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Neighbourhood Built Environment and Its Impact on Physical Activity and Health: A Case Study of Leeuwarden

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Abstract: The influence of built environment factors on health and transportation modes has been extensively studied. However, results remain inconclusive and the main body of literature originates from the Anglo-American context. This study, which utilized quantitative methods, aimed to answer the question: How does the built environment, on a neighbourhood level, influence physical activity and physical health among the residents of Leeuwarden? Built environment indicators used in this study are: population density, access to urban green space and the average distance to a large supermarket. The statistical analysis conducted resulted in no statistically significant relationship between the built environment variables and BMI and only a weak statistically significant result between the variable distance to supermarket and physical activity. However, a higher share of active transportation in a neighbourhood strongly correlates with a lower BMI level. The socioeconomic variables age and income did also tested statistically significantly to health and physical activity. By focusing on improving socio-economic conditions and promoting physical activity, policymakers have the potential to create healthier, more active communities for residents of Leeuwarden.

Keywords: Leeuwarden, Neighbourhood, Built Environment, BMI, Active Transportation.

Table of contents

Introduction

background

The world faces significant global health challenges in the 21st century, including increases in unhealthy diets, physical inactivity, non-communicable diseases, obesity and the rise of cardiovascular diseases (Giles-Corti *et al* 2016). This is a source of concern for the general population's health and well-being. The number of people suffering from cardiovascular diseases has been rising and is expected to be the main cause of death, together with cancer in the year 2040 in the Netherlands (Ministerie van Volksgezondheid, 2023). In 2023, 16 per cent of adults aged 20 years or older were obese which was three times as many as in the early 1980s when 5 per cent were obese (CBS, 2024). The incidence of more severe forms of obesity also increased, from 1 per cent in 1981 to 4 per cent in 2023 (CBS, 2024). Physical inactivity significantly contributes to obesity (Martínez-González et al., 1999). With the Netherlands being a highly urbanised country where more than 90% of the inhabitants live in urban areas, the urban environment plays a crucial role in people's living conditions. Giles-Corti et al. (2016) found that the urban environment significantly influences the health of its residents. Therefore, understanding the impact of built environment factors on health is vital in an urban context.

Throughout the history of urban areas, hygiene and air pollution have been the main concerns for the health of urban residents. Today, lifestyle factors are increasingly becoming a topic with which urban design has to cope. Urban planning influences the behaviour patterns of residents and can influence the health of residents of a city (Yin, Zhang and Shao, 2020). There has been a growing understanding of the built environment's role in physical activity and obesity. Since around 2002, publications on this topic from the disciplines of public health, exercise science, urban planning, transportation, and leisure science have skyrocketed (Ding and Gebel, 2012). However, results have not always been the same, Anglo-American public health literature claims that built environment factors such as walkability, green space, traffic noise and air pollution affect diverse health outcomes, health behaviours and risk factors (Schulz et al., 2018). German scholars argued that the majority of studies on this topic have been Anglo-American oriented and question whether previous findings from Anglo-American countries can be applied to the European context because urban structures differ considerably between European countries and the USA (Schulz et al., 2018).

The topic of the health influence of the built environment has widely been studied over the world at different scales, such as city and neighbourhoods (Yin, Zhang and Shao, 2020). Also in the Netherlands this topic has been studied; however, there are differences between urban areas which makes this topic context-specific, for that reason this study focuses on one specific geographical setting to get a more contextual understanding of this topic. The city of Leeuwarden has been chosen as the geographical context of this study. Leeuwarden is a city in the north of the Netherlands with approximately 95.890 inhabitants. The city ranked 13th in the national Healthy City Index which was 3 places lower than the year before and is the lowest-ranked city in the north of the Netherlands (Arcadis, 2022).

Research problem

The aim of this research is to identify the relationship between the built environment and the physical health of residents at the neighbourhood level in the city of Leeuwarden. By answering the research question: *How does the built environment, on a neighbourhood level, influence physical activity and physical health among the residents of Leeuwarden?* By focusing on this specific city, the study's outcomes can inform future policy implementations and highlight potential problems and solutions for policymakers. The main research question is supported by three sub-questions:

1. *How does the built environment relate to active travel modes?*
2. *What is the relationship between physical activity and health?*
3. *How does the built environment relate to health?*

Structure:
After the introduction, the key concepts and theories on which this thesis is built are discussed in the theoretical framework. Following the theoretical framework, the conceptual model is discussed with the aligning hypothesis. Then, the research design is explained, and the methods used are explained in the Methods section. Then, the results are presented and discussed in the result section, leading up to the final conclusion, where the main points are quickly summarised and reflected upon the whole study.

Theoretical framework:

This research is based on concepts drawn from the literature, forming the theoretical framework. The following section describes and defines those concepts and their relation to each other.

Built environment
Studies have indicated that physical activity − and as a result overall health levels − are affected by people's residential neighbourhood and travel behaviour e.g., mode choice (De Vos, 2018). The built environment refers to human-made or modified surroundings, such as buildings, land use (e.g., layout of communities, transportation systems, food infrastructure), or green spaces (Schulz, Romppel, and Grande, 2018). The built environment can be divided into the objective built environment and the subjective built environment. The objective built environment includes quantifiable and measurable elements such as the density of buildings, the presence of parks, the layout of streets, and the availability of public transportation. In contrast, the subjective built environment is based on individuals' perceptions and experiences of their surroundings. Brownson et al. (2009) have reviewed literature surrounding the topic of physical inactivity and physical—or built—environment. They noted that the data of measurement of the built environment can be divided into 3 categories: 1) perceived measures obtained by telephone interview or self-administered questionnaires; (2) observational measures obtained using systematic observational methods (audits); and (3) archival data sets that are often layered and analysed with GIS. The first category of measures is based on the perceived built environment, and the latter two on the objective built environment. Numerous studies worldwide have found relationships between the built environment and the health of inhabitants. The built environment influences health through direct influences such as air quality and noise pollution, but various studies have also shown the relationship between the built environment characteristics and health-related behaviour such as travel behaviour and mode choice(Bauman *et al.*, 2012; Yin, Zhang and Shao, 2020), even though the results are not consistent

(Bauman et al., 2012). The built environment can be analysed at different scales, such as city and neighbourhood. The city-level BE has a much stronger relevance to active commuting time, BMI, and life satisfaction but a weaker relevance to active commuting modes than the neighbourhood-level BE (Yin et al., 2020)

Green space accessibility

Accessibility to green space has been found to be positively correlated with health (Dillen *et al.*, 2012). A key indicator of accessibility is proximity to green space from a residence or neighbourhood to the nearest green space. The distance may be expressed as simple linear (straight line) distance, travel distance (by road/path network) or converted into estimated travel time (WHO, 2016). However there is no universally accepted guidance on a distance threshold that defines ‘accessible (WHO, 2016). The built environment is usually measured by neighbourhood administrative definitions or buffers around respondents' home addresses or neighbourhood centroids. The latter is preferred and is the method used for the green space accessibility because it considers residents’ potential exposure to the neighbourhood area (Duncan et al., 2018). Distance to services assesses the proximity of residential areas to amenities such as supermarkets, healthcare facilities, and public transportation hubs. The arrangement and distribution of land use activities in an urban district is one potential way to influence urban mobility behaviours. Providing facilities and services for residents in the vicinity of their living areas can minimise the need for long-distance travel and increase the chance of having active travel (Saghapour et al., 2015).

Population density

Population density is a built environment factor found to be related to multiple health and behaviour outcomes. A study in the Netherlands found that higher population density was modestly related to increased mortality independently of baseline socioeconomic position and health. Next to that, a higher density resulted in more perceived urban stress and a higher share of smoking. However, a higher population density did also relate to more active transportation (Beenackers et al. 2018). In a more international context (Sun et al., 2022), the results of studies examining the relationships between density and health are mixed; some found positive relations for health and some found negative relationships between density and health.

Access to services

The distance to services and activities can significantly impact daily life and physical activity. Studies show that older adults tend to engage in physical activity within 500 meters of their homes (Portegijs et al., 2020), emphasising the importance of proximity to encourage movement.

Physical activity

Physical activity influences the prevention of non-communicable diseases (e.g., coronary heart disease, stroke, type 2 diabetes, cancers, and the overall maintenance of psychological, social and cognitive functioning (Laddu, Paluch and LaMonte, 2021). Health and transportation researchers have examined physical activity from different perspectives. Although health is affected by total physical activity, for a long time, health research has been focused on leisure or recreational physical activity, of which walking is the most common form (USDHHS, 1996). Brisk walking is protective of physical health, particularly if done consistently (Wagner et al., 2001), with health effects independent of the benefits of more vigorous

activity (i.e., activities traditionally considered “exercise”, such as running, swimming, etc.) (Manson et al., 1999). There are a large number of techniques for the assessment of physical activity, which can be grouped into five general categories: behavioural observation, questionnaires (including diaries, recall questionnaires and interviews), and physiological markers like heart rate, calorimetry, and motion sensors (Westerterp, 2009). The scope of this study encompasses multiple neighbourhoods in Leeuwarden, therefore the most applicable assessments are the secondary questionnaire data and physiological markers since those are more applicable to large quantitative research.
An indicator of physical activity that is influenced by the built environment is time spent on active transportation. Active transportation modes are walking, cycling and the use of public transport since they increase walking time (Rissel *et al.*, 2012).

BMI
Physical health is often measured through BMI (Drewnowski et al., 2019, 2020; Yin et al., 2020). Body Mass Index (BMI) is a numerical measure of body fat based on a person's weight and height. It's a widely used tool to assess whether an individual falls into categories like underweight, normal weight, overweight, or obese. BMI is a variable influenced by physical activity and is convenient for quantitative analyses (Papas et al., 2007).
Multiple studies have found relationships between built environment characteristics such as green space accessibility, walkability index, population density, access to services, and BMI. BMI is, therefore, it is the variable used in this study to represent physical health.

Socioeconomic factors
The study's main aim is to discover the relationships between the built environment and health and health-related behaviour; however, it might be interesting to compare the significance of the built environment factor and socioeconomic factors to see which variables have a stronger relationship with Physical activity and physical health. It is widely known that someone's economic status is a strong predictor of someone's health; a higher socioeconomic status correlates with better physical health and lower BMI (Barakat and Konstantinidis, 2023). This is also the case in the Netherlands, where the average income per inhabitant has a negative relationship between income and obesity (vzinfo, 2024). This means that the higher income people have, the less likely they are to have a BMI higher than 30 (vzinfo, 2024). Also age is correlated with BMI in the Netherlands, there is a positive relationship between age and the occurrence of being overweight meaning older age groups are more likely to be overweight (RIVM, 2024). Next to that age also influence active transportation, a study in the US found that older adults were less likely to be active commuters (Bopp et al., 2013). Therefore, it is important also to include socioeconomic variables in the analysis of active transportation to compare the relevance with each other.

Conceptual model:

Based on the theoretical framework, the conceptual model visualises the relationship between the variables. As mentioned before, Physical health is the dependent variable in this study, dependent on physical activity and the built environment. Next to that, the variable physical activity serves as a dependent variable and independent variable, being placed between physical health and built environment it serves as the independent variable for physical health and as the dependent variable on built environment. The variable built environment is represented by the variables; population density, the average distance to a large supermarket and access to green space. Physical activity is represented by the variable: share of trips walking or biking to school or work and Physical health is represented by the variable: share of BMI higher than 30.

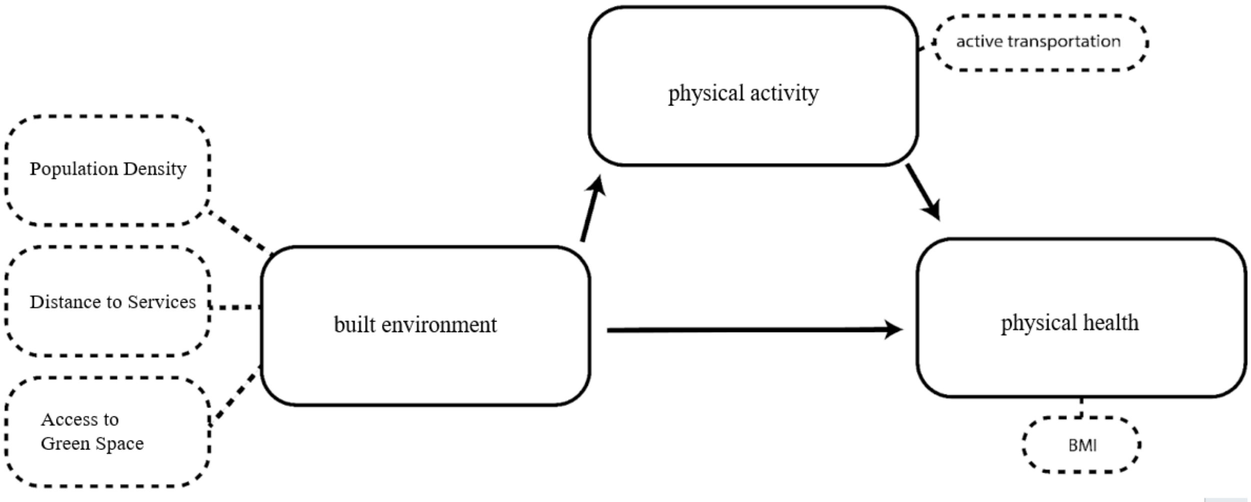

Figure 1, conceptual model

Hypothesis

Based on the literature and conceptual framework, the following hypotheses have been formulated for the research questions.

1. Population density has a positive relationship with physical activity and physical health
2. Distances to services have a negative relationship with physical activity and physical health
3. Access to green spaces has a positive relationship with physical activity and physical health
4. Physical activity has a positive relationship with physical health.

Methodology:

This study used quantitative methods to answer the research questions. Secondary data is used because of its high quality, great availability, and great sample of the available data sets. The built environment, especially the objective built environment, is a phenomenon that can be easily quantifiable through statistics and measures. Through the use of quantitative methods, a larger sample of neighbourhoods can be selected than through qualitative methods. It thus will provide a broader understanding of the topic that can also easily be replicated in different geographical settings.

Study area:

The city of Leeuwarden is the area of study for this research. Leeuwarden serves as the capital of the province of Friesland and lies in the equally named municipality of Leeuwarden. Leeuwarden has around 95.890 inhabitants (CBS, 2024). The city of Leeuwarden is divided into multiple neighbourhoods called "buurten" in Dutch. The selection process of the neighbourhoods started with all neighbourhoods in the city of Leeuwarden, after that, the neighbourhoods with less than 120 inhabitants were excluded due to not having enough data. Examples of neighbourhoods that are not included in this study are industry parks and very rural areas on the edge of the city where few people live. After the selection procedure, 54 neighbourhoods were selected for this study (figure 1). 54 neighbourhoods is a sufficient number of cases on which to perform statistical analysis.

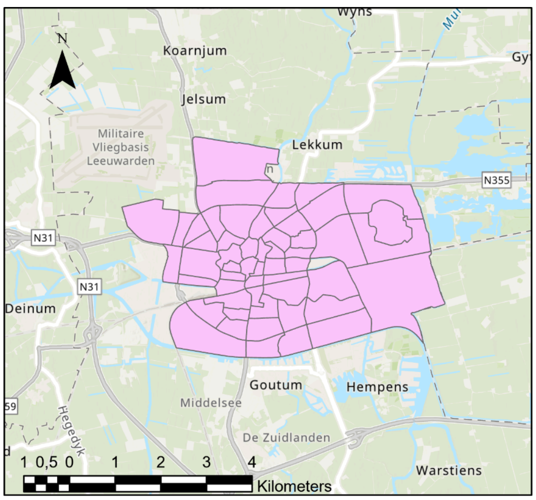

Figure 2, Selection of neighbourhoods in Leeuwarden.

Figure 3: Location of Leeuwarden in the north western part of the Netherlands.

Data sets:

Data for variables were extracted from multiple data sets: CBS (Dutch Central Bureau of Statistics) RIVM(National Institute for Public Health and Environment) and Esri Nederland. For each variable, the dataset origin and content will be discussed.

variable	dataset
Population density	CBS

Average distance to supermarket	CBS
Share of overweight	RIVM health monitor
share of trips to school and work made by bike or walking	RIVM health monitor
Share of green space	Esri Nederland
Average income per inhabitant	CBS
Share 15-44 year olds	CBS

Data on Population density, average distance to a large supermarket, average income per inhabitant, and the Share of 15-44-year-olds were extracted from the 2024 CBS StatLine publication. This publication contains key figures on demographic and socio-economic topics broken down by municipalities, districts and neighbourhoods of the Netherlands; the 2024 publication contains only data from 2022. The key figures enable users to compare different areas (municipalities, districts and neighbourhoods). To increase comparability, relative measures of the included key figures have often also been calculated as percentages and figures per thousand inhabitants.

The data on overweight and active travel mode was extracted from the most recent RIVM health monitor, which was last been updated in 2022. Based on the Health Monitor for adults and the elderly from the local health organisations, CBS and RIVM, the RIVM has calculated figures on health and lifestyle for almost all districts and neighbourhoods in the Netherlands. There have now been four measurements: in 2012, 2016, 2020 and 2022. The 2022 health monitor has approximately 365,000 respondents. The 2020 Monitor contains more than 540,000 respondents, 2016 has approximately 460,000 and the 2012 Monitor approximately 400,000. Despite the fact that these are very large samples, there are often too few respondents per neighbourhood or district for direct, reliable estimates. That is why the RIVM uses a model to estimate the figures. A sufficient number of respondents is required to make these types of estimates. The more respondents there are the better the data quality.

Data Collection

Neighbourhoods

The division of municipalities into districts and neighbourhoods is more than half a century old. It dates from the 1947 census. The division into districts and neighbourhoods is determined by municipalities themselves and is in line with wishes for policy making. Municipalities are formally the owners. CBS coordinates the compilation of the classification and ultimately integrates the maps of municipalities into a national district and neighbourhood map. As previously mentioned, the neighbourhoods defined by the municipalities form the basis for this study. RIVM and CBS datasets contain statistical information based on these neighbourhood definitions. Every neighbourhood in the Netherlands has its own code and is commonly used in data sets, this made the process of gathering data from multiple datasets easier as variable data from different data sets could be linked to each other by the use of neighbourhood codes. The selection process mentioned before resulted in 54 neighbourhoods used in this study (figure 1).

BMI

The RIVM healthmonitor dataset contained information about the share of overweight people for each neighbourhood. Only data for people older than 18 is included. Being overweight is based on body mass index (BMI); someone with a BMI of 25.0 kg/m2 and higher is classified as overweight. The numbers are based on self-reported height and weight. BMI is calculated by dividing someone's weight (in kilograms) by the square of their height (in meters). This variable represents BMI and, thus physical health well since it gives for each neighbourhood a quantifiable average based on BMI that can be compared with different neighbourhoods.

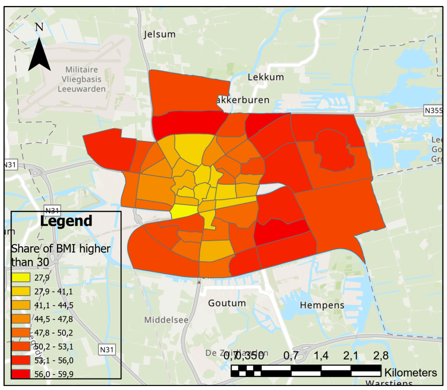

Figure 4: descriptive visualisation of differences
in overweight percentages between the neighbourhoods on a map.

Active Transportation

The RIVM healthmonitor dataset also contained information about active transport modes, such as walking and cycling. The data shows the percentage of people between the ages of 18 and 65 who complete at least part of the journey to work or school on foot and/or by bicycle. Even though the data does not include the duration or distance of the active transportation part of the commute, the data is still valuable since it is an average and it is safe to assume that neighbourhoods with a higher share also have the highest time active travel time duration. A higher share might show what neighbourhoods are more cycling/walking friendly.

Access to green space.

The GIS data set containing spatial features about vegetation is very detailed and was updated on 15 March 2022. ESRI Nederland, the owner of the dataset, updates it on data from Kadaster extracted from BGT files containing all land uses in the Netherlands. The BGT (Basic Registration of Large-Scale Topography) is compiled using aerial photographs, terrain measurements, and other sources of geographic information. These data are then processed and coded accurately to provide a precise and detailed representation of the land.

This digital dataset contains information about all kinds of green features in the city, ranging from urban parks and sports fields to small bushes, roadside vegetation and single trees. All green features included in the dataset are used for this study Some studies only use recreational features in their studies and exclude smaller green features from their study, however since the small plots of green space still have an influence on the neighbourhood's character, air quality and it has been proven that only looking at some green natural vegetation improves mental health, all vegetation features have been included in this study, even though they might not have a high recreational value. After selecting the neighbourhoods used in this study, a 300 m buffer was created around each neighbourhood, this is done to include green areas that are close outside of a neighbourhood so they are still relatively accessible and should be taken into the neighbourhood's accessible green space areas. After creating the buffer every vegetation polygon was summarised within the buffer zone of each neighbourhood resulting in the total area of green space accessible for each neighbourhood. When the total green area was calculated it was divided by the area of the buffer to make sure that larger neighbourhoods do not automatically have a higher number but that it is relative to each other. All the spatial processing, calculations and summarised within was done in ArcGIS.

Population density

Population density is extracted from the CBS database. Population density is calculated by dividing the number of residents in a neighbourhood on January 1 by the surface area in km^2.

Access to services

The variable most useful in representing access to services is the average distance to a large supermarket. Supermarkets are an important service to residents that are visited regularly by most age groups unlike schools and hospitals whose amount of visits are more influenced by the age composition of a neighbourhood. CBS qualifies a large supermarket as: a shop with multiple types of daily items and a minimum area of 150 m2. The average distance is the average distance of all residents in an area to the nearest large supermarket, calculated over the road.

Age

For every neighbourhood statistics are known about how many people from each age cohort live in them, the age groups are: 0-14, 15-24, 25-44, 45-64, 65+. Because the dependent variable only has BMI statistics for people ages 18+ the youngest age cohort (0-15) is left out of this study. To make a difference between relative old and young neighbourhoods the share of 15-44 of the age groups is calculated. This means that a relatively younger neighbourhood will have a higher number of people in this age group than a relatively old neighbourhood.

Income

Average personal income per neighbourhood (divided by 1000) based on the total population of private households.

Results and analysis

The following section discusses each of the 3 subquestions, and statistical tests are performed to answer the question. Each subquestion has a separate statistical test, a multiple linear regression test in all 3 cases. Each test has a dependent variable and independent variables related to the research question. The two variables: share of the population aged 15-44 and average income per person are added to each test to compare the relevance of the built environment and physical activity against those two socioeconomic factors.

Sub question 1: How does the built environment influence active travel modes?
To answer this question, the variables 1. Average distance to a large supermarket, 2. Population density, and availability of greenspace are tested with the variable Biking or walking to school or work through the use of a multiple linear regression test.
The null hypothesis for this test: There is no relationship in Leeuwarden neighbourhoods between the built environment variables (average distance to a large supermarket, population density, availability of greenspace) and socio-economic variables, and the share of active travel mode (biking or walking to school or work). When looking at the ANOVA table for this test the the null hypothesis for this test is rejected since the sig. value is less than p=0,05 (p<0,001). Moreover, the R2 value for the regression model is 0.599. This means that the model can explain approximately 59.9% of the variability in the share of biking or walking to school or work, which includes both the built environment and socio-economic variables. While this indicates a moderate level of explanatory power, it also suggests that 40.1% of the variability is due to other factors not included in the model. The next step is to look at the coefficients table to see which variables are statistically significant and in what direction.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2422,431	5	484,486	14,337	<,001[b]
	Residual	1622,073	48	33,793		
	Total	4044,504	53			

a. Dependent Variable: Biking or walking to school/work

b. Predictors: (Constant), population density, Average income per inhabitant, %15-44, Average distance to large supermarket, m2 groen for each m2

Looking at the coefficient table, it can be concluded that no built environment variable has been tested as strong significant. Only the variable Average distance to the supermarket tested positive with a sig value of ,085. This means that when the average distance to supermarkets increases, people tend to take the bike or walk less to work or school, meaning they are less likely to engage in active transportation. The other built environment variables did not test statistically significant, which is in contrast with the literature and the hypotheses that were found and formulated in the theoretical framework. This does not mean that the built environment has no influence on mode choice, it means that between the neighbourhoods in Leeuwarden, there might be no big difference between the built environment, meaning they all have a comparable built environment standards.

Looking at the sig. values, only the variable that tested significant was the share of the population aged 15-44 with a sig. value is less than p=0,05 (p<0,001). In conclusion, age is more related to active transportation choice than built environment factors in the neighbourhoods of Leeuwarden. Looking at the standardised coefficient B value of ,599 it is clear that the relationship is moderately positive, meaning that the higher the share of 15-45 year population in a neighbourhood, people tend to take the bike or walk more often to school or work.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	40,820	8,467		4,821	<,001
	%15-44	35,747	6,476	,599	5,520	<,001
	Average income per inhabitant	,041	,293	,014	,141	,889
	m2 groen for each m2	,803	1,689	,053	,475	,637
	Average distance to large supermarket	-4,051	2,302	-,187	-1,759	,085
	population density	,000	,000	,136	1,273	,209

a. Dependent Variable: Biking or walking to school/work

Sub question 2: What is the relationship between physical activity and health?
To answer this question, the variables 1. share of trips done biking/walking to school or work, 2. share of the population aged 15-44 and 3. average income per person are tested against the dependent variable: share of overweight through the use of multiple linear regression test.
Null Hypothesis: there is no relationship between the physical activity variable (share of trips done biking or walking to school or work), socioeconomic variables (share of population aged 15-44, average income per person) and the prevalence of overweight within Leeuwarden neighbourhoods.

The ANOVA table for this test is significant, allowing examination of the coefficient table to assess the individual variables. All tested variables are significant, with p-values less than 0.05 ($p < 0.001$).
The R2 value for this regression model is 0.873, indicating that 87,3% of the variability in the share of overweight can be explained by the model. This high R2 value suggests that the model provides a very good fit to the data, meaning the independent variables included in the model account for most of the variation in the dependent variable.

The physical activity variable has a strong negative relationship with the BMI of residents(B= –,712), this is an expected result supported by the literature; however, a relationship does not mean causation. Kroesen and De Vos (2020) mentioned this problem in their research and blamed the cross-sectional data as the reason why no direction of causation could be determined. Studies based on cross-sectional data, such as this study, only use data from a single moment and therefore can not look at the changes over time and the results certain changes in data might have. The direction of causation remains uncertain from this statistical test, i.e. does active travel lead to improved health or vice-versa, are healthier individuals more inclined to participate in active travel? Kroesen and De Vos, (2020) found out that over time – more obese individuals tend to decrease their walking frequency, but walking does not lead to lower BMI over time, meaning that active travel does not have a big impact on BMI level but BMI level has an impact on the decision to use active modes of transportation such as walking and cycling.

Next to that, the socio-economic factors are also statistically significant, with both having a sig. value of <,001. Both relationships are weak and negative (B value= –,270 and –,294), meaning that a higher average income and a larger share of people aged 15-44 in the neighbourhood correlate with a lower share of obesity in the neighbourhood. These relationships are in the same direction as the literature describes them to be ((Barakat and Konstantinidis, 2023, vzinfo, 2024); however, this test highlights the greater importance of the relationship between active travel and health.

In conclusion, the high R2 value indicates that the model effectively explains the variability in the prevalence of overweight based on the included variables. While the findings emphasise the significance of physical activity in relation to health, they also underscore the necessity of longitudinal studies to better understand the direction of causation and the dynamics between active travel, socio-economic factors, and health outcomes.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	101,054	3,756		26,904	<,001
	Biking or walking to school/work	-,522	,053	-,716	-9,769	<,001
	%15-44	-11,738	3,229	-,270	-3,635	<,001
	Average income per inhabitant	-,619	,109	-,294	-5,700	<,001

a. Dependent Variable: overweight 18+

Sub question 3: How does the built environment relate to health?

To answer this question, the variables 1. access to green space, 2. average distance to supermarket, 3. population density, 4. share of population aged 15-44, and 5. average income per person are tested against the dependent variable, share of overweight, through the use of a multiple linear regression test.

The Null hypothesis for this test is: In the population of neighbourhoods in Leeuwarden, there is no linear relationship between the dependent variable (share of overweight) on the one hand and the independent variables (access to green space, average distance to supermarket, population density, share of population aged 15-44, average income per person) on the other hand.

Looking at the sig. value of the corresponding ANOVA table (sig. value of <,001), the null hypothesis is rejected, meaning there is a relationship between the variables. The coefficients table shows that only the two socioeconomic variables are significant with a sig. value of <,001 for the age group variable and ,006 for the income variable. In conclusion, from this table, the built environment does not influence health in neighbourhoods in Leeuwarden. This is not what was expected from the literature since numerous aspects of the built environment are related to physical activity and other key health behaviours and outcomes (Boone-Heinonen *et al.*, 2010).

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1384,811	5	276,962	17,513	<,001[b]
	Residual	759,094	48	15,814		
	Total	2143,905	53			

a. Dependent Variable: overweight 18+

b. Predictors: (Constant), Average income per inhabitant, population density, %15-44, Average distance to large supermarket, m2 groen for each m2

The R2 value for this regression model is 0.646, indicating that 64.6% of the variability in the share of overweight can be explained by the model. This suggests a moderate to strong fit, where a significant portion of the variation in the dependent variable is accounted for by the independent variables included in the model (mainly by the socioeconomic variables). However, it also indicates that 35.4% of the variability is due to other factors not included in the model.

The relationship between age and BMI is the strongest of the two significant relationships, with a B value of -,733 meaning that the relatively younger a neighbourhood is the fewer people with overweight live in the neighbourhood. This indicates a positive relationship between age and BMI that is in according to the literature (vzinfo, 2024). The relationship of income with BMI is negative although with a B value of –,271 the relation is considered weak. Nonetheless the relationship was significant meaning that relatively richer neighbourhoods have generally a lower average BMI. Both relationships are no surprise since it is extensively discussed in the literature that higher income and younger age relates to people with better physical health and a lower BMI.

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Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	81,256	5,792		14,028	<,001
	m2 groen for each m2	-1,161	1,155	-,106	-1,005	,320
	Average distance to large supermarket	-,671	1,575	-,043	-,426	,672
	population density	,000	,000	-,084	-,836	,407
	%15-44	-31,856	4,430	-,733	-7,191	<,001
	Average income per inhabitant	-,571	,201	-,271	-2,846	,006

a. Dependent Variable: overweight 18+

Conclusion

This study tried to answer the research question: *How does the built environment on a neighbourhood level influence physical activity and physical health among the residents of Leeuwarden.* Secondary data was used in combination with 3 multiple linear regression tests to answer the main question and subquestions. The statistical test is done to answer the first sub-question: *Does the built environment* *influence active travel modes? This* resulted in a weak statistical relationship between distance to a large supermarket and active transportation, no significant relationships were found between the other built environment variables and active travel modes. The variable age did as expected had a significant relationship with active transportation. The second statistical analysis for the subquestion: *Is there a relationship between physical activity and health;* resulted in a strong relationship between active transportation and health indicating the importance of physical activity for health or health for physical activity. The third analysis tried to discover relationships between the built environment and health also did not find any significant relationships between the two variables however, the socioeconomic variables income and age did have a relationship with health, indicating that the socioeconomic characteristics of a neighbourhood are a bigger indicator of health than the built environment characteristics on a neighbourhood level.

As discussed before, the outcomes of cross-sectional tests should be interpreted with care, as they can result from effects in either direction. Future research that considers this limitation and tries to solve this through multiyear data is needed to further understand the direction of causation between various variables. Due to practical reasons, this study used only 3 built environment variables, future research could include more built environment variables so that a more complete overview of the neighbourhoods is used in the analysis. The access to green space was measured with the use of a buffer and an average of the whole neighbourhood, future research might look more at the individual differences between inhabitants of neighbourhoods. Also, the 300m buffer chosen in this study to calculate the green space accessibility can be changed since no universal method has been developed yet. The findings of this study are based on data from neighbourhoods in Leeuwarden, which may limit the generalizability to other contexts. While the relationships observed between socio-economic factors, physical activity, and health are consistent with existing literature, the specific built environment characteristics and their impacts may vary in different cities or regions with different urban layouts, cultural contexts, and infrastructure. Therefore, caution should be exercised when applying these results to other settings. Future studies could replicate this study in different geographical contexts due to the relatively extensive and generalised data that is available in the Netherlands on this topic.

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