockdown in Spain (López-Moreno et al., 2020). While the results of this study do not show significant changes in COVID-19 restriction period in six European countries. However, Foggia in Italy, Malatya in Turkey, Rijeka in Croatia, and Thessaloniki have changes in BMI from 2016 to 2022. Only the results of Thessaloniki confirm the Spanish study indicating increases in obesity and BMI during COVID-19.

Another investigation in Chinese cities indicated inverse results with this study that people with BMI<4 gained weight during pandemic while men with BMI≥24 lost weight and women with BMI≥24 gained weight. Most of studies confirm the increase in BMI and weight of people during COVID-19 pandemic (Jarnig, Jaunig, & van Poppel, 2021; Weaver et al., 2021; Yang et al., 2020). Therefore, the result of the current paper is in contrast with the most of the studies on changes of BMI of adults during COVID-19 pandemic. The impacts of different social and age groups with different lifestyles during COVID-19 could be different particularly, for children. Although a study on changes of BMI of children and adults ages 5-17 years indicated increases in BMI during COVID-19, these increases were very small in children in the U.S (Woolford et al., 2021).

A limitation of this study is that due to lack of sources and workforce, only aggregate built environment variables were applied to the models. In future studies, quantification of disaggregate land use and street network variables can add to the variability of the models. Moreover, larger city-level sample sizes can add to the prediction power of the BMI models.

Conclusion

The physical and physiological health of schoolchildren are associated to various factors including socioeconomic features, nutrition diets, the cultural issues and attitudes of parents, the physical activity, sedentary behavior, and urban built environment characteristics. The BMI determinants of eight European cities in six countries were modeled in this paper for before and during COVID-19 pandemic. Age, commuting distance, and the open/green space in the neighborhood are positively associated with the BMI of 9-12 years old children. In addition, income, the number of intersections to school, street connectivity, and the accessibility to public transportation have negative correlations with the BMI among schoolchildren.

This paper compares mean and variance of the BMI of schoolchildren before and during COVID-19 by using T-test for two datasets in 2016 and 2022. According to findings of this paper, there is no considerable difference between the BMI of schoolchildren in 2016 and 2022. However, there are decreases of BMI in 2022 compared with 2016 in Foggia, Italy, and Rijeka, Croatia, and there are two increases in Malatya, Turkey, and Thessaloniki, Greece.

Collecting data from different school in six European countries was very difficult during COVID-19 restrictions. Hence, the total sample size was reduced in 2022 compared with 2016 and the Dutch survey was removed in 2022 because of difficulties for collecting data from schoolchildren in Netherlands in pandemic.

There is a need for more studies to consider the relationship of land use and urban form structures with the physical activity and the BMI of different socioeconomic groups to provide deep knowledge on the heathier residential areas for different age and social groups.

Acknowledgments

The current study has been designed as a part of the project "Promotion of Physical Activity of the Youth through Active Mobility to School"-PAYAMOS. (project number 613171-EPP-1-2019-1-De-SPO-SCP) funded by the ERASMUS+ program of the European Commission. The funders had no role in undertaking this review. The authors are greatful the following survey staff, who contributed to management of the survey in the selected schools by negotiating with schools' authorities, guiding participants about the questions, and/or translating the questionnaires from English to local languages and preparing them for distribution.

Also, this study has been used dataset from the project "Multisport Against Physical Sedentary"-M.A.P.S. (project number 567236-EPP-1-2015-2-IT-SPO-SCP) funded by the ERASMUS+ program of the European Commission. The funders had no role in undertaking this review. The authors would like to thank the following survey staff, who contributed to management of the survey in the selected schools by negotiating with schools' authorities, guiding participants about the questions, and/or translating the questionnaires from English to local languages and preparing them for distribution: Carla Calabrese (IT), Gordon E. Jamerson, B.Sc. (DE), Georgios Patsakas, M.Sc. (GR), Georgios Parisopoulos, M.Sc. (GR), Ioannis Meimaridis, B.Sc. (GR), Konstantinos Anagnostaras, M.Sc. (GR), Andreas Perrostis, B.Sc. (GR), Eleni Dessi, B.A. (GR), Toni Družeta, B.Sc. (HR), Tatjana Udović, M.A. (HR), Ingmar Daams, BA (NL), Paweł Drużek, M.A. (PL), and Ahmet Dalcı (TR).

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