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To cite this version:

Dominique Lange, Morten Wahrendorf, Johannes Siegrist, Sandra Plachta-Danielzik, Beate Landsberg, et al.. Associations between Neighbourhood Characteristics, Body Mass Index and Health-Related Behaviours of Adolescents in the Kiel Obesity Prevention Study: A Multilevel Analysis. European Journal of Clinical Nutrition, 2011, 10.1038/ejcn.2011.21 . hal-00627923

HAL Id: hal-00627923

https://hal.science/hal-00627923v1

Submitted on 30 Sep 2011

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Associations between Neighbourhood Characteristics, Body Mass Index and Health-Related Behaviours of Adolescents in the Kiel Obesity Prevention Study: A Multilevel Analysis

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Running title: Neighbourhood Characteristics, BMI and Health-Related Behaviours

Abstract

Objective: To understand determinants of overweight, several studies addressed the association between neighbourhood characteristics and adult obesity. However, little is known about the association ~~influence~~ of such characteristics with ~~on~~ adolescents' overweight. This study aims at the influence of neighbourhood characteristics on adolescent BMI and lifestyle and to what extent BMI- and lifestyle variation between neighbourhoods can be explained by neighbourhood characteristics.

Subjects / Methods: We used cross-sectional data from the Kiel Obesity Prevention Study collected between 2004-2008 in 28 different residential districts of the city of Kiel (North Germany). Anthropometric data were available for 1675 boys and 1765 girls (n=3440) aged 13 to 15 years, and individual lifestyle factors and socio-demographic data were included in the analysis. At the macro-level, six different neighbourhood characteristics were used: unemployment rate, population density, traffic density, prevalence of energy-dense food supply, number of sports fields and parks, and crime rate. To test our main hypothesis, linear and logistic multilevel regression analyses were performed to predict BMI and lifestyle factors in individuals nested in neighbourhoods.

Results: Findings of multilevel analysis show little between-neighbourhood variations in BMI and health-related behaviours. 2% of BMI variation, 4% of media time variation and 3% of variation in snacking behaviour could be attributed to differences in neighbourhoods.

Conclusion: Environmental factors are significantly associated with adolescent BMI and health-related behaviour, however their total effect is small. Due to these results recommendations for structural policy measures as part ~~of comprehensive measures~~ of prevention of overweight in adolescents must be made cautiously.

Keywords: Body Mass Index, health-related behaviour, adolescents, built environment, neighbourhood characteristics, multilevel analysis

Introduction

During the last 20 years, increasing rates of overweight and obesity in children and adolescents have become a major public health challenge in most European countries (2006, Lobstein et al., 2004). In Germany, about 15% of children and adolescents aged between 3 and 17 are overweight or obese (Kurth & Schaffrath Rosario 2007). Childhood overweight is due to multiple interacting determinants which have not yet been completely elucidated. At the individual level, parental overweight and a low socio-economic status (SES) were identified as major determinants (Danielzik et al., 2004, Plachta-Danielzik et al., 2010). When compared with the individual level there is less scientific evidence on ecological determinants, e.g. whether deprived neighbourhood characteristics affect the weight status of adolescents.

Area-related inequalities in health are often explained by factors such as distribution of leisure time facilities or healthy food choices (Cummins et al., 2005, Estabrooks et al., 2003, Macdonald et al., 2007, Stafford et al., 2007), but features of an obesogenic environment that promote sedentary lifestyles and unhealthy food choices are spread across urban areas, affecting all socio-economic population groups. Along these features, the so-called built environment is of particular interest. Traffic density, land-use-mix, public sport facilities and parks provide opportunities, or restrictions, of physical-activity-promoting behaviour (Black & Macinko 2008). Furthermore neighbourhood crime and perceived safety (e.g. crime rate, badly lit streets) inhibit physical activity in residential areas (Black & Macinko 2008). Several studies show a lower prevalence of overweight in adults living in areas with high land-use-mix, greenery and street connectivity (Ellaway et al., 2005, Frank et al., 2004, Smith et al., 2008).

A high supply of energy-dense food points to further contextual aspect of causes of overweight. Whether individuals with high fast-food-exposure make more unhealthy food choices and show higher prevalences of overweight is still debated (Elinder & Jansson

2009). In addition to food environment, little is known about factors affecting physical activity and overweight in young age.

Investigating individuals that are nested in environmental units requires a specific approach to avoid statistical flaws. Multilevel-analysis accounts for the hierarchical structure of aggregated data, as it considers separately individual (level 1) and contextual area (level 2) effects. In recent years, the number of publications using multilevel approaches regarding characteristics of the built environment and weight status has increased (Harrington & Elliott 2009, Rundle et al., 2007, Santana et al., 2009). Yet, to our knowledge, there is no multilevel-analysis dealing with neighbourhood characteristics and Body Mass Index (BMI) in adolescents.

This study aims at investigating whether different contextual variables affect BMI in 13-15 year-old adolescents in the city of Kiel, North Germany. We address the following specific questions: 1. Are neighbourhood characteristics associated with BMI and lifestyle factors? 2. Do adolescents' BMI and lifestyle factors vary between different neighbourhood districts? 3. To what extent are these variations explained by contextual neighbourhood characteristics?

Methods

Study Design

Cross-sectional data of 13-15 year old adolescents were collected as part of the Kiel Obesity Prevention Study (KOPS). Details of the KOPS design and recruitment procedure are described elsewhere (Danielzik et al., 2005, Landsberg et al., 2008, Müller et al., 2001). Between April 2004 and August 2008 school directors of all 35 schools in Kiel were contacted and informed, of which 3 to 9 per year refused to participate. All eight-grade students (n=10526) of the remaining schools were invited to attend the study. Participation was on a voluntary basis and there were no eligibility criteria except the willingness to participate. In total, 48% (n=5025) of the students agreed to take part in the investigation. Response rate was equal for girls (48%) and boys (48%) but increased with increasing educational level of the adolescents (low: 33%, middle: 46%, high: 58%). Anthropometric measures were conducted by trained staff of the Institute of Human Nutrition and Food Science, ethnic and lifestyle factors were assessed by a validated questionnaire (Grund et al., 2001, Mast et al., 1998). The current report is restricted to those students whose place of residence was within the city of Kiel and who delivered complete data on socio-demographic and lifestyle characteristics (n=3440, 48,7% boys). Previous analyses documented that this subpopulation is well comparable to a German reference population, thus enabling us to generalize findings beyond the specific study group (Lange 2009).

Anthropometric measures

Students' weight [kg] and height [m] were measured directly following standard procedures (Landsberg et al., 2008). BMI [kg/m²] was calculated and German age- and gender-specific reference curves were used to determine overweight and obesity with adolescents above 90th percentile being overweight and those above 97th percentile being obese (Kromeyer-Hauschild et al., 2001). Adolescents self-rated their pubertal development by standard pictures (Tanner 1962) on scales from 2 to 5, a method validated by Duke et al. (1980).

Neighbourhood definition and characteristics

Definition of neighbourhood followed the official census tract classification in Kiel. Students' addresses were dedicated to their corresponding district. Kiel has a total of 30 districts. In this study, we left out two of the inner city districts because there were no students living.

In our study, we used the following contextual characteristics:

1. Unemployment rate. Data of unemployment rates of 28 districts of Kiel in the years 2001-2006 was provided by the Kiel Statistic Department. Averages were built over these years and tertiles were calculated to classify unemployment rate into the categories low, medium and high.

2. Traffic density. Data of traffic density was available from the Kiel Civil Engineering Office. Number of cars per day was registered in several street sections all over the city and was then summed up for each census district. Number of cars per district was referred to the area (0.01km²) of each district.

3. Population density. Number of households within each census tract was collected by the Kiel Statistic Department between 2001 and 2006. Average values were summed up, and population density was expressed as number of households per km².

4. Crime rate. Number of registered criminal acts between 2001 and 2006 was obtained from the Kiel Statistic Department on an annual basis. No detailed information on type and severity was given. Average crime rates were computed over the years for each census tract, and related to average number of inhabitants.

5. Sports fields and parks. Number of sports fields was provided by the Census Bureau of Kiel for the years 2001-2006. Parks were counted for each district by using an official city map of Kiel. Number of parks and sport fields were added, and average values over the years were calculated for districts and referred to 1000 inhabitants.

6. Energy-dense food supply. Food supply was assessed by walking through 7 districts and counting the number of supermarkets, fast food restaurants and takeaways, kiosks, petrol stations and bakeries in each district. After testing accordance with the first method in two districts food supply was assessed by online-search for all other districts. For each neighbourhood the number of food stores was calculated, and stores selling a high amount of energy-dense food (fast-food restaurants and takeaways, kiosks, petrol stations) were given double weight, given their contribution to an obesogenic environment. Again, these numbers were adjusted for the population size of each district.

Lifestyle factors

Physical inactivity. Daily media time was assessed as a proxy measure for physical inactivity. Adolescents were asked how many hours per day they spend watching TV and using a computer. Tertiles of media time were defined for each gender, whereas both girls and boys with >3 hours time use per day were categorized in the upper tertile.

Dietary behaviour. Food consumption was assessed by a 26 item validated food frequency questionnaire (FFQ) (Mast et al., 1999). Consumption was classified as 'never', '2-3 times per week', '3-5 times per week' and 'daily'. Five 'healthy' items (whole meal bread/granola, fruits, vegetables, fish and milk/dairy products) and five 'risky' items (white bread, meat/sausage, soft drinks, fast food and sweets/chips) were chosen to characterize dietary patterns (Landsberg et al., 2008). Consumption of ≥3 'healthy' and <3 'risk-related' foods at least 3-5 times/week corresponds to a *healthy dietary pattern*, consumption of ≥3 'risk-related' and <3 'healthy' foods least 3-5 times/week corresponds to a risk-related dietary pattern and consumption of ≥3 'healthy' foods and ≥3 'risk-related' foods at least 3-5 times/week corresponds to a mixed dietary pattern. A continuous healthy eating index was calculated from all items of the FFQ (Mast et al., 1999) and used for multilevel analysis.

Snacking behaviour was assessed by asking how often adolescents buy food on their way to school ('daily', '3-4 times/week', '1-2 times/week', 'less frequently or never'). The first two items were summarized as 'often' and the latter items as 'rarely'.

Nationality

Students' nationality was defined by their parents' nationality. Students whose both parents possessed a non-German nationality were classified as adolescents with non-German parentage.

Statistical analysis

Scatter diagrams are presented to explore associations between BMI (median values) and the neighbourhood characteristics at aggregate level. Moreover associations between the neighbourhood characteristics and lifestyle factors are studied. Linear multilevel models were conducted to predict BMI and lifestyle factors with individuals (level 1) nested in neighbourhoods (level 2) (Rabe-Hesketh & Skrondal 2005). This procedure offers the opportunity to disentangle between- and within-neighbourhood variations of BMI and to study the variations of BMI and lifestyle factors at each level separately. We were particularly interested to study whether and to what extent these neighbourhood characteristics explain the between-neighbourhood variations in BMI and lifestyle factors. In sum, we calculated four models. Model 1, an 'empty' model, was estimated to disentangle the between-neighbourhood variation from the within-neighbourhood variation. In model 2 individual variables were introduced to account for socio-demographic differences at individual level. Third, the macro indicators were added, and the reduction of the between-neighbourhood variation was assessed. Given the relatively small number of district at the macro level, we estimate one model for each neighbourhood indicator separately (Model 3a-3f). The final model (Model 4) included all significant variables. Maximum likelihood estimation is used for parameter estimation. We present estimated regression coefficients together with level of statistical significance. For the random component of the models we display the between-neighbourhood variations. Moreover, a model fit statistic (AIC, Akaike Information Criterion) is reported, which shows the preferred model having the lowest AIC value, as well as the proportional reduction of between-neighbourhood variance (R^2) according to Snijders and Bosker (1994). Logistic multilevel model was estimated for

snacking behaviour as binary outcome. Odds ratios and confidence intervals are shown as well as variability parameters between neighbourhoods for the random component (sigma u, rho). Level of significance was defined at $p<0.05$ and was reduced at $p<0.003$ to avoid coincidental results because of multiple testing (Bonferroni-correction α/number of tests) in table 2. All analysis were performed using STATA software version 10.

Results

Descriptive statistics of the study population and the 28 neighbourhood districts in Kiel are presented in **table 1**. Girls were significantly younger, showed higher BMI and advanced pubertal development than boys. More than 40% of the students' families had a high SES. However, the majority of the study population was living in neighbourhood districts with high unemployment rates. Definitions of neighbourhood characteristics are given, together with their median and interquartile-range.

Figure 1 gives an overview of the associations between neighbourhood characteristics and median BMI. Traffic density, number of sport fields and parks, and crime rate remain unrelated to BMI, whereas low correlations were observed in case of unemployment rate ($R^2=0.29$, $p=0.003$), population density ($R^2=0.15$, $p=0.055$) and food supply ($R^2=0.13$, $p=0.056$). Strongest associations were found for unemployment rate.

Next, associations between neighbourhood characteristics and each of the three unhealthy lifestyle factors were studied using logistic regression models. Each neighbourhood characteristic was rescaled by dividing through interquartile-ranges (for better visibility of the direction of the association) and odds ratios are presented – each adjusted for age, gender and SES. While high unemployment rates ~~and high crime rates~~ were associated with high media time, high media time was less likely in neighbourhoods with high number of parks and sport fields. Adolescents living in neighbourhoods with high unemployment rates showed more often unhealthy eating patterns, a high number of parks and sport fields decreased the risk of unhealthy eating patterns. Moreover, adolescents living in a

neighbourhood characterized by a high unemployment rate or a high food supply ~~or a high crime rate~~ had a more frequent snacking behaviour (**table 2**).

The neighbourhood characteristics within the census tracts were strongly correlated (**table 3)**. Population density was highly correlated with traffic density (r=0.83), while food supply showed less strong correlations with unemployment rate, population density and traffic density (between r=0.41 and 0.48). The number of sport fields was negatively correlated with population density, but had a positive correlation with crime rate. High unemployment rates were associated with high crime rates. Furthermore, crime rate was positively correlated with unemployment rate, whereas a negative association was found in case of traffic and population density.

Using multilevel models with BMI as dependent variable (**table 4**) the empty model showed a significant between-neighbourhood variation of BMI, but the intra-class correlation was relatively small (ICC=0.02) indicating that 2% BMI-variation can be attributed to differences between the neighbourhoods. The analyses indicated that the largest variation exists within neighbourhoods. In model 2, individual characteristics were included and a reduction of the between-neighbourhood variation is observed (44%). This indicates that variations of BMI at the neighbourhood level can partially be explained by differences in the composition of the single districts. In models 3a-f, where the neighbourhood characteristics are additionally introduced, the between-neighbourhood variation was additionally reduced in case of unemployment rate (model 3a) and food supply (model 3d). Both characteristics showed significant effects on BMI and additionally explained 40% (unemployment rate) and 14% (food supply) respectively of the between-neighbourhood variations. The final model shows that all variables included explained 94% of the between-neighbourhood variation.

The between-neighbourhood variation for media time (ICC=0.04) and healthy eating index (ICC=0.03) was reduced by unemployment rate, food supply and crime rate in case of media time and unemployment rate and sport fields and parks in case of healthy eating index (**table 5**). A higher ICC (`rho') was found for snacking behaviour: In neighbourhoods

with high food supply adolescents showed an increased risk for frequent snacking. About 10-13% of the variation of snacking behaviour could be attributed to differences between the neighbourhoods.

Discussion

This study investigated whether certain neighbourhood characteristics are associated with adolescent BMI in 28 neighbourhoods in the city of Kiel. For this purpose, different multilevel models were estimated, including socio-demographic and lifestyle variables as well as neighbourhood characteristics. Between neighbourhoods, there were small but significant variations in BMI. Part of these BMI-variations was explained by individual characteristics, i.e. age, gender, pubertal stage, nationality and physical inactivity. Neighbourhood unemployment also had a considerable effect on BMI.

Furthermore, food supply was shown to have a significant effect, while population density, traffic density, sports fields and parks as well as crime rate had no effect. However, one has to take into account that these characteristics cannot be clearly disentangled from each other. As shown in **table 3**, several correlations exist between certain macro-variables, suggesting that effects can be strengthened or weakened depending on interactions. In addition, there were some interrelations between neighbourhood characteristics and individual lifestyle factors. For instance, high crime rate was positively associated with high media time whereas high numbers of parks and sport fields were inversely related to high media time (**table 2, table 5**). Similar results were found in a multilevel study performed in adults in the city of Lisbon, Portugal (Santana et al., 2009). Hence, creating attractive and safe environments including parks and sport facilities for adolescents as well as organized youth groups as spots of communication and education is a recent challenge for health policies and urban planning.

Previous findings indicate that in adult populations high walkable and obesity-inhibiting environments are associated with high population density and high land-use-mix. This is

likely because daily errands can be easily made by foot or bike (Black & Macinko 2008). Previous data of the KOPS did not confirm this association in adolescents (Lange 2009). Obviously, daily tasks differ between adults and adolescents so that other macro-characteristics are supposed to be associated with adolescent overweight. For instance, short distances to school and attractive sport facilities or traffic calmed streets in residential areas may be important predictors of physical activity as compared to the diversity of shops and services in residential proximity.

In line with the positive correlation between food supply and BMI, adolescents showed more frequent snacking behaviour if their neighbourhood had a high food supply (**table 2, table 5**). However, the present literature is inconsistent concerning adolescents' eating behaviour and weight status in association with their food environment, especially around their schools (Crawford et al., 2008, Davis & Carpenter 2009). Nonetheless, because of relatively high intra-class correlation coefficients in case of snacking (**table 5**) and because of adolescents' preference of energy-dense food (Story et al., 2002), rising trends in fast-food availability and consumption certainly defines a public health issue that need to be addressed by an increase in healthy food alternatives.

Study strengths

This study has several strengths, e.g. the objective measurement of BMI. Furthermore, study population size as well as number of neighbourhood districts are large and enable the application of multilevel analysis. Data collection of individual and environmental characteristics is updated, reflecting the current state. Therefore, large structural changes in the neighbourhood environment over time can be excluded as potential confounders. Although only a few environmental factors were found to affect BMI, the final model that included individual and contextual factors, in particular neighbourhood deprivation and energy-dense food supply, had a high explanatory power. At least 94% of the BMI-variation between the neighbourhoods were explained. To our knowledge, this is the first study

examining the association of adolescent weight status linked with different neighbourhood contextual factors, using a multilevel approach.

Study limitations

Because of the cross-sectional study design, we cannot know what the potential long-term effects may be, and no conclusion concerning the causal sequence can be drawn. Unfortunately, we have no data on the duration of the students' lifetime spent in their residential unit, thus remarkable differences in exposure time may exist between students.

In addition, it is not clear whether neighbourhood contexts determine higher body weight or whether effects are based on the composition of residential units. The individual SES is a strong determinant of overweight (Langnäse et al., 2002). Low SES families with overweight children ~~who belong more often to low SES, may~~ more frequently live in socially and structurally disadvantaged neighbourhoods because of lower rental prices. Vice versa, families with high SES rather choose attractive neighbourhoods with green spaces, less traffic and more leisure time facilities. However, as students cannot be defined by own SES and as parents' SES is highly correlated with the neighbourhood unemployment under study, parental SES is not included in the multivariate analysis.

Our study does not give quantitative estimates of the amount of leisure time spent by adolescents in their own residential unit. It is possible that a substantial part of leisure time is spent in more attractive districts. More refined, more comprehensive measurements of neighbourhood exposure are desirable (Frank et al., 2004, Smith et al., 2008).

Finally, the low intra-class correlation coefficient needs to be mentioned, indicating relatively small heterogeneity between neighbourhoods. That implies a small overall relevance of environmental factors on BMI. It is probable that ~~is~~ the low ICC can be related to the relatively small number of districts. An increased number of districts would allow of testing this more strictly and of increasing the robustness of our findings. However, previous

studies including a higher number of districts were not able to increase intra-class correlation coefficients (Harrington & Elliott 2009, Rundle et al., 2007), and we still found a significant between-district variation in our data.

In conclusion, this study shows that distinct neighbourhood characteristics, in particular a high unemployment rate and a high prevalence of energy-dense food supply, are associated to a small extent with adolescent BMI and lifestyle factors, net of individual-level determinants. Results do not clearly underline the need for structural policy measures in addition to established programmes of health education and behavioural change.

Acknowledgements

This work was supported by the „Kompetenznetz Adipositas (Competence Network on Obesity)“ funded by the Federal Ministry of Education and Research (FKZ: 01GI0821) and by grants from Deutsche Forschungsgemeinschaft (DFG-MU 714-5.1-5) and WCRF.

Conflict of interest

The authors declared no conflict of interest.

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Figure Legends

Figure 1: Associations between neighbourhood characteristics and median BMI

BMI=Body Mass Index

Table 1: Characteristics of the study population and the 28 census tracts in Kiel

Study population		
	boys (n=1675)	**girls (n=1765)**
	median (IQR) or %	
Age	14.7 (14.3-15.2)[a]	14.6 (14.2-15.0)[a]
BMI (kg/m²)	20.2 (18.6-22.3)[a]	20.4 (19.0-22.6)[a]
overweight + obesity	12.9	13.1
obesity	4.4	5.2
Tanner Stage		
II / III / IV / V	2.3 / 29.5 / 59.4 / 8.8[b]	2.1 / 20.7 / 61.4 / 15.9[b]
Nationality		
non-German parentage	14.6	
Unemployment rate		
low	11.7	
middle	32.7	
high	55.6	

Census tracts		
		median (IQR)
Unemployment rate	(% unemployed inhabitants per year)	7.9 (6.2-11.2)
Population density	(no. of households per km²)	1194.3 (484.4-2950.9)
Traffic density	(no. of cars per day and 0.01 km²)	19.2 (7.3-39.1)
Food supply	(no. of food stores per 1000 inhabitants)	2.0 (1.6-2.7)
Sports fields and parks	(no. per 1000 inhabitants)	1.3 (1.0-2.1)

Crime rate	(no. of registered criminal actions per year and inhabitants)	36.9 (16.5-54.0)

IQR=Interquartile range, BMI=Body Mass Index; [a]significant differences between boys and girls: Mann-Whitney U-Test $p<0.01$), [b]significant differences between boys and girls Chi^2-Test $p<0.001$

Table 2: Associations between neighbourhood characteristics and lifestyle factors (logistic regression analyses)

	high media time[a]	unhealthy eating pattern[a]	frequent snacking[a]
	Odds-ratios (95% confidence interval)		
Unemployment rate	**1.48 (1.35-1.63)*** **	**2.05 (1.46-2.86)*** **	**2.10 (1.70-2.60)*** **
Traffic density	1.05 (0.98-1.13)	1.03 (0.94-1.13)	1.16 (1.00-1.36)
Population density	1.01 (0.93-1.11)	1.06 (0.94-1.19)	1.22 (0.97-1.52)
Food supply	1.07 (0.95-1.21)	0.90 (0.77-1.06)	**1.58 (1.17-2.12)** **
Sport fields, parks	**0.82 (0.73-0.92)** **	**0.77 (0.66-0.90)** **	0.85 (0.62-1.16)
Crime rate	1.18 (1.03-1.35)	0.93 (0.78-1.11)	1.58 (1.09-2.30)

[a]adjusted for age, sex and socio-economic status (defined by highest number of school years achieved by either mother or father (<10 years=low, 10 years=medium, >10 years=high))

***p<0.001, **p<0.003

Table 3: Correlation coefficients among neighbourhood characteristics and census tract characteristics

	Unemployment rate	Traffic density	Population density	Food supply	Sport fields, parks	Crime rate
Unemployment rate	1	0.137	0.134	0.478*	-0.074	0.427*
Traffic density		1	0.832*	0.412*	-0.255	-0.379*
Population density			1	0.459*	-0.422*	-0.377*
Food supply				1	0.005	0.147
Sport fields, parks					1	0.409*
Crime rate						1

Pearson correlation coefficient *p<0.05, **p<0.01

Table 4: Multilevel estimates for BMI

	Model 1 Empty Model	**Model 2** Individual variables	**Model 3a** Model 2 + Unemploy-ment rate	**Model 3b** Model 2 + Traffic density	**Model 3c** Model 2 + Population density	**Model 3d** Model 2 + Food supply	**Model 3e** Model 2 + Sport fields, parks	**Model 3f** Model 2 + Crime rate	**Model 4** Full Model[a]
Fixed parameters									
Individual variables									
Age		0.45***	0.44***	0.45***	0.45***	0.45***	0.45***	0.45***	0.45***
Male		-0.28*	-0.27*	-0.28*	-0.28*	-0.28*	-0.28*	-0.28*	-0.27*
Tanner stage 3		0.31	0.31	0.31	0.31	0.32	0.31	0.31	0.32
Tanner stage 4		0.90**	0.91**	0.90**	0.90**	0.91**	0.90**	0.90**	0.92**
Tanner stage 5		2.17***	2.18***	2.17***	2.17***	2.17***	2.17***	2.17***	2.19***
Non-German parentage		0.68***	0.65***	0.68***	0.68***	0.67***	0.68***	0.67***	0.66***
High media time		0.25*	0.24*	0.25*	0.25*	0.25*	0.25*	0.25*	0.24*
Neighbourhood variables									

Unemployment rate									
middle			0.04						0.01
high			0.60**						0.57**
Traffic density				0.00					
Population density					0.00				
Food supply						0.19*			0.17*
Sport fields, parks							0.07		
Crime rate								0.01	
Random parameters (SD)									
Level 2	0.434***	0.323***	0.173***	0.307***	0.323***	0.281***	0.326***	0.308***	0.102*
Statistics									
R^2		0.44	0.84	0.50	0.45	0.58	0.44	0.50	0.94
AIC	18093.05	17918.46	17909.37	17919.80	17920.45	17915.33	17920.17	17918.24	17904.96

SD=Standard Deviation
[a]including individual variables, unemployment rate and food supply
***p<0.001, **p<0.01, *p<0.05

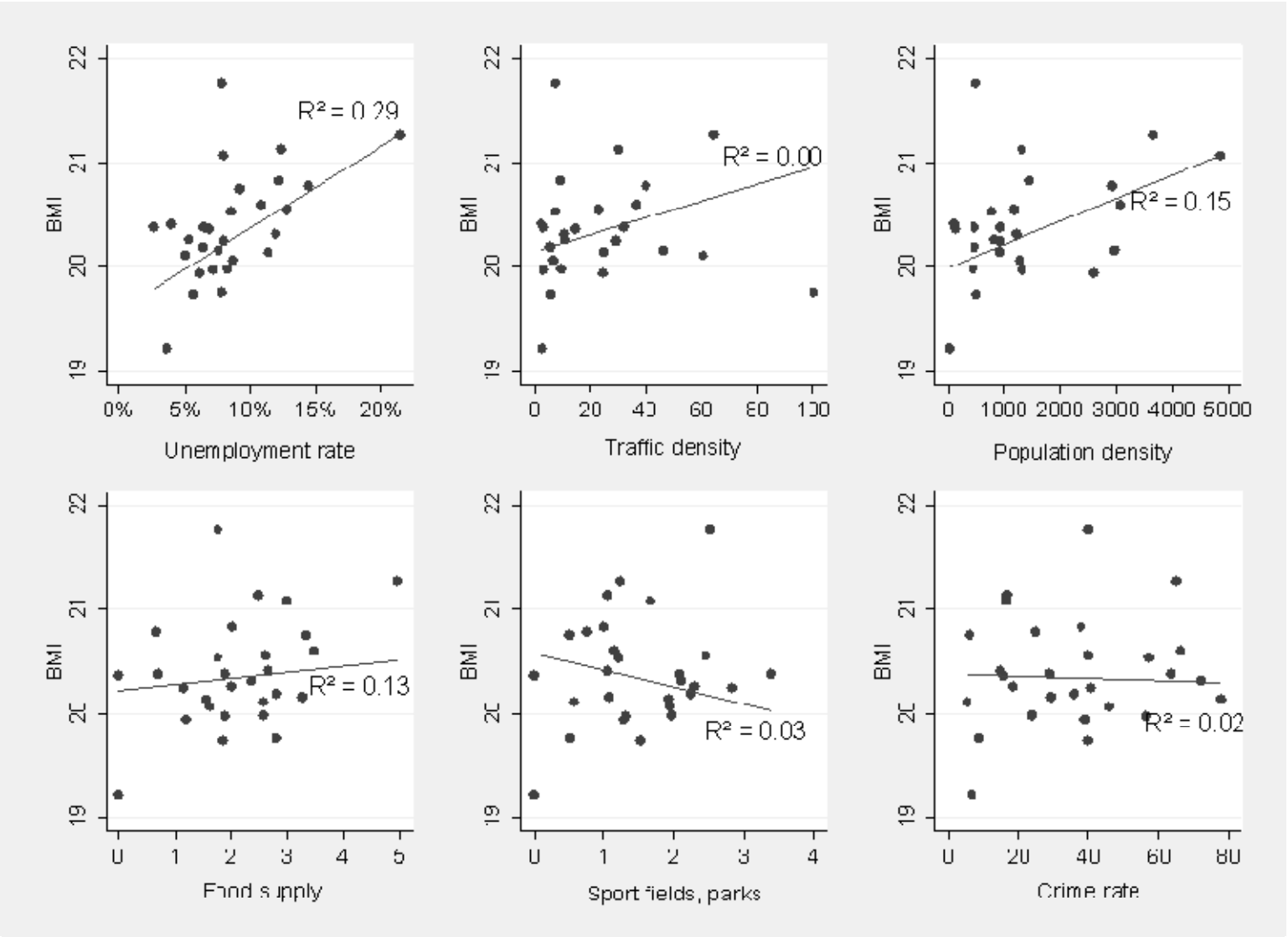
Table 5: Multilevel estimates for media time, healthy eating index (linear model) and snacking behaviour (logistic model)

	Model 1 Empty Model	**Model 2** Individual variables	**Model 3a** Model 2 + Unemploy-ment rate	**Model 3b** Model 2 + Traffic density	**Model 3c** Model 2 + Population density	**Model 3d** Model 2 + Food supply	**Model 3e** Model 2 + Sport fields, parks	**Model 3f** Model 2 + Crime rate	**Model 4** Full Model[a]
MEDIA TIME									
Unemployment rate									
middle			0.39**						0.41***
high			0.60***						0.64***
Traffic density				0.01					
Population density					0.01				
Food supply						0.25**			0.18**
Sport fields, parks							-0.10		
Crime rate								0.21*	-0.06
Random parameters (SD)									
Level 2	0.311***	0.251***	0.128***	0.252***	0.251***	0.224***	0.217***	0.240***	0.094***

Statistics									
R^2		0.35	0.83	0.35	0.35	0.51	0.41	0.48	0.91
AIC	12978.04	12799.49	12785.59	12801.462	12801.34	12797.34	12793.85	12800.00	12781.26
HEALTHY EATING PATTERN									
Unemployment rate									
middle			-0.05						-0.05
high			-0.79**						-0.73**
Traffic density				0.07					
Population density					0.10				
Food supply						-0.27			
Sport fields, parks							0.47**		0.41**
Crime rate								-0.15	
Random parameters (SD)									
Level 2	0.730***	0.505***	0.273***	0.507***	0.508***	0.498***	0.479***	0.412***	0.000***
Statistics									
R^2		0.52	0.86	0.52	0.52	0.57	0.68	0.54	1.00

AIC	19225.89	18787.55	18780.95	18789.03	18789.08	18789.13	18787.95	18783.39	18774.67
SNACKING BEHAVIOUR									
Unemployment rate									
middle			0.76 (0.24-2.36)						
high			1.95 (0.68-5.60)						
Traffic density				1.06 (0.81-1.39)					
Population density					1.14 (0.77-1.67)				
Food supply						1.55* (0.90-2.66)			
Sport fields, parks							0.90 (0.51-1.59)		
Crime rate								1.45 (0.77-2.73)	
Sigma u		0.70	0.60	0.69	0.69	0.64	0.60	0.71	
Rho		0.13	0.10	0.13	0.13	0.11	0.10	0.13	
AIC		869.48	867.26	871.07	871.30	870.25	869.24	871.35	

SD=Standard Deviation
[a]including individual and significant neighbourhood variables
***p<0.001, **p<0.01, *p<0.05


BMI
R² = 0.29
Unemployment rate
R² = 0.00
Traffic density
R² = 0.15
Population density
R² = 0.13
Food supply
R² = 0.03
Sport fields, parks
R² = 0.02
Crime rate