Solveig Nordengen // Bicycling in the right direction?

DISSERTATION FROM THE
NORWEGIAN SCHOOL OF
SPORT SCIENCES
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Two systematic literature reviews with meta-analyses of cycling and cardiovascular disease, followed by national correlates of commuter cycling and the presentation of a novel bike traffic index to describe trends in cycling over the years.

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SAMMENDRAG

Bakgrunn: Verdens befolkning trenger å være mer fysisk aktive. Hjerte- og karsykdommer (HKS) er en ledende årsak til død, og kan forebygges ved å være fysisk aktiv. Sykling som transport kan være en metode for å bedre folkehelsen. Når man skal tilrettelegge og evaluere tiltak for å fremme sykling, trenger vi mer informasjon om faktorer som har sammenheng med sykling. Det er også viktig å ha gode målemetoder for å fange opp utvikling i antall sykkelreiser i befolkningen.

Mål: Målet med arbeidet er å undersøke forholdet mellom sykling og HKS og tilhørende risikofaktorer. Videre er målet å undersøke individuelle og miljømessige faktorer som kan påvirke nordmenns valg om å sykle som aktiv transport. Til slutt presenteres en sensitiv metode for å beskrive utviklingen av sykling i Norge, på lokalt, regionalt og nasjonalt nivå.

Materiale og metode: Denne avhandlingen er basert på to systematiske litteraturstudier med metaanalyser om HKS og tilhørende risikofaktorer for mer enn én million individer. Videre er arbeidet basert på en tversnittundersøkelse av offentlig ansatte i de tre norske fylkene Sogn og Fjordane, Aust-Agder, og Vest-Agder. Den nasjonale sykkelindeksen består av 89 stasjonære tellere, basert på åpne data distribuert av Statens Vegvesen.

Hovedresultat: Basert på de systematiske litteraturstudiene er sykling assosiert med 22% lavere risiko for HKS dødelighet, HKS tilfeller og HKS risikofaktorer sammenlignet med ikke-syklister (Artikkel I). Sammenlignet med ikke-syklister, var det å være syklist assosiert med mer hensiktsmessig risikoprofil, med unntak av risikofaktoren blodtrykk (Artikkel II). I tverrsnittstudien fant vi både individuelle og miljømessige faktorer som var assosiert med sykling. Reisevei kortere enn 5 km og det å bo i et område med høy befolkningstetthet økte sannsynligheten for å sykle til arbeid. Det å ha god helse, være fysisk aktiv og eie en el-sykkel økte sannsynligheten for å være syklist (Artikkel III). I Norge ser vi en signifikant økning på 11% i antall telte sykkelreiser fra 2018 til 2020. Det ble observert store geografiske forskjeller i utvikling av telte sykkelreiser (Artikkel IV).

Konklusjon: Syklister har lavere risiko for HKS dødelighet, HKS tilfeller og noen HKS risikofaktorer. Sykling anbefales som metode for å forebygge HKS og man bør forsøke å øke sykling generelt. Både individuelle og miljømessige faktorer er assosiert med økt sannsynlighet for sykling. Karakteristikker som kjennetegner syklister ser ut til å være relativt like uavhengige om man er fra et område med store eller liten grad av sykling. Nasjonalt observerte vi en signifikant økning i antall telte sykkelreiser fra 2017 til 2020, med store geografiske forskjeller. De geografiske forskjellene tydeliggjør behovet for lokal indekser og kan være et utrykk effekten av lokale, regionale eller nasjonale tilrettelegging for økt sykling.

Nøkkelord: Fysisk aktivitet, aktiv transport, sykling, sykling som transport, folkehelse, hjerte- og karsykdommer, offentlig ansatte, GIS, måling av sykkel reiser, nasjonal sykkelindeks

SUMMARY

Background: The world population needs to be more physically active. Cardiovascular disease (CVD) is one of the leading causes of death and can be prevented by physical activity. Cycling as transportation may be a means of improving the health of the general population. To facilitate and evaluate interventions to increase cycling in Norway, we need more information about factors associated with cycling and a method to follow future trends.

Main aims: To investigate the relationship between cycling and CVD and its associated risk factors and to investigate individual and environmental factors that may affect Norwegian people's choice to travel by bicycle. We also aimed to develop a sensitive method to describe cycling trends in Norway over the years at the local, regional, and national levels.

Materials and methods: This thesis is based on two systematic reviews and meta-analyses of CVD and associated risk factors in more than one million individuals, as well as a cross-sectional study of Norwegian public-sector employees in Sogn og Fjordane, Aust Agder and West Agder counties that used a web-based questionnaire combined with objective measurement by a geographical information system. Finally, the thesis is based on open-source data from 89 stationary cycle trips counters in Norway describing the trends in counted trips from 2017 to 2020.

Main results: Based on the systematic review, we found that cycling was associated with a 22% lower risk of CVD mortality, CVD incidence, and associated CVD risk factors compared with passive transport (Study I). Being a cyclist was also associated with beneficial risk factor levels, except for blood pressure, compared with non-cyclists (Study II). In the Norwegian environment, we found both individual and environmental factors associated with a higher likelihood of commuter cycling. Travel distance below 5 km and living in a highly populated area increased the probability of cycling. Having good health, being physically active, and owing an e-bike also increased the likelihood of cycling (Study III). Finally, we observed an 11% increase in counted cycle trips from 2018 to 2020, with large geographical differences (Study IV).

Conclusions: Cyclists were at lower risk of CVD incidence, CVD mortality, and some CVD risk factors. Health professionals, city planners, and stakeholders can recommend cycling to prevent CVD and should aim to increase the amount of cycling. Both individual and environmental factors were associated with likelihood of being a cyclist. Characteristics of cyclists seemed to be similar regardless of whether they lived in areas with smaller or larger numbers of cyclists. Nationally, we observed a significant increase in counted trips, while the regional and local indices indicated geographical differences. The indices may highlight effects related to local and national bicycling strategies.

Key words: Physical activity, active transportation, active travel, active commuting, cycling, bicycle, bicycle transportation, cardiovascular disease, public health, public employees, adults, GIS, monitoring bicycle ride, national bike traffic index

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Solveig Nordengen,

Sogndal, June 2021

LIST OF STUDIES

The thesis is based on the following original research studies, which are referred to in the text by their Roman numerals:

Study I

Nordengen, S., Andersen, L. B., Solbraa, A. K., & Riiser, A. (2019). Cycling is associated with a lower incidence of cardiovascular diseases and death: Part 1 – systematic review of cohort studies with meta-analysis. *British journal of sports medicine*, *53*(14), 870–878. Doi: 10.1136/bjsports-2018-099099

Study II

Nordengen, S., Andersen, L. B., Solbraa, A. K., & Riiser, A. (2019). Cycling and cardiovascular disease risk factors including body composition, blood lipids and cardiorespiratory fitness analysed as continuous variables: Part 2 – systematic review with meta-analysis. *British journal of sports medicine*, *53*(14), 879–885. Doi: 10.1136/bjsports-2018-099778

Study III

Nordengen, S., Ruther, D. C., Riiser, A., Andersen, L. B., & Solbraa, A. (2019). Correlates of commuter cycling in three Norwegian counties. *International journal of environmental research and public health*, *16*(22), 43–72. Doi: 10.3390/ijerph16224372

Study IV

Nordengen, S., Andersen. L. B., Riiser, A., & Solbraa A. K. (2021).
National trends in cycling in light of the Norwegian bike traffic index. *International journal of environmental research and public health*, 18(12), 61–98; Doi: 10.3390/ijerph18126198

ABBREVATIONS

BMI	Body Mass Index
CHD	Coronary Heart Disease
CI	Confidence Interval
CRF	Cardiorespiratory Fitness
DBP	Diastolic Blood Pressure
eCRF	Estimated Cardiorespiratory Fitness
GIS	Geographic Information Systems
GPS	Global Position System
HDL-C	High-Density Lipoprotein Cholesterol
HR	Hazard Ratio
IF	Inflation Factor
LDL-C	Low-Density Lipoprotein Cholesterol
MET	Metabolic Equivalent
MetS	Metabolic Syndrome
NPRA	Norwegian Public Road Administration
PA	Physical Activity
RCT	Randomised Controlled Trial
RR	Risk Ratio
SBP	Systolic Blood Pressure
SD	Standard Deviation
SES	Socioeconomic status
SRH	Self-Rated Health
SMD	Standardised Mean Difference
TC	Total Cholesterol
TG	Triglycerides
WC	Waist Circumference

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INTRODUCTION

In 2016, cardiovascular disease (CVD) was one of the five leading causes of years of life lost [1] and the leading cause of death in the world [2]. Physical inactivity, defined as failing to meet the WHO recommendations for daily physical exercise, is associated with CVD and CVD risk factors [3, 4], and the World Health Organization (WHO) has declared physical inactivity the fourth leading risk factor for global mortality [5]. Approximately a quarter of the world's adults are physically inactive [6], with global levels of physical activity (PA) decreasing over previous decades [7]. Although evidence of the importance of PA is strong and consistent, PA levels have not improved [6].

The positive relationship between PA and CVD has been extensively investigated and confirmed [8-11] for men [12] and women [13] and across ages [14-16]. Active travel, as a form of PA, is associated with reduced all-cause mortality [17-19], and it can improve health on the population level [20]. Furthermore, active travel is inversely associated with obesity at both the country [21] and individual levels [22] and has promising associations with lower levels of CVD risk factors [7, 19]. In a meta-analysis that adjusted for other forms of PA, active travel was observed to have a protecting effect on cardiovascular outcomes [23], and it may be a promising approach to increasing PA levels and reducing the risk of CVD and associated risk factors. Active travel is a type of PA with great potential and cycling in particular is known to improve health. One limitation of research studies investigating active travel is that they often combine walking and cycling [20]. This is a problem, as cycling is often performed at a higher exercise intensity than walking is [24], and higher exercise intensity is associated with further reduction in the risk of coronary heart disease (CHD) [25]. Therefore, cycling may be more effective than walking for preventing CVD [20].

In the latest WHO strategy [26], PA is introduced as a whole system approach. By using system maps, the complexity of PA was visualised including the complexity of the behaviour of cycling as mode of transportation. However, evidence of individual and especially objectively measured environmental factors associated with commuter cycling is sparse. Owing to the health benefits of commuter cycling, it is important to understand the characteristics of cyclists, especially as their numbers differ within and between countries. Understanding of the factors associated with commuter cycling is necessary for designing specific public-health actions. As illustrated by Kelly and colleagues [27] and conceptualised by socioecological models, a wide range of interventions, intensives, and facilitations may be considered to increase the use of the bicycle as a mode of transportation. When evaluating public health interventions (or actions), specific and sensitive evaluation methods are always needed, but seldom included.

Therefore, this thesis aimed to investigate the relationship between cycling and CVD and its associated risk factors and to investigate individual and environmental factors that may affect Norwegian people's choice to travel by bicycle. Finally, we aimed to develop a sensitive method to describe the trends in cycling in Norway and a potential tool to evaluate public health actions of cycling.

Definitions and clarifications of concepts

In the following, I will give a brief introduction to the key terms used in this thesis, followed by a presentation of the current evidence and research gaps relevant to CVD and cycling. In addition, I will use a socioecological framework to present the current evidence on individual and environmental influences on the choice of commuter cycling and present different approaches to monitoring trends in cycling. Finally, I will present the research gaps and research questions.

Physical activity and recommendations

Physical activity is defined as 'any bodily movement resulting from contraction of skeletal muscle that results in an increase in energy expenditure' [28]. The amount of energy required to perform or complete an activity may be measured in kilojoules (kJ) or kilocalories (kcal) [28]. Measures of total PA include frequency (how often), duration, intensity (i.e., energy expenditure), mode (type of activity), and domain (the context or reason). The WHO [29] recommends that adults should 1) regularly undertake PA, 2) do at least 150-300 minutes of moderate-intensity aerobic PA or 75-150 minutes of vigorous-intensity throughout the week, and 3) do strength-enhancing PA on a weekly basis.

Active travel and commuter cycling

Physical activity can be categorised in many ways [28]. 'Active travel' refers to the WHO's concept of transport domain PA. Transport domain PA is PA performed for the purposes of getting to and from a place, and it refers to walking, cycling, and wheeling (the use of non-motorised means of locomotion with wheels, such as scooters, rollerblades etc.) [29]. 'Active travel' and 'transport domain PA' are used interchangeably. Bicycling as active travel is often described as commuter cycling or utilitarian cycling. Hereafter, I will use ‘commuter cycling’ and ‘cycling for transportation’ to describe this practice.

Cardiovascular disease and associated risk factors

Cardiovascular disease includes diseases of the heart, vascular diseases of the brain, and diseases of the blood vessels [2]. In 2016, CVD was one of the five leading causes of years of life lost [1] and the leading cause of death in the world [2]. The WHO divide CVDs into two types: 1) those due to atherosclerosis, which include ischemic heart disease or coronary artery disease, cerebrovascular disease, and diseases of the aorta and arteries, including hypertension and peripheral vascular disease [2], and 2) those including congenital heart disease, rheumatic heart disease, cardiomyopathies, and cardiac arrythmias [2]. Due to scope of this thesis, I will focus on the first of these (namely, CVDs due to the atherosclerosis process).

Atherosclerosis is the major cause of CVD and underlying cause of heart attacks (CHD) and strokes (cerebrovascular disease) [2]. Atherosclerosis is an inflammatory process changing the blood vessels in the cardiovascular system [2]. If the inside barrier (endothelium) is exposed to high levels of low-density lipoprotein cholesterol (LDL-C), the walls start to absorb lymphocytes and monocytes that are stored deep in the blood vessels [2]. This results in the attraction of more LDL-C to the site. In addition, LDL-C are surrounded by monocytes, which are altered into macrophages [2]. Smooth muscle cells and collagen form a fibrous cap, and the macrophages begin to die. The process continues as more lipids and cells accumulate, and the inflammation with the cap grows into the vessel lumen. As the process continues, the fibrous cap may rupture [2]. If the cap ruptures, a thrombus is established [2]. If the thrombus is large enough to block the vessel, this causes ischaemia due to restricted or blocked blood flow.

It is well established that behavioural and metabolic risk factors have a major impact on the atherosclerotic process [2] and may lead to CVD [30]. Tobacco use, physical inactivity, an unhealthy diet, and large alcohol consumption are all behavioural risk factors [2]. Metabolic risk factors include hypertension, diabetes, dyslipidaemia, and overweight and obesity [2]. These risk factors are all included in the definition of metabolic syndrome (MetS), which is a complex risk factor for CVD and doubles the risk of CVD caused by atherosclerosis [31, 32]. Another major independent risk factor is low cardiorespiratory fitness [33, 34]. Other risk factors include low socioeconomic status (SES), increased age, and being male [2].

Over the last three decades in Norway, there has been a continuous decrease in the number of deaths caused by CVD [35]. In 1990, a total of ~20,000 people died of CVD, while this number had halved by 2019, falling to ~10,000 deaths (Figure 1). This reduction was mainly due to a reduction in ischaemic heart disease. Due to the increasing proportion of people with CVD risk factors – such as obesity [36, 37] and type-2 diabetes [38] – this decrease in CVD mortality may stop [39].

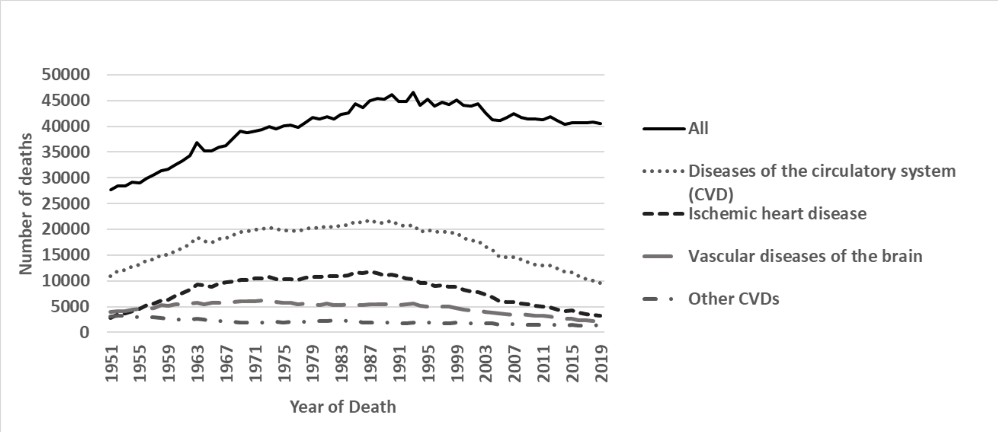

Figure 1. *All causes of death and death related to cardiovascular disease by yea, for men and women, from 1951 to 2019. Source: Norwegian Cause of Death Registry. NIPH. Retrieved 16.04.21.*

Until recently, death registers and disease registration by the International Classification of Disease have been the only source of data on the influence of cycling on morbidity and mortality in longitudinal, prospective, and retrospective cohort studies. Today, databanks such as the UK Biobank and the China Kadoorie Biobank are of a sufficient size to enable the analysis of rarer exposure (i.e., commuter cycling) and outcomes. This has enabled these database researchers to examine more specific relationships between commuter cycling and health, as done by Celis-Morales and colleagues in 2017 [40].

Cardiovascular disease risk factors include a wide range of health outcomes, thus CVD is a key factor in the relationship between commuter cycling and health outcomes. Other important health outcomes are cancer and diabetes, but these are not within the scope of this thesis. In the following section, I will briefly present the major behavioural risk factors associated with CVD.

Physical activity

The positive relationship between PA and CVD has been extensively investigated and confirmed [8-11] for men [12] and women [13] and across ages [14-16]. The important mechanisms of PA related to CVD are increased blood pressure control, improved endothelial function, more favourable lipid profile [23], and increased insulin sensitivity [41]. Physical inactivity, defined as not meeting the recommendations for daily physical exercise, is associated with CVD and CVD risk factors [3, 4], and the WHO has declared physical inactivity the fourth leading risk factor for global mortality [5]. Approximately a quarter of the world's adults are physically inactive [6]. Globally, levels of PA have decreased in recent decades [7]. Since 2010, PA has been considered a major key preventive factor for CVD [42], resulting in national and global promotion [26] and surveillance of PA. Although the evidence of the importance of PA is strong and consistent, PA have not improved [6].

In Norway, from 1979 to 2016, self-reports indicated increasing participation in exercise ($p < 0.001$), including increases in both intensity and frequency [43]. In 2008, only 20% of the Norwegian population met the national recommendations for PA [44], while 32% met the recommendations in 2015 [45]. However, this evidence is based on self-reports, and cultural changes in relation to PA may influence perceptions, which may result in a given PA being reported differently today than it would have been a decade ago [46]. Although the recommendations of PA changed between 2008-09 and 2014-15, from a minimum of 30 minutes of moderate daily PA to 150 minutes of moderate or 75 minutes of vigorous PA during the week, the trend is similar to those observed in the Tromsø study. From 2008 to 2015, there was a significant increase of 2.8% in the mean activity level (counts/min; 95% CI: 2.4-3.2) [45].

Cardiorespiratory fitness

Cardiorespiratory fitness is one of the five components of health-related fitness. This is the ability of the circulatory and respiratory system to supply fuel during sustained PA and to eliminate fatigue products [28]. Health-related fitness also includes muscular endurance, muscular strength, body composition, and flexibility [28].

The hypothesis of an inverse relationship between PA and cardiovascular health was introduced in 1953 by Morris and colleagues [47], who were investigating CHD among workers with low and high levels of PA. This was investigated again in the 1970s by

Paffenbarger and colleagues [48], who found that men who perform PA with vigorous intensity are at a lower risk of hypertension. They also observed that a higher body mass index, weight gain, and a lack of strenuous exercise independently predicted increased risk of hypertension [48]. Later, strong, graded, and independent associations of CRF with CVD mortality in men and women were observed [34]. Independent of other risk factors – such as obesity, smoking, family history of CVD, and elevated blood pressure – being moderate or highly fit reduced the risk of CVD mortality, compared to the least fit people [34]. The protective effect of cardiorespiratory fitness (CRF) on CVD is now well documented [15]. There is a consensus that – independent of an individual's age, sex, and race – aerobic PA improves CRF [24], and CRF is now viewed as an important vital sign, providing important insights into health [49].

The golden standard for measuring CRF is the graded maximal test on a motor-driven treadmill or cycle ergometer, where VO_2 is assessed by analysing expired gas [50]. This is both a complex and costly method, which reduces the limit the number of study participants. CRF may also be estimated based on work performance during a maximal exercise test on a treadmill or cycle ergometer, without equipment to measure gas exchange. CRF estimations without equipment to measure gas exchange (i.e., the Balke test) have been shown to be highly correlated with direct measures for both men and women (r = 0.92-0.94) [51, 52]. Other more time-efficient alternative is to estimate VO_{2max} using exercise field tests, such as the 20-metre shuttle run and the Andersen test. The 20-meter shuttle run test has strong evidence for its validity among young people [53]. In addition, non-exercise methods based on algorithms have been developed to denote estimated CRF (eCRF). These tests are predicted by self-reported estimates of age, PA, waist circumference (WC), and resting heart rate, and they have shown high correlation with direct measures of VO_{2max} for men and women (r = 0.74-0.79) [54].

Cardiorespiratory fitness is often expressed as $mlO_2 \bullet kg^{-1} \bullet min^{-1}$ or by metabolic equivalents (METs) to categorise the CRF. One MET is equal to the amount of oxygen the body uses at rest (MET 0 3.5 mL O_2/kg/min) [55]. According to *The Compendium of Physical Activity,* commuter cycling requires 6.8 METs [56], which may be understood as almost seven times the energy used at rest. On average, the fitness levels of young to middle-aged adults range from 8 to 12 METs [55].

In the first published meta-analysis of CRF and its dose-response relationship to CVD and CHD events, a 1-MET increase in maximal aerobic capacity or cardiorespiratory fitness was associated with a 15% reduced risk of CHD [57]. In a longitudinal study of middle-aged men, CRF was associated with an 11% reduction in risk for each MET increase [58]. This relationship was confirmed in a meta-analysis of cohort studies investigating CRF and strokes [59]. Wang and colleagues [59] found that a higher CRF could reduce the risk of stroke by 42% and CRF was more protective for women (59%) than for men (40%). One MET increment in CRF level reduced the risk of stroke by 3%. A 5-MET increase reduced the risk by 15%. Although the biological mechanisms of the phenomenon are unclear [59], there is strong evidence for an inverse relationship between CRF and CVD.

Hypertension

Hypertension (i.e., high blood pressure) is defined as systolic blood pressure (SBP) of ≥ 140 mmHg and diastolic blood pressure (DBP) of ≥ 90 mmHg. Blood pressure is measured in two phases: 1) when the heart is contracting (SBP) and 2) when the heart is relaxing (DBP). In 1983, Paffenbarger and colleagues observed that men who did not participate in vigorous PA were at 35% greater risk of hypertension, compared to men who did [48]. Today, it is well established that hypertension is one of the leading risk factors for CVD incidence and CVD mortality [60], as it is a result of narrowed blood vessels and reduced elasticity (endothelia function) in the vessels due to the atherosclerotic process. Physical activity can affect blood pressure by the regulation of the endothelia function [41]. A systematic review and meta-analysis of randomised controlled trials (RCTs) found that endurance training significantly reduces both DBP and SBP among healthy adults [61]. Larger blood pressure reduction was observed for short exercise durations at moderate to high intensity [61]. However, others have found that vigorous aerobic exercise is not more protective than moderate intensity [62].

Overweight and obesity

Obesity has become a major worldwide health problem. Since 1980, the prevalence of obesity has doubled in more than 70 countries, and most of the other countries have been continuous growth [37]. Overweight and obesity are associated with CVD incidence and CVD mortality [37, 63, 64]. At the global level, more than 40% of deaths related to body mass index (BMI) were caused by CVD among obese adults [65]. Both CVD incidence and CVD mortality are expected to increase as the obesity pandemic continues [65]. Obesity increases CVD risk through a wide range of risk factors, including those associated with MetS [65, 66]. Adipose tissue is active tissue that mediates both metabolic and vascular processes [66]. Its presence causes changes in lipids, blood pressure, coagulation, and inflammation, all of which are known to cause endothelia dysfunction and atherosclerosis [66]. However, some studies have observed a reduced risk of death among overweight people, compared to normal weight people [67]. This is known as the 'obesity paradox'. Nonetheless, a meta-analysis of observational studies provides evidence of a continuous increase in risk of death as BMI increases above 25 [68]. In CVD prevention, weight management is a crucial component. However, most people with obesity do not achieve or sustain sufficient weight loss [69].

Overweight and obesity may be investigated by a variety of methods, such as BMI, waist-to-hip ratio, WC, waist-to-height ratio, and body fat percentage. The WHO defines overweight and obesity by a classification of BMI (kg/m^2), which is the ratio of the body mass in kg divided by the squared height measured in metres. The WHO proposes the following classification: underweight (< 18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obesity (≥ 30.0 kg/m^2) [70].

Dyslipidaemia

Dyslipidaemia may be defined as 'increased levels of serum total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), or triglycerides (TG) and reduced serum high-density lipoprotein cholesterol (HDL-C) concentration' [71]. In large observational studies, a strong and graded relationship is observed between higher levels of LDL-C, lower levels of high-density lipoprotein cholesterol (HDL-C), and increased risk of CHD [72]. Further is the negative role of TG on atherosclerotic CVD well document [73]. The prevalence of dyslipidaemia is dramatically high in the adult population, where more than every second adult has dyslipidaemia [74].

Total cholesterol levels are affected by the diet, albeit cholesterol is naturally in the body, as it is produced by the liver [65]. Triglycerides constitutes most of the lipids in the body. When the level of LDL-C exceeds the normal range, LDL-C contributes negatively to the atherosclerotic process, as it delivers cholesterol to the tissues in the blood vessels. Dyslipidaemia is therefore one major risk factors for atherosclerotic CVD [71], and therefor are above mentioned markers often assessed aiming to evaluate CVD risk [71]. In contrast to LDL-C, TG and TC, HDL-C may reverse the atherosclerotic process as it transports the cholesterol from the blood and tissue to the liver [65].

Physical activity in general and improved CRF have been shown to increase the level of HDL-C and reduce levels of TC, TG and LDL-C [75-77], as lipids are a necessary source of energy when physically active. In a systematic review with meta-analysis with a total of more than 800 participants, found that both moderate intensity endurance training and high intensity interval training resulted in improving the lipid profile [78]. However, may high intensity lead to a larger improvements in HDL-C than moderate intensity [78].

Assessment of commuter cycling

Data of commuter cycling can be derived from observational studies – such as cross-sectional, longitudinal, and cohort studies, where commuter cycling is measured by self-administered questionnaires. However, data on commuter cycling are also derived from transport research. Comparisons of the data are difficult because the measurements are not standardised and various methods and indicators are used [7]. In observational studies, cycling is often described as cycling to work, while transport research data from electronic counters concern the percentage of trips made via different transportation modes. The former are based on individuals and can estimate the prevalence of commuter cycling in the population, while the latter are ecological (i.e., the number of trips is assessed, but not the number of individuals passing the electronic counters). However, most people commute to and from work, so changes in the number of trips may also reflect trends in commuter cycling.

Part II of our systematic review with a meta-analysis [79] found that the self-reported data from observational studies on bicycling are challenged by a wide range of definitions. The studies have variously examined bicycling as the usual mode of travel [80], bicycling as a mode of travel used during the past 3 months [81, 82], 7-day recall about use of different transport modes [83], the dominant mode of transport used by participants during the summer months [84], and daily commutes by cycling of more than 60 minutes [85].

Self-reported data are included in transport research such as the national travel survey (RVU). Here, cycling rates are measured as a percentage of the trips undertaken using different transportation modes, as distance travelled, or depending on the purpose for which the travel was conducted. A third option is to use objective measures, with stationary counters employed to capture a national bike-traffic index to detect changes in cycling rates [86]. In motorised traffic, the method of detection by stationary counters has been used widely since the 1960s [87]. However, the technology of automatic passage sensors has been used since the 1930s, and the first vehicle passage sensor was a pressure-sensitive device [87]. For modern traffic management systems, sensors are necessary to maximise the efficiency and capacity of existing transportation networks due to the continual increase in traffic volume [87].

In Norway, inductive loops and piezoelectric strips are common technologies used for detecting bicycle riders. The inductive loop is a detection system that senses metal objects that pass over the in-ground 'loop' [88], and piezoelectric counters generate a count when the material in the ground is physically deformed [89]. The monitors provide a timestamp and note the direction and speed of the object passing. The advantages of the inductive-loop sensors are the well-understood technology, its wide experience base, its provision of basic traffic parameters, and it is insensitivity to weather (e.g., rain, fog, and snow) that means they are more accurate than other commonly used techniques [87]. However, the weaknesses of the inductive-loop sensors include the need to cut into the pavement and the possible decrease in pavement life, as well as the multiple loops required to monitor a location [87].

To detect bicycle riders (or trips), multiple counters are used and all are prone to error. However, the accuracy of the detection system varies depending on the technology (i.e., piezoelectric or inductive loops) and between the products [89]. The errors can be classified as either missed detection or false detection, and they may be presented as a percentage, derived from the following formula [90]:

$$Error = \left(\frac{Technology\ Count - Actual\ Count}{Actual\ Count}\right) \text{x } 100\%$$

To detect the bicycle, it is essential to ensure that the rider rides over the detecting zone [87-89]. In general, almost all types of counters undercount trips, with a variation of between 0.3 and -50.8% [89] [90], where a negative value indicates underestimation. Counting errors arise for several reasons, and occlusion error (missed detection error) is the most commonly reported [89]. Occlusion errors arise when two or more riders pass the sensor at the same time [89], which can occur when children or adolescents bicycle together. Missed detections also include bypass errors [90]. These arise due to the sensors' limited detection zone, as the loops do not necessarily cover the entire width of the road. The cyclist may either cycle around the edge of the loops or ride on the road and not the infrastructure where the monitor is located (i.e., riding on the road next to walking or cycling path) [90]. This is a common problem for inductive loops. False detection (overcount) is when a trip is counted but no trip has taken place [90]. This is a particular problem for passive infrared sensors, and it may be triggered by temperature, reflection, and background inference [90]. For induction loops, false detection may occur due to misclassification of objects (i.e., strollers or scooters are counted as trips).

The sensors most commonly used in Norway to detect bicycle trips are highly accurate. When automatically and manually observations are compared, the inductive loop and piezoelectric monitors have been shown to have high accuracy and correlation, with Pearson's r of 0.99 and 1.00, respectively [89]. An underestimation of -1.7% to -2.7% of the trips counted by piezoelectric counters and indictive loop monitors has previously been detected [89]. Under testing, the monitor manages on average of 128-129 counts (283-355 maximum) per hour [89]. The hourly volume that the detectors can handle is well within the average volume at most of the Norwegian counting sites.

Over the last decade, new methods of bicycling monitoring have emerged due to the technology revolution. With mobile devices and the Big Data revolution, monitoring bicycling can be conducted by new methods [91]. There is a growing market for commercial data services, with fitness tracking applications being the most commonly used for bicycling [91]. Strava Metro is an application that supports PA recording by global position system (GPS). It could be defined as a continuous counting system, covering an area of interest [91]. Strava Metro covers all areas in which there are users of the application [91]. There is uncertainty, however, about the representativeness of the data for the general population and sampling bias. However, it has been used in several areas (e.g., travel-pattern identification, travel-demand estimation, and air-pollution-exposure assessment) in the last five years to enhance understanding of bicycling [91].

Cycling for transportation and cardiovascular disease

Active travel is associated with reduced all-cause mortality [17-19], and it may improve health on the population level [20]. Active travel is a type of PA with great potential, and commuter cycling in particular improves CVD. Active travel is inversely associated with obesity at both the country [21] and individual levels [22] and has promising associations with lower levels of CVD risk factors [7, 19]. Therefore, active travel may be an effective approach to increasing PA levels and reducing the risk of CVD and associated risk factors. Active travel may appeal to many people uninterested in sport as a means of being physically active, and it is thus a feasible method of encouraging more people to meet the recommended guidelines for PA. Hamer and Chida [23] examined the association between active travel and cardiovascular risk. They included prospective cohorts with cardiovascular outcomes in the meta-analyses. Adjusted for other forms of PA, active travel had a protective effect on cardiovascular outcomes of RR 0.89 (CI: 0.81-0.98). In an 18-month RCT of 120 abdominally obese women, a intervention focusing on active travel to increase both walking and/or cycling as a transportation method significantly reduced WC among the participants [92]. One limitation of research studies investigating active travel is that they often combine walking and cycling [20]. Walking and cycling are often merged in this way due to active travel by foot or cycle being relatively uncommon, which reduces the statistical power. For example, in the UK, less than 1% of the population uses bicycles as a primary transportation mode [40]. Higher rates of cycling for transportation are observed in Western European countries such as Denmark and the Netherlands, with 25% and 21-26%, respectively [7]. The rarity of different commuter modes limits the ability to compare transportation modes; and as a result, walking and cycling are merged into 'active travel'. However, compared to walking, commuter cycling seems to be associated with higher CRF among children [93, 94], men [95], and women [95]. Self-selected intensity is often higher for cycling than for walking [24], and the average energy expenditure during bicycling is approximately two-fold higher than for walking [96]. Higher exercise intensity is associated with a further reduction in risk of CHD [25]. In addition, cycling may be more efficient for preventing CVD than walking because people travel longer when cycling than they do when walking [93]. As there is a dose relationship between PA and all-cause mortality, cycling might therefore be more efficient than walking [97]. The superiority of cycling for CVD prevention [20] may also be a combination of intensity and total PA [93].

In the last few years, there has been a focus on commuter cycling as a means of improving public health and reducing the risk of CVD. However, in 2000, an association between lower risk of all-cause mortality among commuter cyclists was observed [18]. Commuter cycling has also been associated with reduced risk of a number of illnesses, such as type 2 diabetes [98], CVD [99], cancers [100], and obesity [82]. Oja and colleagues [20] summarised the evidence of cycling-specific health benefits. They observed a consistent inverse relationship between commuter cycling and CVD and cardiac heart disease mortality among middle-aged and elderly adults in prospective cohort studies. Since the literature review of Oja and colleagues, several further studies of commuter cycling and CVD have been published. In a cross-sectional study of children cycling to school, cycling was associated with significantly lower BMI and lower odds of being obese, compared to passive travellers [99]. In a prospective population-based study, with 5-year follow-up and more than 250,000 participants, cycling for transportation was associated with lower risk of both CVD incidence and mortality [40]. In a prospective study with 14-year follow-up, commuter cycling was consistently associated with lower risk of diabetes [98]. In intervention studies, commuter cycling is shown to consistently improve cardiovascular risk factors [24, 95, 101-103].

Since the publication of our two systematic reviews with meta-analyses in 2019, more and stronger evidence of the positive association between CVD incidence and CVD mortality and commuter cycling have been presented. To our knowledge, six cohort studies [104-108], one ecological design [109], two RCTs [101, 110, 111], and two reviews with meta-analyses [112, 113] have been published. All the recently published cohort studies with a follow-up time of between 9 and 25 years show consistently reduced risk of both CVD mortality and CVD incidence. However, no relationship between commuter cycling and CVD incidence was observed in the nationwide ecological study from England (hazard ratio [HR] 0.996 [0.983 – 1.010]). Stronger evidence is provided by a systematic review of cycling and both all-cause mortality and CVD mortality, where a linear relationship with all-cause mortality was observed, whereas the relationship was U-shaped for CVD mortality [112]. The GISMO study [110], the latest published RCT of 12-month commuter cycling among hospital employees in Sweden, found the same effect on CRF as observed in previously published RCTs [24, 95, 101, 103, 114]. However, the GISMO study did not show any effects on other CVD risk factors [111].

Socioecological model and interventions to increase cycling

Interest in ecological models has increased over recent decades due to the possibility of developing a population-wide approach to reducing health problems such as CVD [115]. Socioecological models of health behaviour incorporate a range of factors that may affect people's behaviour. By this ecological models underline multiple levels of influence, and it guides to more inclusive interventions [115]. Ecological models consider behaviour at multiple levels of influence and often include the following six categories: 1) intrapersonal, 2) interpersonal, 3) organisational, 4) community, 5) physical environment, and 6) policy [115]. When all levels are included in an intervention approach that systematically seeks change, the possibilities of behavioural change are expected to be enhanced [115]. Already in 1986 the Ottawa Charter for Health Promotion [116] stated that health behaviours would be maximised when the environment and policies supported healthy choices and individuals were motivated and educated to make those choices. Several ecological models and frameworks have since been adapted and developed, and one of the most common is the McLeroy and colleagues [117] ecological model of health behaviour. This model consists of five interrelated levels. The first level is *intrapersonal* factors. This includes knowledge, attitudes, behaviour, skills, and so on. The second level, *interpersonal processes and primary groups,* covers formal and informal social networks and support systems, such as family, colleagues, and friends. The third level, *institutional factors,* covers social institutions with organisational characteristics, formal rules, and regulations. The fourth, *community factors*, is the relationships among organisations, institutions, and so on, within defined areas. The final group is *public policy*, referring to local, regional, and national laws and policies. The levels reflect the possible areas for interventions [117]. Over the last decade, it has become more common to investigate the relationship between the individual and the environmental level in accordance with the ecological model [118]. Furthermore, there has been increased interest in the environment and its relationship with PA in general [119, 120] and active travel in particular [119, 121].

In the latest WHO strategy for increasing PA, a 'whole system approach' was introduced. System maps can be used to visualise complex behaviour [26], including that of commuter cycling. All levels of the socioecological theory are displayed on the map, thus illustrating the complexity of the factors influencing cycling-related behaviour.

Individual and environmental factors in commuter-cycling choices

The popularity of commuter cycling varies across and within countries. For example, in the UK, less than 1% of the population uses a bicycle as a primary transportation mode [40], while higher rates of commuter cycling are observed in Western European countries such as Denmark and the Netherlands [7]. In Norway, the proportion of bicycling as a primary transportation mode have been steady at around 5% since the 1990s [122]. Many of the studies exploring the associations between individual and environmental factors and cycling have been conducted in countries with high number of cyclists. In countries with high numbers of cycling, citizens annually bicycle between 600 km and 900 km per year [123]. Corresponding distances for moderate and low volume countries is 150 km to 300 km, and 30–100 km, respectively. Compared to the other European countries, Norway was defined as a country with medium volume of cycling [123].

Cycling rates also vary across geographies (between cities and between neighbourhoods) [124], indicating the role of policy and practice in shaping commuter cycling behaviour. Due to all positive implications of commuter cycling, it is important to understand the characteristics of those who are cyclists and those who are not, for the purposes of better facilitating commuter cycling. In the following section, I will present individual and environmental factors associated with the decision to engage in commuter cycling.

Individual factors

In the Netherlands, a country with a higher levels of commuter cyclists, cyclists live closer to work and are more physically active [125]. In Australia, commuter cyclists are younger and better educated than non-cyclists and more likely to be male [126]. Further increase the probability to cycle for transportation when individuals report positive attitude towards cycling [127, 128] and perceive behavioural control [127]. In the urban population in Canada, the probability of cycling is reduced with higher age, being female, having lower education or higher income [129].

In a recently published systematic review of factors affecting commuter cycling preference [130], age was found to be one of the most investigated factors, and a negative association between commuter cycling and age is observed. Gender was another well-investigated factor, and it is consistently shown that males are more likely than females to be cyclists [130]. The systematic review further found inconsistent findings for both ethnicity and income [130]. Regarding income, some studies report increased probability of cycling with higher income, others demonstrate a negative relationship between the two, and some studies report a U-shape [130]. Among health-related outcomes, obesity and chronic diseases were negatively associated with probability of commuter cycling, while being active and physically fit have a consistently positive association with commuter cycling [130, 131].

To our knowledge less is known about individual factors associated with cycling in countries like Norway. In a study with comparable volume of cycling to Norway, the probability of cycling was increased when individuals were physical active during leisure time, and especially for women the probability of active travel increased with higher proportion of cycle paths [121]. In the following section, environmental factors (such as cycle path) associated with cycling is presented.

Environmental factors

Environmental factors can be classified as concerning either the natural environment (i.e., topography, weather, green spaces) or the built environment (i.e., street connectivity, density, neighbourhood). For the natural environment there is conflicting results [130]. The weather seems to be a large barrier for those not currently commuting by bicycle, but this was not deemed important by those already commuting by bicycle [130]. Further has cold and rainy weather been reported as a barrier to commuter cycling, but high temperatures and humidity were similarly reported [129, 132]. Previous studies have observed that distance [133] and time to travel by bike relative to time by car [133] also affect people's choice of cycling as transportation. In Canada hilliness has been observed as one major barrier for cycling [134].

The built environment is hypothesised to influence travel due to the '3Ds': density, diversity, and design [135]. In a systematic review summarizing the evidence of cycling and the built environment (including cycling facilities, street connectivity and access to non-residential destinations) from 2007 to 2017, the built environment were strongly associated with cycling for transportation [136]. Cycle-friendly infrastructure, street connectivity, and reduced distance are all associated with increased commuter cycling [130]. In Finland, a country comparable to Norway, cycle-friendly infrastructure was associated with increased likelihood for commuter cycling [121]. In the Nordic environment, the presence of cycle-friendly infrastructure was more important than individual factors such as education and physical activity [121]. Further have several studies observed positive associations and effect between cycling-friendly infrastructure and commuter cycling [131, 133, 137-141]. In European cities with low to medium cycling levels there is observed a strong linear relationship between meters of cycle-friendly infrastructure per citizen and number of cyclists [140]. Others have found that cycle-friendly infrastructure explains one third of variation of commuter cycling rates [139, 141]. However, when several built environmental factors are analysed together, the relationship seem not to be linear [142]. Mechanisms of observed increase in cycling varied between interventions, previous used mode for transportation and distance between home and origin [143]. In a systematic review of interventions in the built environment to promote cycling, interventions aiming to increase accessibility and safety seem to be key factors for success [143]. However, other have found that perceived safety mainly is important for cycling in general [136]. When interventions in the built environment does not increase the level of cycling, this may be of several reasons such as to short time from intervention to follow-up and to small changes in the environment was made [143]. However, the authors also noted that often was the outcomes measured not sufficient specific to the intervention [143], and thus may some study report results not be valid. Koohsari and colleagues [142] observed that the built environment needed to reach high level of cycle-friendliness to increase the probability of cycling, as changes from poor to medium level of cycle-friendliness was not sufficient to increase the probability of cycling [142]. Further seems the importance of the built environment to be mediated by personal factors, as infrastructure is generally required but not sufficient alone to increase cycling rates [27]. While the literature in the field of the build environment is inconsistent, the large proportion of cyclists in Copenhagen, Denmark, is adequately explained by the well-built, cycle-friendly infrastructure found in both rural and urban areas [144].

How can we identify trends in cycling at the local, regional, and national level?

Official Norwegian strategies and recommendations have sought to increase PA in the general population [145, 146] and highlight the necessity of interdisciplinary strategies for promoting PA, including active travel (e.g., cycling). The Norwegian Public Road Administration (NPRA) launched a national strategy for cycling in 2012 [147]. This strategy acts as a base document for the national transport strategy 2014-2023 and highlights the need for increased use of cycling as mode of transportation, and the strategy is restated in the latest national transport strategy [148]. The primary objective of the national strategy is to increase proportion of total daily trips by cycle to 8% at a national level by 2023. In addition, the strategy aims for 80% commuter cycling for children traveling to school, the promotion of cycling as a mode choice, doubled usage of bicycles in high-density cities and municipalities, and an increase in safety and 'bikeability' [147]. However, since the 1990s, the proportion of cycling trips has decreased from 7% to 4% in Norway [149]. The number of total trips is particularly low when one takes into consideration that 80% of the population has access to a bicycle [149].

The national strategies for active travel and the increased interest in cyclists have resulted in projects such as the Førde package[1]. In 2012, the Førde municipality signed an agreement with NPRA and Sogn og Fjordane County authority to become a 'cycle city'. The aim of this agreement is to 'increase bicycle use, among other things by transferring transportation from private cars to cycling'. To increase sustainable commuting, the road network in the Førde

[1] https://www.vegvesen.no/vegprosjekter/fordepakken

municipality will be upgraded with 154 million Euros granted through the Førde package. The upgrades will see the construction of new infrastructure for cycling and walking, over a period of eight years, starting in October 2016. Twenty interventions are proposed in the Førde package's master plan and they include separate bike lanes, shared lanes with walkers, shared lanes with drivers, and cycle roads.

The approval of the Førde package illustrates that policymakers are particularly keen to increase the share of cyclists in Norway, as cycling allows fast and efficient urban travel, requires minimal area for tracks and parking, and creates no air or noise pollution [150, 151]. Such infrastructure interventions have shown promising results in increasing the number of cyclists [137, 139, 152, 153]. When changes in the built environment are made, (e.g., by the Førde package) the opportunities for observing the possible changes in the travel habit are small and seldom at with high research standard. In Norway, there is a surveillance system for children and adolescents (6, 9, and 15 years of age [PANCS]) [154], and repeated cross-sectional studies (both HUNT and KAN) have examined PA in a representative population of the adult population. These systems are based on questionnaires and PA objectively measured by accelerometers. The questionnaires are developed for variety of reasons but usually to collect data on leisure-time and job-related PA [155]. Owing to the technology revolution, measurement methods of PA have progressed. Researchers and others interested in measuring PA started to use pedometers and, later, accelerometers. In general, accelerometers more accurately reflect the actual amount of PA that occurs throughout the day, but different devices provide different estimates of time spent in action of various intensities [156]. When measuring cycling as a mode of PA, the results of accelerometers should be interpreted with caution, as accelerometers have been shown to underestimate by 2.7 minutes MVPA per kilometre cycled [157].

National travel surveys were conducted every fourth year until 2018, and they are now conducted annually. In addition, cycle trips are observed by stationary counters (hereafter 'counters'). As of May 10, 2021, the NPRA have 216 counters in mostly urban areas across Norway. However, the counter can only describe the trends at the sites. In late autumn 2020, the NPRA launched bike traffic indices for some cities, but they only compare two subsequent years (e.g., 2019 and 2020).

A bike traffic index organised at different levels (i.e., regional and national), such as the Danish bike traffic index [86], may provide a reference point and be helpful for municipalities wanting to evaluate cycling-specific public health actions [158]. A bike traffic index based on bicycle counters may be more valid than surveys, as this would reflect the actual number of passing cycle trips independent of residence, age, or recall bias [86]. Furthermore, as the index is based on continuous counting, the model is sensitive to actual changes [86]. Therefore, we aimed to develop a sensitive bike traffic index for use at the local, regional, and national levels, with the goal of providing a public, sensitive, and robust tool for evaluating trends in cycling over long periods of time, modelled on the Danish index and customised to Norwegian needs.

Research gaps

Increasing PA levels in a population is challenging, as many people are not interested in sports or other physical leisure activities. In the last few years, there has been increasing focus on commuter cycling as a means of improving public health and reducing the risk of CVD [81, 82, 159]. One limitation of previous research studies on active travel is that they often combine walking and cycling [20]. This is a problem because cycling is often performed at a higher exercise intensity than walking [24], and higher exercise intensity is associated with greater reduction in risk of CVD [25]. Therefore, cycling may be more effective than walking for preventing CVD [20]. When we planned our systematic reviews with meta-analyses, the association between CVD and cycling had not, to our knowledge, been previously examined. However, two meta-analyses examining CVD and active travel [23, 160] and a literature review on cycling [20] had, in fact, been published. Hamer and Chida called for further studies to examine the association between active commuting and cardiovascular risk and to investigate the dose-response relationship. Furthermore, there was a call for more precise knowledge of the effects of cycling interventions [158]. There were promising results on the promotion of commuter cycling as a public health strategy. However, stronger evidence was needed to support commuter cycling as a strategy for improving public health and reducing CVD and associated risk factors, and so we conducted a systematic review and meta-analysis of studies on the association between cycling and CVD (incidence and mortality) and CVD risk factors. This study fills the gap in the knowledge concerning the dose-response relationships of cycling and provides deeper insights into gender difference and the benefits of cycling, analysing a worldwide population of more than one million children and adults. Our meta-analyses may be of great interest to academics, policymakers, and stakeholders, as they provide robust evidence for the promotion of commuter cycling as a health-enhancing PA.

Due to the positive implications of commuter cycling, it is important to understand the characteristics of cyclists. Some evidence exists for patterns in personal characteristics (such as PA, age, and level of education), but there are conflicting results concerning the importance of built and natural environments, especially in countries with a smaller number of cyclists, such as Norway. To explore this, we conducted a cross-sectional study of the self-reported characteristics of cyclists in Norway and objectively measured the environmental characteristics around their residences and along commuter routes using geographic information systems (GIS).

Norway has initiated national, regional, and local strategies for promoting cycling for transportation. A system that is sufficiently sensitive to observe real-world changes is an important tool for evaluating public health actions. However, there is a need for robust methods of evaluation in Norway. It is hoped that politicians, city planners, and others may be able to use local, regional, and national bike traffic indices to evaluate the rates of cycling in their areas of interest. A national bike traffic index would also be a valuable tool for describing trends over time.

Aims and research questions

The aim of this thesis was to investigate the relationship between cycling and CVD and its associated risk factors and to investigate individual and environmental factors that may affect Norwegian people's choice to travel by bicycle. We also aimed to develop a sensitive method to describe the trends in cycling in Norway. More specifically, this thesis aims to answer the following research questions:

Studies I and II

What are the CVD-related benefits of cycling?

We aimed to assess the strength of the association between cycling and (a) CVD and (b) CVD risk factors compared with non-cyclists. We hypothesised that there would be similar associations for men and women and a dose-response relationship between cycling and CVD.

Study III

What individual and environmental factors are associated with commuter cycling in Norway?

We aimed to describe (a) the individual characteristics of cyclists in a country with low levels of commuter cycling and (b) objectively measured environmental factors associated with commuter cycling in areas around cyclists' residences and along commuter routes.

Study IV

What are the trends in cycling at local, regional, and national levels?

We aimed to a) develop a Norwegian bike traffic index and b) describe the national trends among the observed cyclists.

MATERIALS AND METHODS

In this chapter, the materials and methods for the three research questions are presented. First the methods for the two systematic reviews with meta-analyses (Studies I-II) are presented, followed by presentation of the materials and methods for the survey combined with objectively measures outcomes (Study III), and finally a simplifies method of the development of the national bike traffic index (Study IV). As the methodological have large variation, the statistics are presented sequentially.

Studies I and II: Systematic literature review with meta-analyses

We conducted a systematic review with meta-analyses. Due to differences in the statistical methods used to analyse the outcome measures, we choose to present the results in two separate papers: Study I (dichotomous) and Study II (continuous).

We searched four electronic databases (Web of Science, MEDLINE, SPORTDiscus, and Scopus) for published quantitative studies that examined the association between cycling with CVD or CVD risk factors, with a publication date of before August 8, 2017. In total, 5,174 records were identified, from Web of Science (3,525), MEDLINE (via EBSCO; 522), SportDiscus (41), and Scopus (1086). The search strategy involved the key terms ‘cycling’ OR ‘bicycling’ OR ‘biking’ OR ‘commuter cycling’ AND ‘CVD’ OR ‘CVD risk factors’ OR ‘CVD risk factor’ OR ‘cardiovascular disease risk factors’ OR ‘cardiovascular disease’ OR ‘cardiovascular diseases’ OR ‘cardiovascular disease*’. We hand-searched the reference lists of the included studies and contacted experts in the field to identify any studies that may have been missed in our electronic database search.

Inclusion criteria and selection process

Two reviewers independently assessed the studies for eligibility, with subsequent consensus by discussion. Studies were excluded if they measured domains other than cycling (e.g., stationary cycling) or if cycling were part of a rehabilitation programme or intervention or investigated an unhealthy population. We had no criteria for sample size. We included studies that 1) employed a quantitative design and studied a general population; 2) assessed cycling exposure either as a mode of transportation or as a recreational activity; 3) measured CVD, CVD mortality, or physiological CVD risk factors as an outcome; and 4) reported dichotomous (Study I) or continuous (Study II) outcome measures.

Risk of bias assessment

The included studies were assessed according to the quality assessment tool of quantitative studies [161]. The tool considers six dimensions: representativeness of the target group, study design, confounding factors, blinding of both assessors and participants, reliability and validity of measures, and numbers of withdrawals and dropouts. Each component was rated ‘weak’, ‘moderate’, or ‘strong’, following a standardised rating system in which ‘weak’ and ‘strong’ indicate poor and high quality, respectively. Studies with no weak components were rated as ‘strong’, studies with one weak component were rated as ‘moderate’, and studies with more than one weak component were rated as ‘weak’. For detailed information on the distribution of study quality, see Table 1.

Data extraction Study I

Data extraction was based on the main estimate exposure, which was defined in accordance with the protocol as ‘any cycling’. Main outcomes were defined *a priori* as CVD mortality, CVD incidence, and CVD risk factors. CVD and CHD were treated as CVD for both CVD mortality and CVD incidence. In studies where RR was presented by more than one model of adjustment, the most conservative estimate was included. If both CVD mortality and CVD incidence were reported [40], CVD incidence was included, due to higher numbers of cases.

Data extraction Study II

Data extraction was based on the main exposure. The main outcome was ‘CVD risk factors’. The risk factors were categorised into the following seven categories: body composition, PA, CRF, blood lipids, blood pressure, diet, and physical fitness measures other than CRF. The categories of diet [103] and physical fitness other than CRF [81, 84] were excluded from the meta-analysis due to there being too few (≤ 2) unique studies. In intervention studies lasting more than six months [95, 103], we included results from the first six months.

Table 1. *Quality assessment of included studies based on the quality assessment tool of quantitative studies [75].*

	Study	Year	Selection bias	Study design	Confounding factors	Blinding	Data collection	Withdraws and dropouts	Global rating*
Dichotomous, Study 1	Hoevenaar-Blom et al. [162]	2011	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
	Koolhaas *et al.* [163]	2016	Weak	Moderate	Strong	NA	Moderate	Moderate	Moderate
	Armstrong *et al.* [164]	2015	Moderate	Moderate	Moderate	NA	Strong	Weak	Moderate
	Blond *et al.* [165]	2016	Weak	Moderate	Strong	NA	Moderate	Moderate	Moderate
	Andersen ZJ *et al.* [166]	2015	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
	Celis-Morales *et al.* [40]	2017	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
	Matthews *et al.* [100]	2007	Strong	Moderate	Strong	NA	Moderate	Strong	Strong
	Besson *et al.* [167]	2008	Weak	Moderate	Moderate	NA	Moderate	Weak	Weak
	Oja *et al.* [168]	2017	Moderate	Moderate	Strong	NA	Moderate	Strong	Strong
	Sahlqvist *et al.* [169]	2013	Moderate	Moderate	Strong	NA	Moderate	Moderate	Strong
	Grøntved *et al.* [99]	2016	Moderate	Moderate	Strong	NA	Moderate	Moderate	Strong
	Laverty *et al.* [170]	2013	Weak	Weak	Strong	NA	Moderate	NA	Weak
	Wen *et al.* [171]	2008	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
	Østergaard *et al.* [172]	2012	Moderate	Weak	Moderate	NA	Weak	NA	Weak
	Bere *et al.* [173]	2011	Weak	Moderate	Moderate	NA	Moderate	Weak	Weak
	Sahlqvist *et al.* [126]	2012	Weak	Weak	Strong	NA	Moderate	NA	Weak
	Millett *et al.* [174]	2013	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
	Berger *et al.* [175]	2017	Weak	Weak	Moderate	NA	Weak	NA	Weak
	Evenson *et al.* [176]	2003	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
	Hu *et al.* [85]	2001	Strong	Weak	Moderate	NA	Moderate	NA	Moderate
	Ramirez-Velez *et al.* [177]	2017	Strong	Weak	Moderate	NA	Moderate	NA	Moderate
Continuous, Study 2	Andersen *et al.* [80]	2011	Moderate	Weak	Strong	NA	Moderate	Moderate	Moderate
	Andersen *et al.* [84]	2009	Moderate	Weak	Moderate	NA	Moderate	NA	Moderate
	Larouche *et al.* [81]	2016	Weak	Weak	Strong	NA	Moderate	NA	Weak
	Boone-Heinonen *et al.* [159]	2009	Moderate	Weak	Strong	NA	Moderate	Moderate	Moderate
	Møller *et al.* [178]	2011	Weak	Strong	Strong	Moderate	Strong	Moderate	Moderate
	De Geus *et al.* [179]	2008	Moderate	Strong	Moderate	Weak	Strong	Strong	Moderate
	De Geus *et al.* [103]	2009	Moderate	Moderate	Moderate	Moderate	Strong	Strong	Strong
	Bueno *et al.* [180]	2017	Moderate	Weak	Weak	NA	Moderate	NA	Weak
	Fuller *et al.* [82]	2014	Moderate	Strong	Strong	NA	Moderate	Moderate	Strong
	Yang *et al.* [83]	2012	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
	Østergaard *et al.* [181]	2012	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
	Østergaard *et al.* [182]	2012	Moderate	Weak	Moderate	NA	Weak	NA	Weak
	Hendriksen *et al.* [95]	2000	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
	Oja *et al.* [183]	1991	Weak	Strong	Moderate	Weak	Strong	Strong	Weak
	Hu *et al.* [85]	2001	Strong	Weak	Moderate	NA	Moderate	NA	Moderate

Not applicable: NA

*Weak, moderate, and strong indicated poor, moderate, and high study quality, respectively.

Statistics

The analyses were performed in Stata v.12.1 (StataCorp LP, USA), using user-written commands described by Egger *et al.* [184], with random estimate models.

Heterogeneity is presented as I^2 and the p-value. The I^2 was calculated using the Stata-derived test for heterogeneity (Cohen's Q) and degrees of freedom (df):

$$I^2 = 100\% \times (Q-df)/Q$$

As proposed by Higgins *et al.* [185], I^2 describes the percentage of total variance across the studies, with values of between 0% and 100%, where 0% indicates no heterogeneity. Negative values were set equal to zero [185]. Heterogeneity was tested in all analyses. Following the rule of thumb described by Sterne *et al.* [186], the test for funnel plot asymmetry was only used when there were > 9 studies in the meta-analysis. In all analyses, we ensured that individuals were not analysed more than once (i.e., 'overweight or obese' and 'obesity').

Statistics Study I

Studies were only included once for CVD incidence and CVD mortality but may have been included in different subgroup analyses or for equivalent CVD risk factors. For analyses of CVD incidence or CVD mortality, we calculated pooled RR or pooled HR. For analyses of each CVD risk factor, we calculated adjusted odds ratio (OR).

The estimates are presented as multivariate adjusted RR (CVD incidence and CVD mortality) or OR (CVD risk factors), with 95% confidence intervals. Dose-response relationships and differences between the sexes were analysed using meta-regression and presented as β-coefficients and p-values.

Statistics Study II

The estimates are presented as the standardised mean difference (SMD), with 95% confidence intervals (CI). Dose-response relationships were analysed by meta-regression and are presented as β-coefficients and p-values.

Study III: Correlates of commuter cyclists in Norway

Sample

During the spring and autumn of 2017, we invited all public sector employees in three Norwegian counties (Sogn og Fjordane, Aust-Agder, and Vest-Agder [hereafter 'Agder']) to participate in a web-based questionnaire survey. From a list provided by Statistics Norway, we contacted all public sector institutions, contact people, councillors, health coordinators, and IT employers by email, with a request to provide their employees' email addresses. In total, was there 74,500 eligible public employees. In cases of unclear replies or non-response, the institution was contacted by phone to clarify. Where we received positive responses, we collected email addresses and names. In total, 76 institutions agreed to participate, and 27,663 email addresses were obtained. Additionally, 13 institutions were willing to participate but refused to provide email addresses. In these cases, a separate link was assigned for survey access, using the identifier of the institution. Among these 13 institutions, 10,634 potential responders were given access via the link distributed by the institution. Combining the open link and the unique links sent by email, 38,297 public employees were given access to the survey.

In total, 3,540 individuals (9.2% of those invited) began the survey. To be included in the analysis, dependent and independent variables needed to be reported. We included individuals aged between 18 and 72 years. Ultimately, 1,196 individuals were included in the study (see Figure 2). In the sub-analysis of distance cycled, 19 cases were excluded due to distances of >35 km between their residences and workplaces.

A 'cyclist' was defined using the definition of the Active Transport Norway questionnaire [187]. In the present study, we included only the destination 'work'. Those who reported one or more weekly trips were classified as cyclists and the rest as non-cyclists. 'Distance to work' was sampled by self-reported distance between one's workplace and residence.

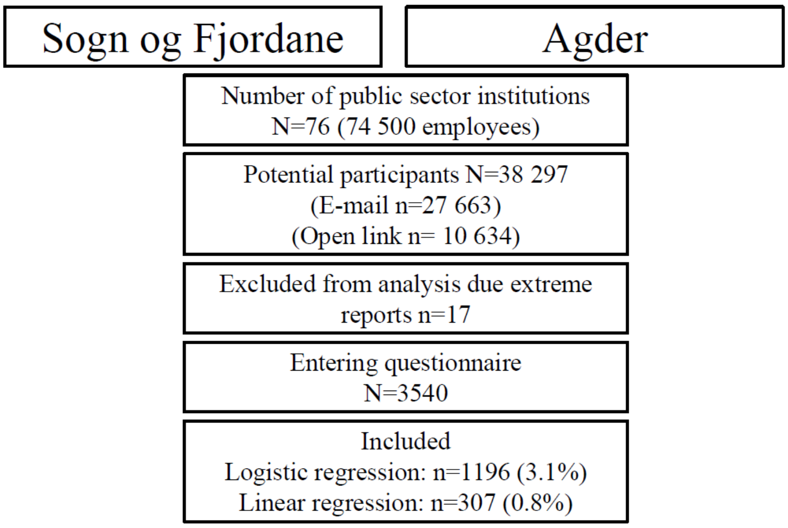

Figure 2. *Flowchart and inclusion process of study III.*

Self-reported covariates

Self-reported age and perceived road safety were treated as continuous variables. Gender, type of cycle owned (e-bike or ordinary), ethnicity (Norwegian vs. non-Norwegian), self-rated health (SRH; good or poor), and current tobacco use (tobacco or non-tobacco) were coded as binary. SRH was investigated using RAND-12's first question. This question elicits relevant health information and is a strong and dose-dependent predictor of mortality [188, 189]. The question was recoded as 'good' (good, very good, and excellent) or 'poor' (poor and fair) health status. Income, BMI, education, and self-reported PA [190] were coded as categorical variables. The Saltin and Grimby question on PA [190] has previously been used in a number of cohort studies assessing health status in the Nordic countries [18] and in a Norwegian representative population, where the question was validated against aerobic fitness (correlation coefficient was 0.18 and 0.39 for men and women, respectively) [191]. With its use in cohort studies, the question has proven able to identify health and mortality in inactive and active respondents [18]. Income was classified as 0-399,999 NOK; 400,000-799,999 NOK; or 800,000-19,999,999 NOK. BMI was classified according to the WHO obesity classification [3]. Level of education was coded as < high school, < 4 years university, or ≥ 4 years university.

Geographic information systems computed covariates

Environmental factors were investigated using a GIS (ESRI ArcGIS PRO 2.3.3, Environmental Systems Research Institute, California, CA, USA). The participants' homes and work addresses (n=1114) were geocoded using the address locator ESRI world geocode. This resulted in 1,080 matched home addresses (97%), and 1,053 work addresses (95%; Figures 3a and 3c). The length of the road in metres (European road, state road, county road, local road, private road, logging road) and shared-use paths (Figures 3b and 3d) were imported for Sogn og Fjordane and Agder. The population was summarised at the district level and categorised by the number of people living within the district (Figure 3a and 3c). To estimate the route between home and work (home-work pairs), we used the network analysis tool 'routes'. Furthermore, we calculated the ratio of time taken to bicycle vs. to drive and the ratio for the distances of the route between home and work. The topography along the routes for each of the original home-work pairs was characterised by cumulative absolute height gains (total elevation) and mean slopes from the Vbase data source. Elevation and slope were categorised into four groups, based on percentile distribution.

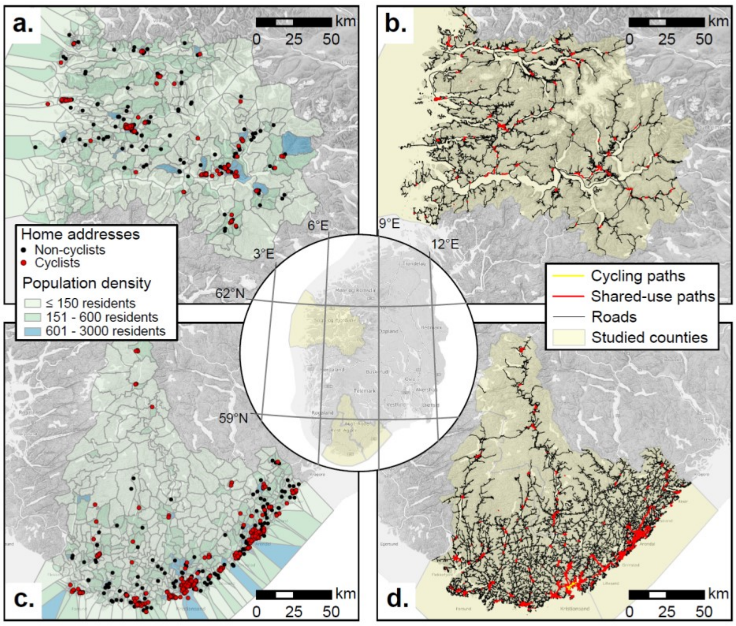

***Figure 3**. Information derived from the geographic information systems (GIS). (a) Population density and location of home addresses in Sogn og Fjordane. (b) Roads, cycling paths and shared-use paths in Sogn og Fjordane. (c) Population density and location of home addresses in Agder. (d) Roads, cycling paths and shared-use paths in Agder.*

Statistics
All analyses were run in the SPSS software, Statistics, version 25 (IBM SPSS Statistics for Windows, Armonk, NY: IMB Corp., USA). Descriptive analyses are presented as mean (SD) or median (min-max). Logistic regression is presented as OR with a 95% CI or with trend *p*-value for variables with more than two categories (education, income, and PA). The results of linear regression are presented as standardised beta (β) and *p*-value (*p*).

An independent sample Mann-Whitney U-test was used to investigate possible differences between cyclists and non-cyclists for non-normally distributed variables. Logistic regression was performed to assess the association between independent variables and being a cyclist. Model 1 contained independent variables (age, distance, gender, income, health status, BMI, e-bike, education, migration, perceived traffic safety, tobacco, and PA levels), taken from the questionnaire. The categorical variables were coded by ascending rank. The lowest group was used as a reference. Women and men were coded 0 and 1, respectively. Both bivariate and multivariate analyses were performed. Model 2 contained eight GIS-generated variables, where categorical variables were coded by ascending rank.

Study IV: Development of the national bike-traffic index and trends in cycling

Included counters
In total, 89 stationary counters were included in the bike-traffic index (Figure 4). All included counters have been operative since January 1, 2018. Following the adapted methods of Minge *et al.* [88], 75 (85%) were defined as 'commute', 11 (12%) as 'commute-mixed', and 3 (3%) as 'multipurpose-mixed' traffic pattern.

We identified 25 local areas with at least one operative counter, hereafter named 'local indices'. The number of counters within the local indices ranged from 1 to 14, with a median of 2. The mean population within the local indices ranged from 840 to 93,176 individuals (see Table 1 in study IV for number of counters and mean population density within the local and regional indices). The local indices were located in the appropriate regions, which were northern, mid, west, southern, or eastern Norway.

The included counters are either inductive loop monitors (83%) or piezoelectric counters (17%) and they classify the passing of vehicles.

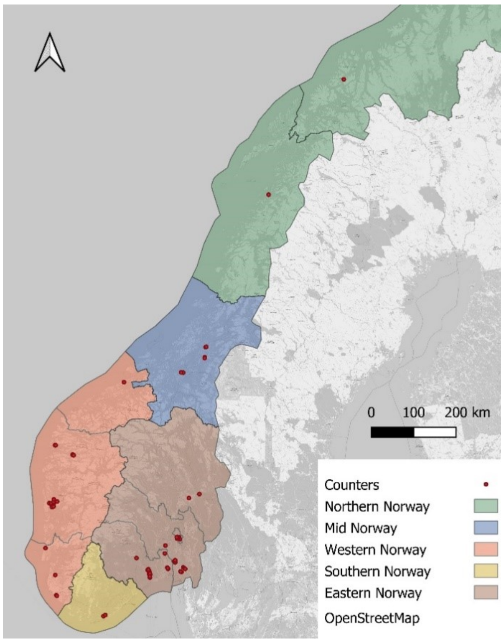

Figure 4. *Location of included counters and regional areas.*

When daily traffic had coverage of less than 95%, the data were set to missing (user-missing). Throughout 2018, 2019, and 2020, a total of 6% of the data were missing. System- and user-missing data were replaced by linear interpolation. When missing data occurred in 2020 (with no valid value after the period of missing values), the period had missing data as it could not be replaced by interpolation. Following the procedure of the NPRA [192], successive data were deleted for the comparable month (i.e., if there were no valid data for December 2020, the data for December 2018 were also deleted).

Principle of the index

The inspiration the bike-traffic index was the Danish bike-traffic index [86]. In simple terms, the index is a ratio between two successive years,

$$R = \left(\frac{Y}{X}\right) 100\%$$

where R is the ratio of Y, the year compared to the baseline year, X, multiplied by 100%. The baseline year is thus set to 100%, and we can follow a percentage change between years X and Y.

The index is organised for three different levels: local, regional, and national. The local index is a sum of the annual counts by each counter, adjusted for population density at the counter level. Separately, the local index is an uncertain measure with a large confidence interval due to small number of counters [86]; therefore, it must be interpreted with caution. In addition, the regional indices and the national index are the weighted sum of all counts in the region or the country.

Calculation of confidence intervals

Confidence intervals for the traffic indices were calculated according to the directions of the NPRA [192]. This approach is based on paired sets of valid data for the period in question and for the reference year, at each site of interest and for each period (e.g., hour, day, month). The variance is calculated for all valid pairs of data. More specifically, for each site, the difference between the index of the site and the average for the whole country (or region or local area) is calculated and squared. The squared difference is weighted in proportion to the traffic volume. A correction is calculated to account for the use of estimated parameters, rather than the true (but unknown) value. These last corrections correspond to dividing by n-1, rather than by n, when calculating the common variance from n different independent values with equal weight, giving an unbiased estimate of the true but unknown variance. The standard deviation is taken as the square root of the calculated variance. Please see section 2.8 in Study IV for formula and denotations.

Ethics

For the two systematic reviews and meta-analyses (Studies I-II), we followed the PRISMA 2009 guidelines [193], and the protocol was registered in the PROSPERO database on December 6, 2016, under registration number CRD42016052421. PRISMA states that protocols are necessary and ensures that a systematic review is carefully planned before the review begins [194]. One of the most important reasons for writing a protocol and registering it is our common responsibility to reduce the risk of bias related to the selective reporting of outcomes [194].

For Study III, the procedure and methods used were in accordance with the ethical guidelines of the World Medical Association's Declaration of Helsinki and its following revisions [195]. The study was further approved by the Regional Committees for Medical and Health

Research Ethics, under reference 2016/1897/REK vest. Entering the survey was defined as informed consent. All potential respondents were given an invitation and information about the study, either by email or an open link distributed by the institution. In both Sogn og Fjordane and Agder, incentives was given to motivate participation. A prize draw to win an iPad was held in Sogn og Fjoradne, while one institution in Agder held a prize draw to win 10 vouchers (worth 500 NOK) for use of the institution's cafeteria.

Study IV contains data under the Norwegian licence for Open Government data distributed by the NPRA.

SUMMARY OF RESULTS

In this chapter, the main findings in response to the three research questions of this thesis are presented. The summary of the results is presented in the same order as the research questions, namely, 'What are the CVD-related benefits of cycling?' 'What individual and environmental factors are associated with commuter cycling in Norway?' and 'What are the trends in cycling at the local, regional, and national levels?'

Studies I and II:

We aimed to assess the strength of the association between cycling and (a) CVD and (b) CVD risk factors compared with non-cyclists. We hypothesised that there would be similar associations for men and women and a dose-response relationship between cycling and CVD-related health.

Included studies

In total, 5,174 studies were identified (Figure 5). Five studies were also identified through the updated search (August 8, 2017), as well as 21 from other sources, such as hand-searching the reference lists of the identified studies. In total, 38 studies fulfilled the primary inclusion criteria; of these, 21 used dichotomous variables (Study I) and 17 used continuous variables (Study II).

Sample characteristics

Study I included 1,069,034 individuals from eight cohorts and four countries in analyses of CVD incidence and CVD mortality. The estimates were based on 12,382 incidents and 5,950 deaths during a follow-up time of 9.8 ± 4.9 years. Furthermore, 72,648 individuals from 10 countries were analysed for one or more CVD risk factors. Study II included 5,775 cyclists and 39,273 non-cyclists.

The majority (56%) of the included studies were graded as moderate quality by the quality assessment tool for quantitative studies [161], with most studies of strong quality reporting dichotomous outcomes and most of weak quality reporting continuous outcomes (see Table 1 for details). See also Table 2 and online supplementary file 3 (in Study II) for a summary of the characteristics of the 38 included studies.

Main findings

Overall, cycling was associated with a 22% (95% CI: 0.74 to 0.82 $P < 0.001$; $I^2 = 58\%$, Q $P < 0.001$; Figure 6) lower risk of CVD mortality, CVD incidence, and associated CVD risk factors compared with passive transport (Study I). The RR for CVD incidence was 0.84 (0.80 –0.88, $P < 0.001$; $I^2 = 30\%$, Q $P = 0.22$). The RR for CVD mortality was 0.83 (0.76–0.90; $P < 0.001$; $I^2 < 0\%$, Q $P = 0.58$).

CVD risk factors

In Study I, the OR for CVD risk factors was 0.75 (0.68–0.82; $P < 0.001$; $I^2 = 54\%$, Q $P < 0.001$; see Figure 7). When analysing ‘overweight or obese’ and ‘obesity’, there were ORs of 0.63 (0.57–0.67, $P < 0.001$; $I^2 < 0\%$, Q $P = 0.81$) and 0.72 (0.63–0.83, $P < 0.001$; $I^2 = 29\%$, Q $P = 0.204$), respectively. There was an OR of 0.71 (0.57–0.90, $P = 0.004$; $I^2 = 72\%$, Q $P = 0.014$) for hypertension, 0.83 (0.71–0.96, $P = 0.013$; $I^2 = 52\%$, Q $P = 0.098$) for triglyceride level and 0.98 (0.82–1.18, $P = 0.855$; $I^2 < 0\%$, Q $P = 0.502$) for HDL-C level. Triglyceride level remained significant only when analysing men and women combined. HDL-C was the only risk factor not significant for men, women, or combined.

In Study II, cyclists had more favourable risk factor levels in 4 of 5 risk factor categories (body composition, PA, CRF, and blood lipids) compared with non-cyclists (Table 3). Cyclists had consistently lower skinfold, WC, and BMI compared to non-cyclists. The combined score of body composition was SMD -0.08 (-0.13 to -0.04), $I^2 = 69\%$ cyclist vs. non-cyclist. However, the result was heterogeneous, $I^2 = 69\%$. Regression analysis of design and SMD showed a relationship in which high-quality design was associated with greater effect size. When analysing RCTs only, the difference was larger: SMD -0.99 (-1.49 to -0.54), $P < 0.001$, $I^2 = 94\%$ Q $P < 0.001$. Furthermore, cyclists had significantly higher levels of other forms of PA compared to non-cyclists, with a moderate to high level of heterogeneity (SMD 0.13, 0.06 to 0.20, $P < 0.001$; $I^2 = 80\%$ Q $P < 0.001$). Cyclists had higher CRF compared to non-cyclists (SMD 0.28, 0.22 to 0.35, $p < 0.001$; $I^2 = 84\%$ Q $P < 0.001$). In addition, for CRF, the effect was larger for RCTs (1.06 (0.85 to 1.28) $P < 0.001$, $I^2 = 71\%$ Q $P < 0.001$). For blood lipids, each outcome was analysed separately. TC, HDL-C, LDL-C, and TG were all significantly enhanced in cyclists. Neither DBP nor SBP were related to cycling ($p = 0.12$ and 0.40, respectively).

Dose-response relationships

In study I, we did not observe any dose-response relationships for total cycling, commuter cycling, or the two combined.

In study II, all exposure measures had at least two levels of cycling, but only BMI and PA had three levels. WC showed a graded association with level of cycling (β -1.56, $p < 0.001$).

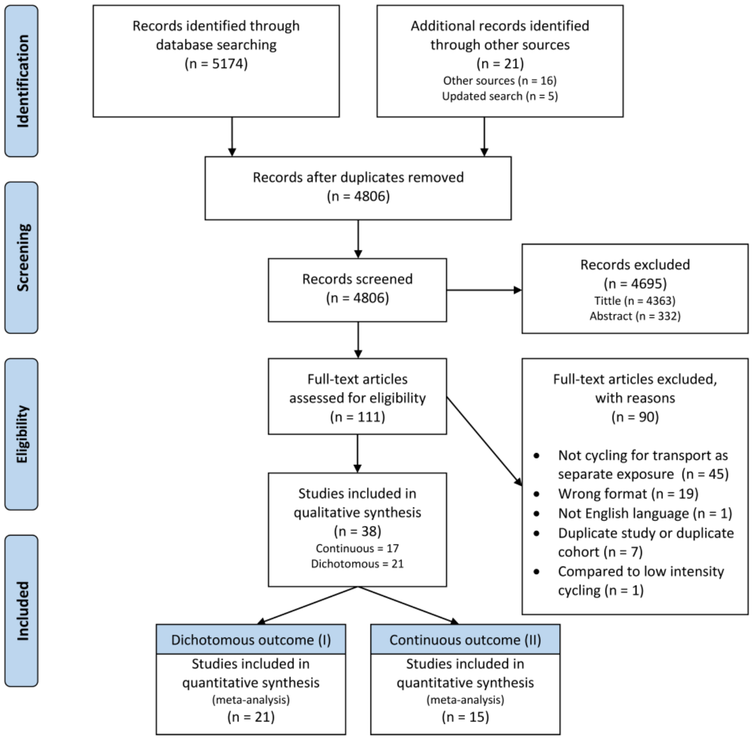

Figure 5. *Flow chart of included studies, as proposed by the statement on preferred reporting items for systematic reviews and meta-analysis (2009).*

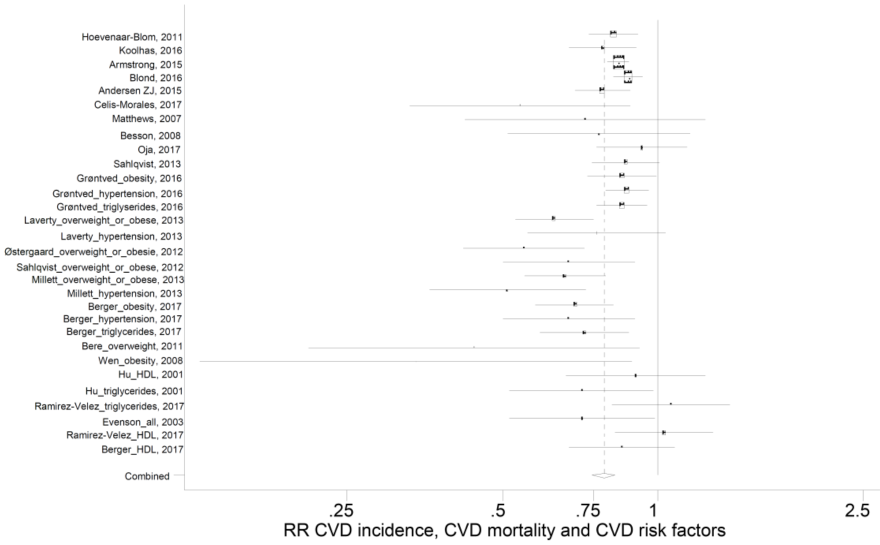

Figure 6. Forest plot of the main analysis of cycling on cardiovascular disease (CVD) incidence (risk ratio), CVD mortality (risk ratio), and CVD risk factors (OR). *The combined random effect estimate was 0.78 (CI: 0.74-0.82) for CVD incidence, CVD mortality and CVD risk factors combined, indicated by the diamond in the bottom of the diagram. The combined estimate was statistically significant but were moderately heterogeneous ($I^2 = 58\%$). From the top, the first 10 studies are either CVD incidence or CVD mortality estimates, and the latter studies are CVD risk-factors.

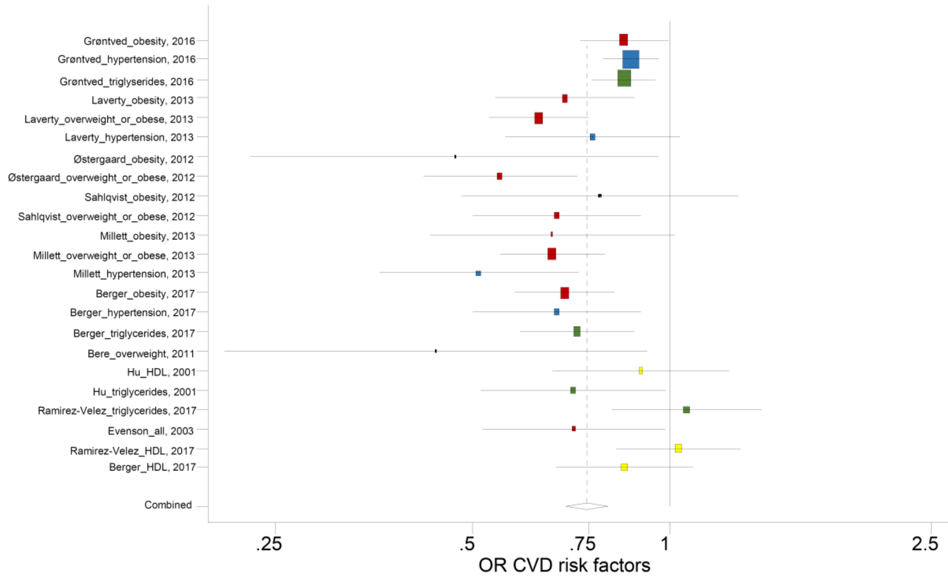

Figure 7. Forest plot of sensitivity analysis of CVD risk factors for commuter cycling. *Combined OR was 0.75 (0.69-0.82, I2 = 54%) indicated by the diamond in the bottom. Red boxes indicate overweight or obese, blue box indicates hypertension, green box indicates triglycerides, and yellow box indicates HDL. All risk factors besides HDL were independently significant.

Table 2. *Characteristics of included studies, Study I.*

Study	Design/Cohort/ Countries	Type of cycling	Population	Dates/ years of follow-up	Total N	Incidence/ death	Outcome	Prevalence of cycling (%) Total/Low/High	RR/OR (95% CI)	Dose Low	Dose High
Hoevenaar-Blom *et al.* [162]	Prospective cohort/ MORGAN/ The Netherlands	Commuter	Men, women; aged 20-65 y at baseline	1993-2006/9.8	16,442	923/NA	Incidence	75%/19%/5%	0.82 0.73-0.92)	Regular cycling	> 2.5 h/wk
Koolhaas *et al*. [163]	Prospective cohort/ Rotterdam study/ The Netherlands	General	Men, women; aged > 55 y at baseline	1997-2012/10.3	5,901	642/NA	Incidence	58%/32%/26%	0.78 (0.67-0.91)	13 min/day	51 min/day
Armstrong *et al*. [164]	Prospective cohort/ Million Women Study/ United Kingdom	Total	Women; aged 55.9 y (SD 4.8) at baseline	1998-9	497,857	6815/NA	Incidence	Not reported*	0.84 (0.80-0.88)	> 0-2 h/wk	> 2 h/wk
Blond *et al.* [165]	Prospective cohort/ Diet, Cancer and Health/ Denmark	Overall, Commuter	Men, women; aged 50-65 y at baseline	1993-2013/20	53,723	2892/NA	Incidence	Not reported	0.87 (0.82-0.93)	> 0-2.5 h/wk†	> 2.5 h/wk†
Andersen ZJ *et al.* [166]	Prospective cohort/ Diet, Cancer, and Health/ Denmark	Commuter, leisure time	Men, women; aged 50-65 y at baseline	1993-2010/13	52,061	NA/1285	Mortality	68%/NA/NA	0.78 (0.69-0.88)	No dose reported. 3.2±3.4 h/wk	
Celis-Morales *et al.* [40]	Prospective cohort/ UK Biobank/ United Kingdom	Commuter	Men, women; 40-69 y at baseline	2007-2014/5	263,540	1110/496	Incidence, mortality	3%/NA/NA	0.54 (0.33-0.88)	Short ‡	Long ‡
Matthews et al. [100]	Prospective cohort/ Shanghai Women's Health Study/ China	Commuter	Women; aged 40-70 y at baseline	1997-2004/5.7	67,143	NA/251	Mortality	NA/19%/5%	0.72 (0.42-1.23)	0-1-3.4 METh/day	> 3.5 METh/day
Besson et al. [167]	Prospective cohort/ EPIC-Norfolk/ United Kingdom	Commuter	Men, women; aged 45-79 y at baseline	1993-2006/7	14,903	NA/370	Mortality	NA/NA/NA	0.77 (0.51-1.15)	< 30 min/wk	> 30 min/wk
Oja *et al.* [168]	Prospective cohort/ HSE & SHeS/ England, Scotland	Any	Men, women; aged 30-98 y at baseline	1991-2008/9.2	75,014	NA/1909	Mortality	10%/5%/5%	0.93 (0.76-1.16)	min/wk low §	min/wk high §
Sahlqvist *et al*. [169]	Prospective cohort/ EPIC-Norfolk/ United Kingdom	Commuter, total	Men, women; aged 40-79 y at baseline	1993-2011/15.3	22,450 commuter; 13,346	NA/1639	Mortality	Total: 30%/NA/NA Commuter: NA/4%/2%	0.86 (0.74-1.00)	1-59 min/wk	> 60 min/wk
Grøntved *et al*. [99]	Prospective cohort/ Västerbottens Health Survey / Sweden	Commuter	Men, women; aged 43.5 y at baseline	1990-2011/10	23,732		Risk factors (1-3)	24%/NA/NA	1. 0.85 (0.73-0.99) 2. 0.87 (0.79-0.95) 3. 0.85 (0.76-0.94)	NA	NA
Laverty *et al*. [170]	Cross-sectional/ Understanding society/ United Kingdom	Commuter	Men, women; aged 16-65 y	NA	20,458		Risk factors (1,2)	3%/NA/NA	1. 0.63 (0.53-0.75) 2. 0.76 (0.56-1.01)	NA	NA
Wen *et al.* [171]	Cross-sectional/ New South Wales Adult Health Survey/ Australia	Commuter	Men, women; aged ≥ 16 y	NA	6,832		Risk factors (1)	3-10%/NA/NA	1. 0.34 (0.13-0.89)	NA	NA

Table 2 Continued

Study	Design/Cohort/ Countries	Type of cycling	Population	Dates/ years of follow-up	Total N	Incidence/ death	Outcome	Prevalence of cycling (%) Total/Low/High	RR/OR (95% CI)	Dose	
										Low	High
Østergaard *et al*. [172]	Cross-sectional/ NA/ Denmark	Commuter	Men, women; aged 12-16 y		3,847		Risk factors (1)	62%/NA/NA	1. 0.55 (0.42-0.72)	NA	NA
Bere *et al*. [173]	Longitudinal/ ENDORSE and Youth in Balance/ the Netherlands, Norway	Commuter	Men, women; aged 13.2 y at baseline	2005-2008/2	890		Risk factors (1)	48%/NA/NA	1. 0.44 (0.21-0.88)	NA	NA
Sahlqvist *et al*. [126]	Cross-sectional/ Bicycle Victoria/ Australia	Commuter	Men, women; aged ≥ 18 y	NA	1,813		Risk factors (1)	100%/NA/NA	1. 0.67 (0.50-0.90)	NA	NA
Millett *et al*. [174]	Cross-sectional/ Indian Migration Study/ India	Commuter	Men, women; aged ≥ 18 y	NA	3,902		Risk factors (1,2)	45-68%/NA/NA	1. 0.66 (0.55-0.77) 2. 0.51 (0.36-0.71)	NA	NA
Berger *et al*. [175]	Cross-sectional/ TCCS/ United States	Commuter	Men, women; aged 20-64 y	NA	1,450		Risk factors (1-4)	100%/NA/NA	1. 0.69 (0.58-0.82) 2. 0.67 (0.50-0.90) 3. 0.72 (0.59-0.88) 4. 0.85 (0.67-1.07)	NA	NA
Evenson *et al*. [176]	Cross-sectional/ YRBS/ United States	Commuter	Men, women; youth in 6th-12th grades	NA	4,448		Risk factors (1)	13%/NA/NA	1. 0.71 (0.52-0.98)	NA	NA
Hu *et al.* [85]	Cross-sectional/ NA/China	Commuter	Men, women; aged 20-49 y	NA	3,708		Risk factors (3,4)	11-19%/NA/NA	3. 0.71 (0.52-0.98) 4. 0.90 (0.66-1.23)	NA	NA
Ramirez-Velez *et al.* [177]	Cross-sectional/ FUPRECOL/ Colombia	Commuter	Men, women; aged 9-17.9 y	NA	1,568		Risk factors (3,4)	23%/NA/NA	3. 1.06 (0.81-1.37) 4. 1.03 (0.83-1.23)	NA	NA

Abbreviations: NA, not applicable; RR, relative risk; OR, odds ratio; METh, metabolic equivalent hours.
* States that cycling is infrequent in this cohort.
† Commuter cycling: low-dose = 0-1.5 h/wk; high dose >1.5 h/wk.
‡ Split into groups according to distance.
§ Groups defined by using the sex-specific medians.
Risk factors:
1) Body mass index (BMI), overweight ≥ 25, and obesity ≥ 30 according to the World Health Organization [70].
2) Hypertension (self-reported or doctor-diagnosed) [170, 175] or systolic blood pressure or diastolic blood pressure > 140 and > 90 mm Hg, and/or use of antihypertensive medications [99].
3) Hypertriglyceridemia (>1.7 mmol/L)[99], self-reported or doctor-diagnosed [175], adverse log transformed scale [85], or ‘high triglycerides’ not defined [177].
4) Low high-density lipoprotein level (self-reported or doctor-diagnosed) [175], adverse scale [85], or low high-density lipoprotein level (Friedwald formula) [177].

Table 3. *Main findings Study II. Meta-analysis for all outcome measures. Bold font indicates significant results. Dose-response calculated from three levels of exposure (1-3).*

Outcome	Number of reported results	Meta-analysis for all outcomes			Back transfer from SDM	Test of heterogeneity		Dose-response	
		SMD	95% CI	P-value		I^2*	P-value	β	p-value
Combined score of body composition**	13	-0.08	-0.13 to -0.04	**< 0.001**	NA	69%	**< 0.001**	0.185	0.540
Skinfold (mm)	5	-0.09	-0.17 to -0.01	**0.029**	-5.22 mm	88%	**< 0.001**	0.453	0.749
WC (cm)	6	-0.58	-0.64 to -0.51	**< 0.001**	-9.6 cm	99%	**< 0.001**	-1.588	**< 0.001**
BMI (kg/m^2)	12	-0.10	-0.14 to -0.05	**< 0.001**	-0.45 BMI	41%	0.069	0.022	0.714
PA***	7	0.13	0.06 to 0.20	**< 0.001**	2.99 MVPA	80%	**< 0.001**	0.015	0.635
CRF	15	0.28	0.22 to 0.35	**< 0.001**	195,63 mL O_2 min^{-1}	84%	**< 0.001**	0.338	0.656
Total cholesterol (mmol/l)	8	-0.06	-0.12 to -0.00	**0.037**	-2.28 mmol/l	43%	0.091	0.014	0.928
HDL cholesterol (mmol/l)	7	0.18	0.12 to 0.24	**< 0.001**	2.95 mmol/l	24%	0.250	-0.024	0.764
LDL cholesterol (mmol/l)	5	-0.15	-0.22 to -0.07	**< 0.001**	-5.35 mmol/l	39%	0.161	-0.033	0.809
Triglycerides (mmol/l)	8	-0.17	-0.23 to -0.11	**< 0.001**	-8,62 mmol/l	20%	0.272	-0.135	0.355
DBP (mmHg)	7	0.03	-0.05 to 0.11	0.405	NA	74%	**< 0.001**	0.105	0.764
SBP (mmHg)	7	-0.06	-0.14 to 0.02	0.122	NA	34%	0.172	0.030	0.927

Abbreviations: SMD, standardised mean difference; WC, waist circumference; BMI, body mass index; PA, physical activity, CRF, cardiorespiratory fitness; HDL, high-density lipoprotein; LDL, low-density lipoprotein; DBP, diastolic blood pressure; SBP, systolic blood pressure.

*25%, 50%, and 75% correspond to low, moderate, and high I^2 values, respectively [185].

** Sample of best measure reported. The risk factors were ranked from high to low quality: 1) skinfold [80, 81, 102]; 2) waist circumference [159]; and 3) BMI [82, 172, 179, 180].

****CPM, MVPA, or min/wk.*

Study III

We aimed to describe the self-reported characteristics of commuter cyclists in Norway, as well as the objectively measured environmental factors in areas around residences and along commuter routes associated with commuter cycling.

We found both individual and environmental factors associated with higher likelihood of commuter cycling. Those living more than 5 km from their workplace were unlikely to be commuter cyclists (OR 0.17 [CI: 0.13–0.23]), while those living in areas of high population density had increased odds of being commuter cyclists (OR 1.49 [CI: 1.05–2.12]). Among individual factors, good self-reported health (OR 1.92 [CI: 1.20–3.07]), higher level (>4 year at university) of education (1.75 [1.14–2.70]), an active lifestyle (OR 2.56 [CI: 1.42–4.60]), and ownership of an e-bike (OR 5.99 [CI: 3.71–9.69]) were all associated with greater likelihood of travelling by bicycle. The odds of being a cyclist were similar for women and men when summer and winter was analysed combined. However, in winter, owning an e-bike increased the chances of being a cyclist more for women than it did for men (OR 7.55 [3.99-14.03] vs. 3.61 [1.73-7.54]).

Study IV

The aim of the study was to develop the Norwegian bike traffic index to describe the national trends in numbers of cycle trips.

From 2018 to 2020, the national index indicated a significant 11% increase in the number of counted trips. The national index was 97 in 2019 and 111 in 2020 (see Table 4 for details). Southern and western Norway had a continuous increase in counted bicyclists, while southern Norway has had a 23% (123 [107-140]) increase over the last three years. The only region with a decrease in counted bicyclists was northern Norway, where the number fell significantly by 8% between 2018 and 2020 (92 [72-112]). The data for both northern and southern Norway have 17-20% uncertainty, mainly due to the small numbers of included counters. Large differences were observed in the local trends over the three last years. In Førde, western Norway, the number of counted cycle trips increased by 4% from 2018 to 2020, but the CI indicated that this result is uncertain. The largest local increases were observed in Drammen (Eastern Norway) and Kristiansand (Southern Norway), which had 153% and 23% increases, respectively. Only in Kristiansand was the increase significant.

Table 4. *National, regional, and local weighted* indices with 95% confidence interval, from 2018 to 2020.*

	Number of counters	2018	2019	2020
National	89	100	97.0 (94.1-99.8)	111.0 (106.2-115.1)
Regional				
Southern Norway	3	100	103.5 (101.2-105.7)	123.2 (106.5-140.0)
Northern Norway	3	100	104.8 (61.3-148.4)	91.7 (71.6-111.8)
Western Norway	29	100	102.0 (96.5-107.6)	111.3 (101.4-120.9)
Eastern Norway	48	100	93.6 (89.6-97.3)	111.3 (104.5-117.0)
Mid Norway	6	100	94.2 (85.7-102.6)	103.4 (95.7-111.1)
Local				
Kristiansand	3	100	103.5 (101.2-105.7)	123.2 (106.6-140.0)
Elverum	1	100	87.8	78.0
Hamar	1	100	91.2	108.8
Kristiansund	1	100	108.6	106.9
Bodø	2	100	106.7 (-78.9-292.2)	89.3 (24.4-154.2)
Oslo	6	100	94.3 (87.5-100.6)	118.8 (91.7-144.3)
Egersund	2	100	101.5 (79.5-123.6)	108.4 (81.7-135.1)
Tromsø	1	100	96.1	100.7
Steinkjer	2	100	91.3 (51.7-130.9)	113.6 (49.6-177.6)
Trondheim	2	100	94.2 (1.2-187.1)	100.9 (96.1-105.6)
Verdal	2	100	96.6 (95.6-97.6)	113.0 (2.5-223.5)
Porsgrunn	6	100	87.1 (80.4-93.8)	104.9 (95.0-114.9)
Sande	1	100	93.4	119.6
Skien	14	100	95.3 (90.4-100.2)	106.2 (100.6-111.8)
Tønsberg	4	100	97.1 (92.1-102.0)	109.2 (101.6-116.8)
Bergen	12	100	103.8 (92.4-115.5)	117.9 (99.8-136.1)
Kinn	3	100	95.0 (91.8-98.1)	86.5 (72.9-100.2)
Førde	8	100	104.0 (92.1-115.9)	104.6 (83.8-125.4)
Drammen	2	100	120.9 (-935.9-1177.7)	253.8 (-150.5-658.0)
Fredrikstad	3	100	68.1 (9.6-126.8)	81.4 (-12.5-175.5)
Moss	5	100	91.8 (83.0-100.5)	106.1 (88.9-123.4)
Sarpsborg	5	100	92.4 (89.7-95.2)	108.8 (101.1-116.6)
Stavanger	1	100	84.0	120.8
Haugesund	1	100	93.2	96.0
Bø	1	100	96.1	98.7

*Weighted for population density.

GENERAL DISCUSSION

This chapter presents the main findings in response to each of the research questions, followed by a general discussion. Following this, the methodological and ethical considerations are discussed. Further is broader of commuter cycling as a public-health strategy from a socioecological perspective discussed. Finally, the implications and recommendations for future research are presented.

What are the CVD-related benefits of commuter cycling?

Cycling was associated with a 16% lower risk of CVD incidence, 17% lower risk of CVD mortality, and a 25% lower risk of CVD risk factors. When CVD incidence, mortality, and risk factors were combined, cycling was associated with a 22% lower risk. However, the main analysis was heterogeneous ($I^2 = 58\%$), possibly because we included cross-sectional and prospective studies of populations of children and adults. To assess CVD incidence and mortality, we analysed prospective cohort studies of adult populations. Our results support those of a previous study of approximately 173,000 adults, showing that active travel – especially cycling – reduces CVD risk [23]. We analysed an almost 10-fold larger population and included only cycling as a transport domain PA. Our results were slightly more consistent, and we found a stronger association for cycling than is found in studies that combine walking and cycling. The findings were later confirmed by another meta-analysis of cycling for transportation and fatal or non-fatal CVD. In this study, commuter cyclists were at a 16% lower risk than passive travellers [113].

CVD risk factors

To our knowledge, no other studies have meta-analysed cycling and its associations with CVD risk factors such as blood lipids, body composition, and fitness measured with continuous outcome variables. However, active travel has been shown to reduce all-cause mortality [19] and CVD [19]. In study II, being a cyclist was associated with a reduced CVD risk, with reductions in four out of five CVD risk-factor categories. However, the results should be interpreted with caution, as only WC and CRF had a small-to-moderate effect, in accordance to Cohen's rule of thumb [196]. The health effects of being a cyclist were stronger when only RCTs were considered. In that case, being a cyclist was associated with both improved body composition (SMD -0.99 [95% CI: -1.49 to -0.54]) and improved CRF (SMD 1.06 [0.85 to 1.28]).

In our systematic reviews, the most reported and most frequently reduced risk factor was overweight or obesity. In a scoping review, Brown *et al.* [160] found a small but significant reduction in BMI with active travel, but the authors conclude that the effect might be smaller than indicated in the literature. However, in contrast, we found a 36% lower risk of both overweight and obesity (OR 0.64, CI 0.58 to 0.70, $I^2 = 0\%$) combined and a 27% lower risk of obesity (OR 0.73, CI 0.57 to 0.94, $I^2 = 66\%$). The relatively low heterogeneity could be erroneous, due to a smaller number of studies [185]. Therefore, it is possible that our results overestimate the risk reduction associated with cycling. However, our main analysis is supported by our subgroup analysis of commuter cycling and CVD risk factors (online supplementary Table 12a to 12b in Study I), adding strength to our conclusions.

In study II, we found a similar result as for continuous variables, but BMI and blood lipids were homogeneous. For other risk factors, the degree of heterogeneity differed between 34% and 99%. Our results underpin the uncertainty of the association between cycling and CVD risk factors, as shown by continuous outcome measures. For single risk factors, the strongest association was observed in the sensitivity analysis of body composition. In our combined score of body composition, the association with cycling was significant, with a moderate level of heterogeneity (SMD -0.08, 95% CI -0.13 to 0.04, $I^2 = 69\%$). When we performed the sensitivity analysis for each of the included risk factors, a moderate effect was observed for WC (SMD -0.58, 95% CI, -0.64 to -0.51) for any cycling. The result was highly heterogeneous ($I^2 = 99\%$). Only six studies were analysed in the WC analysis, thus the heterogeneity may be due to few studies included and therefore be erroneous. Due to the heterogeneity the result should be interpret with caution. Although the consistency of the WC analysis is uncertain, we found no difference between either gender or age (see Table 2 in Study II for details). When we back transferred the SMD to an adult male population [159], any cycling was associated with a reduced WC of 9.5 cm. In study II, cycling was associated with lower BMI, when compared with that of non-cyclists. Flint and Cummins [22] found promising results on the effect of active travel on reduction of BMI in mid-life. Our finding is in accordance with previous studies that have observed reductions smaller than those previously expected [160].

Hypertension was the second most substantially reduced risk factor (OR 0.71, CI 0.57 to 0.90). Two studies [170, 171] defined hypertension based on a self-reported diagnosis by a physician, while Grøntved *et al.* [99] used systolic and DBP of >140 and > 90 mm Hg, respectively, or use of antihypertensive medications. For dyslipidaemia, the risk of a high triglyceride level was reduced by 18% for commuter cyclists, compared with passive commuters. Finally, HDL-C level was the only non-significant, homogeneous risk factor. Commuter cycling therefore seems to be associated with an enhanced CVD profile, thus cycling may be able to prevent CVD incidence or mortality.

Sex differences

In contrast to a previous meta-analysis [23], we found no evidence that women experienced greater effects from cycling than men did. In our systematic review, CVD incidence and mortality results were mainly presented for both sexes combined, whereas the CVD risk-factor results more often included a sex-specific analysis. There was a tendency for women to have greater risk reduction for both high triglyceride and HDL-C levels, compared with men (see online supplementary Tables 10a-12b in Study I).

Dose-response

In contrast to previous suggestions [19, 20], we found no difference between low-dose and high-dose cycling in Study I. However, a trend of lower CVD risk, especially for commuter cycling and CVD mortality, was observed when high dose was reported. This is in accordance with the finding of Kelly *et al.* [19], where the steepest risk reduction for all-cause mortality was for 0-101 minutes per week of cycling, but with further reduction in risk among those cycling > 101 minutes per week. When analysing the dose-response relationship, there were several challenges. First, we divided each study individually into either high or low doses, based on the amount of cycling reported in each study. This resulted in heterogeneity of the definition of low and high dose, and high dose in some studies [167, 169] was akin to low-dose in others (see Table 2 for details). Second, there were fewer individuals in the high-dose groups than there were in the low-dose groups. This was due to the low prevalence of cycling in general and even lower prevalence of high-dose cycling. Therefore, the results regarding the dose-response relationship should be interpreted with caution. In a recently published meta-analysis, a U-shaped dose-response relationship was observed for cycling and CVD [112]. For all-cause mortality, any cycling is better than none; but for CVD mortality, there appears to be an approximate optimum of 130 minutes per week [112].

For study II, we hypothesised that there would be a dose-response relationship. However, of the 11 outcome measures, only WC showed a dose-response relationship. This contradicts previous findings that both active travel [19] and cycling [20] have dose-response relationships with health outcomes. When analysing the effect of cycling, several challenges must be considered. First, when risk factors are analysed in prospective cohorts, there is a strong possibility of misclassification [197], an uncertainty in the results, and an increased possibility of drawing an erroneous conclusion. Second, the definition of 'cycling' and the amount of cycling one needed to engage in to be classified as 'a cyclist' varied among the included studies. The majority of the studies categorised cycling using self-reported questionnaires that asked about cycling as the usual mode of travel [80], cycling as one mode of travel used in the past three months [81, 82], respondents' seven-day recall of transport modes [83], dominant modes of transport used during the summer months [84], daily commutes of more than 60 minutes by bicycle [85], and the amount of weekly recreational cycling [198]. When we removed RCT studies from the analysis, the results remained significant and became homogeneous. Furthermore, Larouche *et al.* [81] seemed to be the source of heterogeneity for WC in the results of cycling more than one hour per week. When WC was analysed without this, the results remained significant and became homogeneous. This indicates that the source of the heterogeneity may be the inconsistent definitions of cycling and, furthermore, that there may be a dose-response relationship, even though it was only observed for WC.

What individual and environmental factors are associated with commuter cycling?

Study III aimed to describe the association between commuter cycling, self-reported individual characteristics, and objectively measured environmental factors. Of the 1,196 participants, 488 were cyclists. Owning an e-bike, being active, and being in good health all increased the probability of being a cyclist by almost six times, three times, and two times, respectively, compared to non-cyclists. On the other hand, living >5 km from work reduced the probability of being a cyclist by 83%, and being overweight or obese reduced the probability by 29%. Of the environmental factors, living in more populated areas increased the odds by almost 50%, while having a total elevation of more than 133 meters from residence to work reduced the odds of being a cyclist by almost 50%.

In the self-reported data, we observed that men were more likely to be cyclists. This finding aligns with those from countries with larger shares of cyclists [126, 129, 199]. Owning an e-bike was associated with a six-fold increase in the probability of being a cyclist, as discussed elsewhere [200]. In addition, we observed that those with higher education were more likely to be cyclists. This is in accordance with observations from Australia [126], Europe [199], and North America [129]. This is known as the 'social gradient of health', where individuals in low SES groups have multiple disadvantages compared to high SES groups [201]. The socio-economic gradient of health may be explored by indicators such as education, occupation, and income, but the magnitude of the gradient may vary depending on indicators used [202]. Individuals in low SES groups are at higher risk of diseases and mortality [201, 203], whereas, especially among adults, those with low SES are less likely to meet the guidelines. The relationship between SES and commuter cycling is unclear and varies between cultures and over time. Andersen *et al.* [18] observed that commuter cycling was more common among men and women in the lowest education group, while those in the highest education group were less likely to cycle. Further, the use of bikeshare is higher in areas with higher levels of socioeconomic disadvantages [204]. In Study III and other recent studies, higher educational attainments were associated with cycling; however, the relationship may have been strengthened due to selection bias, as individuals within low SES groups are less likely to participate in research.

In line with previous findings in Europe [125], those categorised as physically active were up to three times more likely to be cyclists. This indicates that those who cycle for transportation may often also engage in other forms of PA. Interestingly, the likelihood of being a cyclist was almost double among those reporting a good health status. This is in contrast to observations in Brussels, where SRH was not found to be related to commuter cycling [199]. In both studies, the proportions of respondents with good health were high (~ 90%). This may indicate that health status is one of the few factors that differs between countries with smaller shares of cyclists and countries with higher shares. In Study III, the cyclists may have been a self-selected group of individuals who were more likely than the general population to be highly educated, physically active, of normal weight, and in good health. However, a lower rate of CVD incidence and mortality was observed in Study I, even when most of the studies had been adjusted for PA and education.

Overall, cyclists travelled one third of the distance of non-cyclists, while those living >5 km from work were rarely cyclists. Barton *et al.* [205] observed that in the UK, the distance between locations had to be short (500–2,500 m) for active travel. Our findings confirm that commuter cycling is more typical when commuting distances are relatively short (<5 km), albeit twice as long as the UK findings [205]. In Norway, the average travel distance between home and work is 16.3 km, and only 7% of these commuter journeys are undertaken by bike [149]. Independent of mode of transportation, 39% of all journeys are < 5 km [149]. In Study III, 39% of people lived less than 5 km from their workplace. The respondents thus seem to be fairly representative of the whole of Norway in this respect. It may be that Norwegian commuter cyclists are willing to travel longer distances than those in the UK. However, the willingness to travel further might also be affected by the exclusive focus on cycling in our study, whereas Barton *et al.* [205] considered active travel in general, including walking and cycling. In the UK, walking is twice as common as cycling [40]. Interestingly, short distances are reported to be of greater importance than safety when it comes to cyclists' choices of route [206]. This may be why we observed that longer distances were associated with lower perceived safety, as cyclists may choose more unsafe routes to reduce their travel distance.

Another important observation is the positive association between population density and probability of being a cyclist, which is in accordance with previous reports of commuter cycling [133], active travel [205], and higher levels of PA [120]. In more populated areas, the distances between home and work are often shorter [133]. If there is a 5 km threshold for trips to be conducted by bike, it follows that there is a higher potential for trips to be made by bike in such areas. However, in Norway, large areas have scattered settlements (Figure 3a and 3c), and this may be why Norwegian cyclists cycle longer distances, compared to the abovementioned observations from the UK. The scattered settlement in Norway is also a factor that cannot easily be changed and may be one of the main reasons why the proportion of cyclists has not increased [149] despite increased focus on the Norwegian transport plan and cycle strategy [207].

When travel time by bike is shorter relative to time travelled by car, more people are likely to cycle. This is in accordance with findings from British cities and towns [133] and regarding other interventions in bicycle infrastructure [206]. The present ratio concerns the distance between home and work, and the route is estimated by the GIS-tool routes, choosing the most likely route for bike and car. We used an average speed of 15 km/h for cyclists, while the car speed was set to the default by the tool. This means that the commuting routes may differ for bikes and cars. Interestingly, we did observe a positive association between the ratios of shared-use path and roads at home, but not for either car or bike junctions along the routes. This is in contrast to the observations of Cervero *et al.* [133], who observed that increased connectivity increases the number of cyclists. However, our ratio included shared-use paths and was not exclusively cycle infrastructure. Exclusive cycle infrastructure in Norway is sparse and much rarer than shared-use paths (Figure 3b and 3d). In the bivariate results of the model containing GIS-generated variables, we observed a significant negative trend for both mean slope and elevation on commuting route ($p < 0.001$-0.042). Only for elevation along the route did the trend remain significant in the multivariate model. This indicated that a commuter who travelled at a total elevation of 133 vertical metres was 57-63% less likely to commute by bike. Our finding is in accordance with previous observations, where vertical displacement along commuter routes was negatively associated with the probability of being a cyclist [133, 134]. Thus, it seems likely that the built and natural environment affect the rates of commuter cycling.

What are the trends in cycling at the local, regional and national levels?

We developed a national bike traffic index based on actual number of passing cyclists – independent of residence, age, or recall bias. The continuous counting results in a model that is sensitive to actual changes. The present bike traffic index is a robust and dynamic model. With this, we have developed a model that may include both new counters and local indices when more counters are operative.

The national bike traffic index indicates that the number of bicycling trips in Norway increased by 11% between 2018 and 2020. However, we observed regional and local differences. The differences between regions and local areas underpin the advantages of the indices in smaller geographical areas. At the national level, we observed seasonal differences, with the highest level of cycling trips counted between May and August, with a consistent period of fewer counts through the late autumn and winter months. Ninety-three percent of the included counters have a commuter or a commuter-mixed traffic pattern. Therefore, the index describes the trends of commuter cycling and thus may be defined as an index of commuter cycling. The Norwegian government is pursuing a strategy of increasing rates of commuter cycling in highly populated areas [148]. The present national index and local indices may directly evaluate the national, regional, and local strategies and measures.

The aim of study IV was to identify the trends in commuter cycling in Norway. The results must be integrated with knowledge of local, regional, and national strategies and actions to promote commuter cycling by identifying those factors that may affect the trend. However, the national trend saw a small national decrease in counts in 2019, followed by a rather large increase in 2020. We are not aware of any national campaigns in recent years to increase commuter cycling, but there has been a small and steady increase in bicycle-friendly infrastructure owing to the national transport plan [145, 147]. In 2018, 199 km of new bicycle-friendly infrastructure (including cycle paths and combined pedestrian and cycle paths) was finalised, while the corresponding numbers for 2019 and 2020 were 173 km and 322 km, respectively [208]. Several studies [131, 133, 137, 138, 143] have observed positive associations and effects between bicycle-friendly infrastructure and commuter cycling [11,16,19]. In European cities, a linear relationship has been observed between metres of bicycle-friendly infrastructure per citizen and level of cycling [140]. Others have found that bicycle-friendly infrastructure explains one third of the variation in commuter cycling rates [139, 141]. However, even with perfect conditions for commuter cycling, this may not be sufficient for individuals to overcome barriers and start cycling [27, 140].

Another factor that may have affected travel habits in Norway in 2020 is the COVID-19 pandemic. In Norway, there was a national lockdown during spring 2020 and late autumn 2020 due to the COVID-19 pandemic. The national lockdown included closure of preschools, and all levels of schools provided remote learning. All shops, restaurants, and services were closed, and remote work was standard for all citizens whenever possible. Social contact above the absolute minimum was discouraged. After the lockdown, Norwegian citizens were encouraged to minimise the use of public transport, only travel when needed, keep social contact at a minimum, and work remotely when possible. The national index indicates that a higher volume of counted cycle trips may be a result of reduced use of public transport [209]. However, the national index only describes total cycling. The calculated traffic pattern indicates that included counters mainly counted commuter traffic; however, the increase may also have been due to an increase in recreational cycling. In European cities, a total increase of 8% from 2019 to 2020 was observed [209], while in a worldwide cross-sectional study, the proportion of cyclists has increased from 8% to 26% [210]. Some studies report that the largest increase is seen on weekends, indicating an increase in recreational cycling [209, 211].

Methodological considerations

The findings of this thesis must be interpreted with various methodological considerations in mind. First, methodological considerations for Studies I-II are presented, followed by considerations for Studies III and IV.

Methodological considerations in Studies I and II

One of the greatest challenges when analysing cycling behaviour is that cycling is not a singular behaviour: often, individuals regularly engage in multiple physical activities. Although most of the studies included in the meta-analyses adjusted for other physical activities, there may be residual confounding from leisure time physical activities. In addition, in the studies with a low prevalence of cycling, cyclists may be a select group of individuals with superior health (and a lower CVD risk profile). However, the majority of the included studies adjusted for smoking status, alcohol consumption, and level of education (see online supplementary Table 13 in Study I for details of the adjustments).

Cycling and walking have different benefits, as cycling involves a larger amount of vigorous activity than walking does [20]. Therefore, cycling may be more protective than walking. Forty-five studies were excluded due to the merging of walking and cycling groups. This merging may have been done because few of the included studies were designed to evaluate the effect of cycling, but rather aimed to register activity levels in large populations. If studies were not primarily designed to investigate the independent association of cycling and CVD, this may explain the publication bias we found in our funnel plot in Study I. All studies used self-reported measurements of cycling and aimed to register PA levels. Self-report measurements may have been compromised by recall bias [184] as well as social desirability bias by over-reporting of activity and underestimation of body weight. There was also evidence of a small-study effect, as studies with negative results are less likely to be published [184]. This may have influenced our results by increasing the possibility of overestimating the true association between cycling and CVD. On the other hand, the main analysis was primarily based on high-quality studies that consistently reported positive associations between cycling and reduction of CVD incidence and mortality. However, the results concerning the association between cycling and CVD risk factors were less certain, since the studies included in these analyses were of moderate or low quality.

Our results confirm a previous finding [18, 212]. In Study II, all risk factors were analysed separately. This provided new and in-depth insights into the effects of cycling on the separate risk factors. There are well-known challenges when meta-analysing different designs and types of studies [184]. The possibility of a misleading overall estimate of an association is a general problem with meta-analyses, and the problem is more pronounced when different designs are combined [184]. Although it is appropriate to systematically review a body of data, it may be inappropriate to meta-analyse all designs together. To meet these challenges, Egger *et al.* [184] recommend carefully investigating sources of heterogeneity, such as the design and type of study. The quality of the included studies was investigated using the quality assessment tool of quantitative studies [161]. This tool consists of seven dimensions, and we used both the overall rating (global rating) and the design score in the meta-regression to investigate the association between study quality and effect size in studies investigating the same outcome variable. In general, we did not observe any consistent patterns regarding quality. However, we observed that design may be a source of heterogeneity. Therefore, we investigated the heterogeneity of design further (see online supplementary Table 4 in Study II for details). We observed a stronger *effect* of any cycling when RCTs were analysed separately, compared to the *association* observed when all designs were analysed together. Our aim was to summarise the literature as broadly as possible, and so all quantitative studies were included. This approach has some known challenges, but through a careful investigation of heterogeneity, the benefits of this approach may outweigh the disadvantages of combining the analysis designs [184]. However, the stronger associations found in RCTs may suggest that an analysis of all designs can lead to an underestimation of the true effect. Furthermore, in the present meta-analysis, the population was 15% cyclists. This relatively low number may have led to selection bias and residual confounding in the observational studies.

To ensure high precision and minimise the risk of bias, it is vital to include all relevant studies [184]. The search for relevant studies consists of a stepwise process which includes formulating a sensitive search strategy, searching appropriate databases, hand-searching included studies' reference lists, and investigating sources of ongoing or unpublished studies [184]. The number of databases searched is relevant, and in our systematic reviews and meta-analyses, we searched four databases. We could have used more search engines; however, this is not recommended by Egger *et al*. [184] and would have most likely only resulted in more duplicates. Since we also hand-searched included studies' reference lists, and one of the leading professors in the field is one of the authors, we trust we have included all studies which met the inclusion criteria. However, the meta-analysis only comprises published results and thus might be affected by publication bias, since the findings of unpublished studies often differ from those of studies that are published [213]. When investigating risk of bias, we followed the recommendations of Egger *et al.* [184]. However, there is methodological disagreement as to how bias should be considered. For example, Douocouliagos and colleagues [214] argued that the value of statistical life is exaggerated when it comes to the benefits of bicycle helmets. Their solution was to adjust the estimates for selection bias. The correction of selection bias for statistical life will, in the abovementioned example, dramatically lower the criterion for policy decisions based on statistical life. However, our analysis of CVD incidence and mortality involved large prospective studies that are of high quality and are likely to be published, and thus are less at risk of selection bias. In our funnel plots, we did not observe publication bias among the studies; thus, the correction was not deemed relevant. In cross-sectional studies, a tendency for publication bias was observed. Here, we carefully investigated the observed heterogeneity, and we found a clear, consistent pattern among RCTs. Selection bias might be why we observed a small-study effect for 7 of the 11 included outcomes in Study II, which indicated that smaller studies tend to show greater effects [184]. Meta-analyses of observational studies are often more distorted by confounding and selection bias than meta-analyses of RCTs [184], but they can generalise the results to a larger degree. The present systematic review and meta-analysis included only quantitative studies. This means that the observed association might be a result of an underlying confounder due to a large range of designs [184]. Differences in design and adjusted variables may lead to further residual confounding. We were aware of this possible pitfall and therefore analysed all outcomes by regression for study design, overall study quality, and measurement quality.

Methodological considerations in Study III

Self-administrated questionnaires in epidemiological studies can normally be completed within 10–20 minutes [215]. However, the length of the survey marginally affects willingness to complete the survey [215]. In other words, the process before entering the questionnaire is of greater importance than the length of the questionnaire. This is aligned with our experience from the first (Sogn og Fjordane) and the second (Agder) wave of our recruitment process for Study III. Aiming to increase the proportion of both started and completed questionnaires, we reduced the length of the questionnaire between the first to the second wave. However, the proportion of individuals completing the questionnaire was similar in the two waves. Furthermore, the distribution of the questionnaire may have affected the response rate to a larger degree than the length of the questionnaire. We were aware of the challenges involved in making use of email and web-based questionnaires [216, 217], but none of the research team members anticipated a response rate of 3%. The low response rate is likely to have affected the results, even though there was no threshold for a suitable rate of respondents [218]. Due to economical restrictions in the present PhD project, selecting a low-cost method of distributing the questionnaire was necessary. We aimed to find a recruitment method to include the general adult population and include enough participants who could potentially be included in a longitudinal study of travel habits and health. Several methods were discussed and explored, and a short description and reflection regarding the recruitment process follows.

Digital mailboxes (i.e., eBoks and Digipost) was one possible method of distributing the questionnaire. A digital mailbox is a secure online communication portal. They are mandatory for government agencies and recommended in the municipal sector [219]. This service is operated by the Norwegian Digitalisation Agency. The usage of the service has been low in Norway, but the number of registered adults (>18 years) has increased continually from 36% to 58% between 2017 and 2020 [219, 220]. Due to the low number of users of digital mailboxes in 2017, the method was considered unfeasible for the present project. Another distribution method that was explored was distributing an online questionnaire through mobile messaging, using BankID as secure identification to sign in. The message with a link to the questionnaire could theoretically be distributed to all adults. To execute this distribution strategy, we first would have needed access to personal identification information, and we would have had to develop a distribution platform feasible for mobile phones. With this approach, we could have invited all adults in Sogn og Fjordane and Agder with a registered mobile number. However, the total cost of this approach would have been larger than the economic frame of this PhD project. Due to the high cost, this approach was not developed further or used. A third solution that was discussed was distribution of printed questionnaires by mail. Even with a small study population, however, the cost associated with the distribution was too high for the economic frame of this project.

As the above-mentioned methods were not feasible for the present PhD project, we needed to rethink the target population. As described in the materials and methods section, we choose to invite public sector employees, as this is a large group of individuals. All potential respondents were given an invitation by email or an open link distributed by the public sector institution. The theoretical size of the group makes it possible to generalise, at least within regions and within Norway.

For information derived from the geographic information systems there was one major challenge. For the commuting route, we observed that the mean slope in the >75% data gave illogical results, where members of the highest slope group had greater odds of being cyclists.

This was likely due to errors in the dataset. However, we chose to include total elevation change and mean slope derived from the triangular irregular network in the analysis, as topography is likely to be one of the main environmental factors associated with cycling [134].

Methodological considerations in Study IV

The bike traffic index presented in Study IV may supplement the Norwegian travel survey. While the travel survey is conducted annually, the index will provide monthly and annual data with a much larger sample size. The last two travel surveys had 47,806 and 110,672 respondents, a 5% share of which were cyclists [122, 221]. The present bike traffic index covers an area with more than 1.2 million people and is thus likely to be more sensitive to changes in bicycling habits.

Our index is weighted for population density in accordance with the Danish bike traffic index [86]. Other factors – such as the type of road, weather, type of day, traffic pattern, and cycle infrastructure – could possibly also be weighted for [222]. For the present model, multiple models built on parameters such as counts, population density, distance between counters, and counters' number of operative days were tested. The variance between the models was 4.1% (see Appendix A in Study IV), and the present index was weighted only for the population around the counter.

The index is a measure of the cycle trips counted by a stationary counter and does not necessarily show the same trends as travel surveys, which either look at bicycle trips (as a proportion of total trips) or the number of cyclists (as a proportion of all commuters). The bike traffic index describes trends in counts. An increased number of counts may reflect that either more people are bicycling or that people are bicycling more often.

The CI of the bike traffic index should be interpreted with caution. During the development process of the index, we calculated CIs using three different methods. First, we used chi-square and Poisson distribution. This is a recognised method for large datasets [223, 224], but the principle did not fit our data material. Second, we developed a calculation model using the same principle as the first method, but with an additional inflation factor (IF) [225]. The aim of including the IF was to handle the clustering effect in the data material. As individuals in clusters potentially lack independence of one another, the regulation of sample size calculations – and 95% CI – is often required and commonly used in RCTs [225, 226]. The equation for cluster adjustment is [226]:

$$IF = 1 + (n - 1)\,\rho$$

where ρ is the intracluster correlation coefficient, n is the average cluster size, and IF is the inflation factor (95% CI multiplied by IF). Effective sample size was calculated by dividing the sample size by IF. The intracluster correlation coefficient was calculated as

$$\rho = s_c^2 / (s_c^2 + s_w^2)$$

where s_w^2 is the within cluster variance of observations taken from individuals in the same cluster and s_c^2 is the variance of the true cluster means. Finally, the 95% CI was adjusted by the square root of IF to adjust the sample size for the clustering effect. The clustering effect was rather large, with an IF of 12. Therefore, we needed an approach to account for the clustering effect, but neither the first nor second approaches were suitable for our data material, due to the Poisson distribution consideration mentioned above.

The third and final calculation of CIs used the calculation of the NPRA city bike index [192]. The calculation weights counters with higher numbers of counts higher than counters with fewer counts. The formula proposed by the NPRA [192] calculates the variation (standard deviation) among all counters. If all local indices are similar, and thus the index of the city or local area is similar, the variation equals zero. The deviation for the local area is weighted, with counters with high traffic volume weighted higher than counters with low traffic volume. Thus, the final approach was suitable for our data material and accounted for the clustering effect. However, it also has limitations. One limitation is the lack of a method to account for increased number of counts, as an increased number of counts per counter does not reduce the CI as a larger n would do in other situations. In other words, a five-fold increase in evenly distributed counts would not reduce the CI, even though the accuracy is likely to have increased.

One limitation of the present national bike traffic index is that it is mainly based on counters in urban areas. However, in Norway, there are large areas with rural populations. The index also has the limitation of not describing rural bike traffic trends due to the lack of counters in rural areas. In urban areas, the present bike traffic index has several advantages when it comes to detecting changes. Moltved *et al.* [86] highlighted three specific advantages for bike indices with methods similar to those of the present indices. First, the bike counters include the actual number of passing bicyclists independent of residence, age, and recall bias. Second, the counters' locations are precisely described; and third, continuous counting means that the model is sensitive to actual changes. Furthermore, the present bike traffic index is a robust and dynamic model. It uses the sum of counts in local indices in both the national and regional indices. With this, we have developed a model that includes both new counters and local indices when more counters are operative.

Ethical considerations

Study III was conducted in accordance with ethical guidelines, but an ethical dilemma regarding publishing did emerge due to low response rate and the responsibility to publish our findings.

The topic of Study III is important as it enhances understanding of the associations with commuter cycling. The study was well planned, using the interdisciplinary approach of leading researchers, but there were still problems with compliance. Due to factors out of the research teams' control, the study had to be scaled down. The restructuring of the study led to the use of a challenging strategy of inclusion of participants – namely, the usage of email and a web-based survey [216, 217]. This was further challenged by the WannaCry ransomware attack, which may have affected respondents' willingness to open emails and links. The WannaCry ransomware attack was a worldwide cyberattack on Friday 12 May 2017 which encrypted data and demanded payment to release the data [227]. The attack started the same week that the web-based FACT survey was distributed in Sogn og Fjordane. Regardless of challenges, none of the research team members could have anticipated a response rate of below 5%.

Low response rates may lead to selection bias and publication bias. There is a tendency towards publication bias because positive findings are more likely to be published; this has been observed in sports medicine [228], commuter cycling, and CVD-related health [79, 229]. Publication bias is a large problem, as it may lead to inaccurate or misleading recommendations being made to public [228]. In this case, the impact of low response rate is similar to that of selection bias, with problems regarding sample size and possible differences between responders and non-responders [216]. Therefore, selection bias and the low response rate challenge the validity of these results [216], increasing the possibility of type 2 errors and making it difficult to generalise the findings [216]. The low response rate is likely to have affected the results, even though there was no threshold for a suitable rate of respondents [218].

The national research guidelines [230] cover a broad area of research ethics, intended to guide researchers towards conducting research in ethically sound ways. A central principle is *integrity*, and the guidelines say, ‘Researchers shall comply with recognised norms and… behave responsibly, openly and honestly towards their colleagues and the public’ [230]. Furthermore, the research should be of *high quality,* and the researchers must possess the necessary competence [230]. The guidelines also state that the researcher is responsible for conducting research that is of *interest to society* [230].

The relevant paragraphs of the ethical guidelines [230] in this case are as follows: *§1 Quest for truth, §3 Quality, §11 Availability of results*, and *§12 Social responsibility*. Paragraph 1 covers the area of new insights and highlights the need for honesty, openness, and systematic work. Paragraph 3 states that research should be of high academic quality, and researchers must possess the necessary competence. The final two paragraphs included here are *§11* and *§12*, which say that research should be published, and researchers have a responsibility to ensure the benefits of their work for society.

The low response rate was alarming. Therefore, in the following section, I will discuss the relevant principles from two sides and share subsequent conclusions. These principles are as follows: quest for truth, quality, availability of results, and social responsibility.

Quest for truth (§ 1)

My initial feeling was not to publish. This feeling was mainly anchored in *§1 Quest for truth* [230]. The methodology had failed, and I was concerned that we had too much bias in our results (i.e., selection and confirmation bias) [228] and that this had reduced the chances of reproducibility [228]. As our results were biased by selection, the included variables were thus affected and were not normally distributed. Due to this, many statistical adaptions were made, and the results were to some degree unstable (conclusions must be changed according to methods chosen). In the scientific world, where we strive to ensure validity, reliability, and generalisability, this is a significant issue. In terms of internal norms, I was concerned by the rules of honesty, scepticism, and quality. We were able to describe some characteristics of the commuter cyclist, but the respondents were most likely not representative of the general population. Thus, any findings would likely not apply to those whom we wanted to influence with public health interventions. The scepticism about our findings and the quality of the results discouraged me from publishing the results.

Quality (§ 3)

Furthermore, research should be conducted in accordance with the norms and quality expected in the field *§3* [230], and publications ought to add new insights. To my knowledge, the quality of this study was in accordance with previously published studies of cross-sectional design in the field of commuter cycling [125, 126, 176]. The study used a questionnaire for the general population to identify cyclists, which is the most common method of investigating commuter cycling and health [18, 22, 40, 99]. Interestingly, our results were in accordance with previous findings on health benefits (e.g., BMI) [79, 229] and the characteristics of cyclists (i.e., gender, income, level of education) [125, 126]. However, although the methods were in accordance with the norms of the field, I found the quality to be reduced by the low response rate. While I did not think that there was any harm in publishing the study, as our results confirmed previous findings, the impact and new insights of the study are critically minimal.

Availability of results (§ 11)

Paragraph 11 in the Norwegian ethical guidelines states that all results should be published [230]. This ensures transparency and is thus beneficial for society in general, providing an important tool for engaging with the public [230]. The question of interest here is whether to publish results from a web survey with a critically low response rate. From my point of view, the low response rate itself is not decisive, but rather it would be if it had affected the quality and the accuracy of the findings. The results should thus be published to inform those who are interested in commuter cycling either in Norway or in other countries with low numbers of cyclists.

Social responsibility (§12)

There were also concerns about social responsibility. The aim of the study was to inform those with a public health interest in commuter cycling interventions. To advise policymakers and stakeholders, we need robust findings [231, 232]. However, what if the new insights are minimal, and the strength of the findings is low, but the results are in adherence with those of previous studies? If there are any new insights that even indirectly contribute to better public health, they should be published. In regard to publishing, there is a loophole in academia that allows an author to make their point very narrowly and specifically to give the impression that a study has not previously been conducted [233]. For instance, this might mean describing the characteristics of commuter cyclists in three counties in Norway, while commuter cyclists in other regions have previously been described [125, 126]. As a result, the present study may be interesting, as there has been little research on this topic in countries with low rates of commuter cycling.

Paragraph 1 (*§1*) is the only one that yields a conclusion of 'do not publish'. Two other paragraphs (*§11* and *§12*) recommend publication, and there is no clear conclusion for *§3*. As *§1 Quest for truth* describes when a paper should not be published, there may be situations in which it is wrong to publish, even though most of the other paragraphs conclude otherwise. Therefore, we chose to publish by applying the following solution. In addition, the data were published transparently so that readers could judge the conclusions for themselves.

A solution: Publish the survey within a new methodological framework

If a study with large methodological issues is to be published, the paper should also have a second aim: namely, to learn from mistakes and to develop and discuss how other researchers may avoid similar pitfalls. I was in doubt as to whether a cross-sectional design and web-based surveys would be a sufficiently strong method for investigating the characteristics of commuter cyclists. It has been observed that short web-based questionnaires tend to achieve higher response rates, but this may not be the only solution [234]. To solve the problem, we chose to use GIS. This is a method with increased interest, and it has previously been used to investigate environmental factors affecting active travel [120, 235, 236]. This inclusion of environmental factors resulted in an innovative paper that enhances ecological understanding and provides information beyond what it would be possible to derive from survey data alone.

Commuter cycling as public health strategy from a socioecological perspective

Globally, there is a goal of increasing levels of PA [26]. In Norway, there is a specific goal to increase the proportion of daily trips undertaken by bicycle from 5% to 8% at the national level and 20% in cities by 2029 [148]. To achieve this goal, travel behaviour needs to be changed. A scoping review of interventions to increase commuter cycling found solid evidence for large-scale environmental approaches [27]. This further highlights a gap in the evidence for social- and individual-level approaches [27].

The results of the three research questions raised in the present thesis enable robust recommendations for cycling as a public health strategy. In Study I, we observed that any cycling, regardless of dose, was associated with a lower risk of CVD and its associated risk factors. As the newest recommendations for physical activity underlines, reduced risk for diseases and mortality follows if any level above sedentary is achieved [29]. There is no specific recommendation for active transport in general and commuter cycling particularly in Norway, but commuter cycling is a feasible path to meet the recommendations for physical activity [237]. However, only one third of adults in Norway meet the recommendations for physical activity [45], and the proportion of cycling for transportation in Norway has been steady at ~5% since the 1990s [122]. In Norway, the national bike strategy aims to increase trips undertaken by bicycle. Our bike traffic index (Study IV) indicates large geographical differences and a national increase in counted cyclists over the last three years.

Interventions to increase commuter cycling are more likely to succeed when a socio-ecological approach is taken. The core of the socioecological perspective is recognition that change is more likely to *happen* and *to be sustained* when the whole system supports and motivates a specific behaviour [115]. The strength of the approach is improved further when it is behaviour-specific [115]. Specific (environmental and policy) variables need to be identified to precisely nudge behaviour in the right direction, as approaches to promote cycling in general are not equivalent to promoting commuter cycling. Therefore, interventions need to be tailored at multiple levels to improve behaviour. A literature review of policies for promoting active travel revealed that the core of the promotion strategy is provision of convenient, safe, and connected cycle infrastructure [238]. The authors highlighted that the research in the field comes from a diverse range of disciplines, including public health and transportation and planning. In addition, with relevance to landscape planning, it is noted that active travel in general and cycling specifically are more likely when homes and workplaces are located close together [238]. This may also be one of several reasons why variation in the proportions of cyclists is observed in different geographical areas [121].

In accordance with our findings, active travel may also be promoted by discouraging passive travel, as the probability of cycling increases when the time cost is lower for cycling than for driving [238]. However, promotion is more effective when conducted using comprehensive packages that target society, city, routes, and individuals [238]. As the effect of any specific policy to increase cycling is nearly impossible to identify [238], a customised approach should be considered. It is especially important to design and evaluate promotion that targets those who are less physically active.

Implications and future research

The present thesis has contributed to the field of cycling and health with a broad perspective of the CVD-related health benefits of cycling. We observed that risk factors for CVD, CVD incidence, and CVD mortality are lower in individuals who cycle, and the highest-quality studies found the strongest associations. Surprisingly, we did not observe a consistent dose-response relationship, although it is likely to be more beneficial to bicycle more. However, a dose-response relationship between cycling and CVD mortality has been observed in a systematic review with meta-analysis published in 2021 [112]. In contrast with previous research, did we not observe gender differences for any of the CVD risk factors in our meta-analyses. Based on the results and discussion in this thesis, we therefore recommend that researchers report gender-separated data where possible. Further, we encourage researchers to be more consistent when creating categories for cycling doses and to report data, including that of low prevalence, in each category. If this is done, recommendations can be designed more precisely.

In addition, this thesis identifies, interprets, and discusses the influences of personal, natural, and built-environment factors. The present thesis identified several factors, including population density, elevation along commuting route, level of PA, and gender, that were significantly associated with commuter cycling. However, we also observed that the associations were different among those cycling short and long distances. There seems to be no single factor that drives people's choice of transportation mode [120, 133]. However, adaptions in the built environment in areas of high population density and generally smaller distances between home and work may increase the number of cyclists. To better understand the importance of the built environment in general and the bicycle-friendly environment especially, future research should evaluate both the short- and long-term effects of adaptions in built environments. With more knowledge about the characteristics of cyclists, it would be possible to design better interventions and campaigns to increase the rates of cycling.

Based on the observations in this thesis, there is a need for more knowledge about what interventions should be undertaken in different geographical or cultural environments so that individuals can make a shift from passive travel to cycling for transportation. Norway's local, regional, and national bike traffic index may be an important tool for evaluating upcoming interventions and campaigns when promoting cycling. The index will be published online to ensure its availability to those who are interested in and in need of such tool.

For policymakers, urban planners, and stakeholders, this doctoral thesis provides an argument for the green shift and makes a case for cycling cities. It may well be that a cycling city is a healthy city.

CONCLUSIONS

I: Cyclists were at lower risk of CVD incidence, CVD mortality, and some CVD risk factors. Similarly low risks of CVD were observed for men and women. Health professionals, city planners, and stakeholders can recommend cycling to prevent CVD and should aim to increase the amount of any cycling.

II: Cycling was associated with lower levels of CVD risk factors. There were no sex differences or dose-response relationship between the amount of cycling and effect size. Future studies should investigate which changes in the environment may increase the numbers of cyclists and aim to better understand the obstacles to exchanging car transit for cycling.

III: In the present study, both individual and environmental factors were associated with likelihood of being a cyclist. Owning an e-bike, being active, and being in good health all increased the likelihood, while living more than 5 km from work or being overweight or obese reduced the probability. With the exception of good health, the characteristics of cyclists seemed to be similar, regardless of whether they were in areas with smaller or larger shares of cyclists. Thus, adaptions of the built environment in areas of high population density and shorter distances between home and work may increase the proportion of cyclists.

IV: A robust and sensitive bike traffic index has been presented, and the present bike traffic indices of local, regional, and national trips describe both the 2018 level and the trends in Norway over the following three years. Nationally, we observed a significant increase in counted trips, while the regional and local indices indicate geographical differences. The indices may highlight effects related to local and national bicycling strategies.

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Study I

Cycling is associated with a lower incidence of cardiovascular diseases and death: Part 1 – systematic review of cohort studies with meta-analysis

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ABSTRACT

Objectives Physical inactivity is a risk factor for cardiovascular disease (CVD). Cycling as a physical activity holds great potential to prevent CVD. We aimed to determine whether cycling reduces the risk of CVD and CVD risk factors and to investigate potential dose-response relationships.

Design Systematic review and meta-analysis of quantitative studies.

Eligibility criteria for selecting studies We searched four databases (Web of Science, MEDLINE, SPORTDiscus and Scopus). All quantitative studies, published until August 2017, were included when a general population was investigated, cycling was assessed either in total or as a transportation mode, and CVD incidence, mortality or risk factors were reported. Studies were excluded when they reported continuous outcomes or when cycling and walking were combined in them. We pooled adjusted relative risks (RR) and OR. Heterogeneity was investigated using I.

Results The search yielded 5174 studies; 21 studies which included 1,069,034 individuals. We found a significantly lower association in combined CVD incidence, mortality and physiological risk factors with total effect estimate 0.78 (95% CI (CI): 0.74–0.82; P<0.001; I^2=58%). Separate analyses for CVD incidence, mortality and risk factors showed estimates of RR 0.84 (CI, 0.80 to 0.88; P<0.001; I^2=29%), RR 0.83 (CI, 0.76 to 0.90; P<0.001; I^2=0%), and OR 0.75 (CI, 0.69 to 0.82; P<0.001; I^2=66%), respectively. We found no dose-response relationship or sex-specific difference.

Conclusions Any form of cycling seems to be associated with lower CVD risk, and thus, we recommend cycling as a health-enhancing physical activity.

Systematic review registration Prospero CRD42016052421.

What is already known?

- ► The rise of non-communicable diseases is a growing challenge worldwide.
- ► Physical inactivity is associated with CVD as well as its risk factors.
- ► Thus, it is necessary to increase physical activity levels by means of multi-sectorial and multidisciplinary public health actions.
- ► Active transport may be a promising approach to increase levels of physical activity and reduce CVD risk.

What are the new findings?

- ► Cycling was associated with 22% lower risk of combined CVD risk than using passiv transport.
- ► There was no sex-difference or dose-response relationship of cycling and risk of CV
- ► Politicians, stakeholders and city planners may promote cycling as public health action.

INTRODUCTION

The rise in non-communicable diseases (NCDs) is a growing challenge worldwide.[1 2] In 2016, cardiovascular disease (CVD) was one of the five leading causes of years of life lost.[3] Physical inactivity is associated with CVD and CVD risk factors,[4 5] and the WHO has declared physical inactivity the fourth leading risk factor for global mortality.[6] Approximately a quarter of the world's adults are physically inactive.[7] Globally, the level of physical activity has decreased over previous decades[8] and is still decreasing.[7] Multi-sectorial and multidisciplinary public health actions are needed to tackle the problem of physical inactivity.[9]

Changes in the built environment are likely to increase the activity level among children and adults.[10] Walking and cycling separately, adjusted for other physical activity, may reduce the all-cause mortality at a population level.[11] Active transportation may also reduce the incidence of NCDs, including CVD.[8] Therefore, active transportation may be a promising approach to increase physical activity levels and reduce CVD risk. In addition, cycling as transportation may appeal to many people who are not interested in participating in sport as a means of being physically active.

One limitation of research studies investigating active transportation is that they often combine walking and cycling.[12] This is a problem since cycling often is performed at a higher exercise intensity than walking,[13] and higher exercise intensity is associated with a further reduction in risk of coronary heart disease.[14] Therefore, cycling may be more effective than walking in preventing CVD.[12] To our knowledge, there has not been a meta-analysis examining prevention of CVD and cycling. Nevertheless, there are two meta-analyses examining CVD and active transport[15 16] and one literature review of cycling.[12] Therefore, this systematic review with meta-analysis of cycling and CVD adds increased power to investigate the association, as data are pooled, and accounts better for the observed heterogeneity than when walking and cycling are combined.

We aimed to assess the strength of association between cycling and (1) CVD and (2) CVD risk factors. We hypothesised there would be similar associations for men and women, and a dose-response relationship between cycling and health.

METHODS

We conducted a systematic review with meta-analysis. The protocol was registered with the PROSPERO database on 6 December 2016 (PROSPERO ID: CRD42016052421) (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42016052421) and complied with Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009 guidelines.[17]

Literature search

We searched for published quantitative studies (prospective, retrospective, cohort, longitudinal design and cross-sectional studies or randomised controlled trials) that examined the association of cycling with CVD or CVD risk factors to 8 August 2017. The first author (SN), in cooperation with a librarian, performed the search. Published and peer-reviewed articles in English were identified from four electronic databases: Web of Science, MEDLINE, SPORTDiscus and Scopus. The search strategy consisted of the terms 'cycling' OR 'bicycling' OR 'biking' OR 'commuter cycling' AND 'CVD' OR 'CVD risk factors' OR 'CVD risk factor' OR 'cardiovascular disease risk factors' OR 'cardiovascular disease' OR 'cardiovascular diseases' OR 'cardiovascular disease*.'' In total, 5174 records were identified: Web of Science (3525), MEDLINE (via EBSCO) (522), SPORTDiscus (41)and Scopus (1086). After elimination of duplicates, 4785 records remained (figure 1).[17] See online supplementary table 1, for example, of full search strategy run in MEDLINE via EBSCO. We searched the reference lists of included studies and contacted experts in the field to identify any studies that may have been missed in our electronic database search.

Inclusion criteria and selection process

Studies were excluded if they measured domains other than cycling, such as stationary cycling, or if cycling was a part of a rehabilitation programme/intervention or investigated an unhealthy population. We had no criteria for sample size.

We included studies that (1) employed a quantitative design and studied a general population; (2) assessed cycling exposure either as a mode of transportation, or as a recreational activity; (3) measured CVD, CVD mortality or physiological CVD risk factors as an outcome and (4) reported dichotomous outcome measures.

Two reviewers (SN and AR) independently assessed the studies for eligibility with subsequent consensus by discussion.

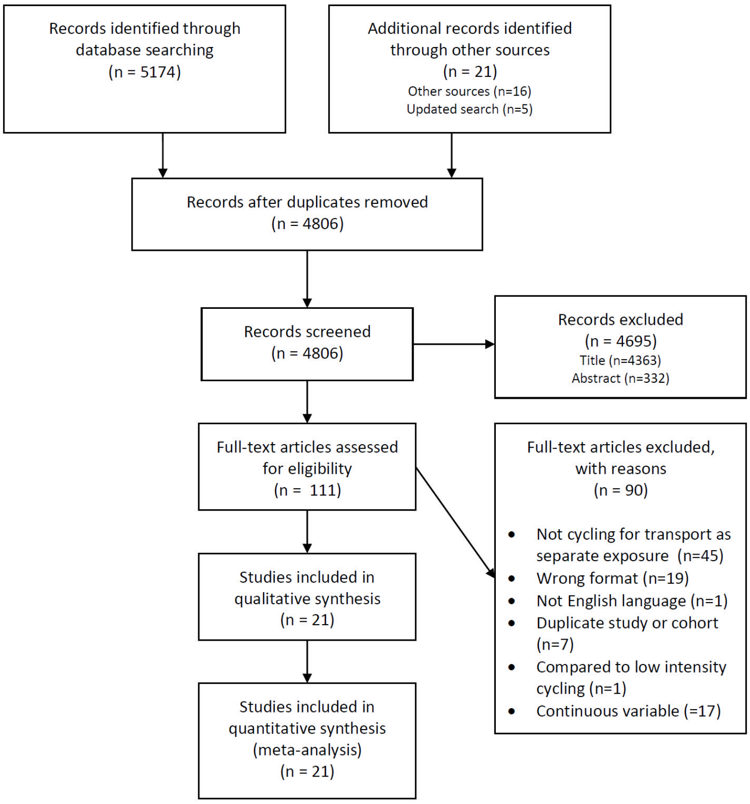

Figure 1 Flow chart of included studies as proposed by Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement 2009.[17]

Table 1 Quality assessments of included studies based on the Quality Assessment Tool of Quantitative Studies[18]

Study	Selection bias	Study design	Confounding factors	Blinding	Data collection	Withdraws and drop-outs	Global rating*
Hoevenaar-Blom *et al*[19]	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
Koolhaas *et al*[20]	Weak	Moderate	Strong	NA	Moderate	Moderate	Moderate
Armstrong *et al*[21]	Moderate	Moderate	Moderate	NA	Strong	Weak	Moderate
Blond *et al* [22]	Weak	Moderate	Strong	NA	Moderate	Moderate	Moderate
Andersen *et al* [23]	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
Celis-Morales *et al* [24]	Weak	Moderate	Strong	NA	Moderate	Strong	Moderate
Matthews *et al*[25]	Strong	Moderate	Strong	NA	Moderate	Strong	Strong
Besson *et al*[26]	Weak	Moderate	Moderate	NA	Moderate	Weak	Weak
Oja *et al*[27]	Moderate	Moderate	Strong	NA	Moderate	Strong	Strong
Sahlqvist *et al*[28]	Moderate	Moderate	Strong	NA	Moderate	Moderate	Strong
Grøntved *et al*[29]	Moderate	Moderate	Strong	NA	Moderate	Moderate	Strong
Laverty *et al*[30]	Weak	Weak	Strong	NA	Moderate	NA	Weak
Wen *et al*[31]	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
Østergaard *et al* [32]	Moderate	Weak	Moderate	NA	Weak	NA	Weak
Bere *et al*[33]	Weak	Moderate	Moderate	NA	Moderate	Weak	Weak
Sahlqvist *et al* [34]	Weak	Weak	Strong	NA	Moderate	NA	Weak
Millett *et al*[35]	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
Berger[36]	Weak	Weak	Moderate	NA	Weak	NA	Weak
Evenson *et al* [37]	Moderate	Weak	Strong	NA	Moderate	NA	Moderate
Hu *et al*[38]	Strong	Weak	Moderate	NA	Moderate	NA	Moderate
Ramirez-Velez *et al*[39]	Strong	Weak	Moderate	NA	Moderate	NA	Moderate

*Weak, moderate and strong indicated poor, moderate and high study quality, respectively.
NA, not applicable.

Risk of bias assessment

The included studies were assessed according to the Quality Assessment Tool of Quantitative Studies.[18] SN and AR independently assessed each study. Any case of disagreement was resolved by discussion. The tool consists of six components: representativeness of the target group, study design, confounding factors, blinding of both assessors and participants, reliability and validity of measures and number of withdrawals and dropouts. Each component was rated 'weak', 'moderate' or 'strong' following a standardised rating system, where 'weak' and 'strong' indicates poor and high quality, respectively. Studies with no weak components were rated as 'strong', studies with one weak component were rated as 'moderate' and studies with more than one weak component were rated as 'weak'. For detailed information of distribution of study quality, se table 1 .[19–39]

Contact with authors

We (SN or LBA) contacted the corresponding author when there was a lack of clarity or when additional information was needed.[39]

Data extraction and main analysis

Data extraction was conducted by SN based on the main estimate exposure, which was defined in accordance with the protocol as any cycling. Main outcomes were defined a priori as CVD mortality, CVD incidence and CVD risk factors. CVD and coronary heart disease were treated as CVD for both CVD mortality and CVD incidence. In studies where relative risk (RR) was presented with more than one model of adjustment, the most conservative estimate was included. If both CVD mortality and CVD incidence were reported,[24] CVD incidence was included due to higher numbers of cases.

For single risk factors, each risk factor was included in the main estimate, but not when both 'overweight or obese' and 'obesity' were reported in a single study. In this case, only 'overweight or obese' was included due to higher numbers of cases. If studies only reported high and low dose or reported men and women separately or reported more than one level of dose, we meta-analysed each study and included the combined estimate (online supplementary table 2).

Among those 10 studies reporting either CVD mortality or CVD incidence only, the following was analysed: (1) CVD incidence and total cycling,[24] (2) CVD incidence and estimated total cycling,[20–22] (3) CVD mortality and estimated total cycling,[28] (4) CVD mortality and estimated commuter cycling,[25 26] (5) CVD mortality and total cycling[23 27] and (6) CVD incidence and estimated commuter cycling.[19] We included only the estimate of highest statistical power from each study. This was important to ensure that individuals were included in the meta-analysis only once.

Data extraction subgroup analysis

Due to a wide range in reporting of exposure and outcomes, we classified exposure as total cycling or commuter cycling. Outcomes were classified by subgroups for CVD mortality, CVD incidence, grouped CVD risk factors, and single CVD risk factors. CVD risk factors were only analysed when reported by ≥2 studies (online supplementary table 4). This resulted in subgroup analyses of (1) overweight or obese, (2) obesity, (3) hypertension, (4) HDL-cholesterol level and (5) triglyceride level. See table 2 for details of classifications of risk factors. We analysed hypertensive versus not hypertensive. All subgroups were analysed for men, women and men and women combined.

Dose-response

Each study was individually recoded into low-dose and high-dose cycling when possible. Low dose was defined as the lowest amount of cycling reported, and high dose was defined as

Table 2 Characteristics of included studies.

Study	Design/cohort /countries	Type of cycling	Population	Dates/years of follow up	Total N	Incidence /death	Outcome	Prevalence of cycling (%) Total/low/high	RR/OR (95% CI)	Dose Low	Dose High
Hoevenaar-Blom *et al*[19]	Prospective cohort/MORGAN/ The Netherlands	Commuter	Men, women; Aged 20–65 y at baseline	1993–2006/9.8	16 442	923/NA	Incidence	75%/19%/5%	0.82 (0.73 to 0.92)	Regular cycling	>2.5 hour/wk
Koolhaas *et al*[20]	Prospective cohort/Rotterdam study/ The Netherlands	General	Men, women; aged>55 y at baseline	1997–2012/10.3	5901	642/NA	Incidence	58%/32%/26%	0.78 (0.67 to 0.91)	13 min/day	51 min/day
Armstrong *et al*[21]	Prospective cohort/ Million Women Study/ United Kingdom	Total	Women; Aged 55.9 (SD 4.8) y at baseline	1998/9	497 857	6815/NA	Incidence	Not reported*	0.84 (0.80 to 0.88)	>0–2 hour/wk	>2 hour/wk
Blond *et al*[22]	Prospective cohort/ Diet, Cancer and Health/ Denmark	Overall, commuter	Men, women; Aged 50–65 y at baseline	1993–2013/20	53 723	2892/NA	Incidence	Not reported	0.87 (0.82 to 0.93)	>0–2.5 hour/wk†	>2.5 hour/wk†
Andersen ZJ *et al*[23]	Prospective cohort/ Diet, Cancer, and Health/ Denmark	Commuter, leisure time	Men, women; Aged 50–65 y at baseline	1993–2010/13	52 061	NA/1285	Mortality	68%/NA/NA	0.78 (0.69 to 0.88)	No dose reported. 3.2±3.4 hour/wk	
Celis-Morales *et al*[24]	Prospective cohort/ UK Biobank/ United Kingdom	Commuter	Men, women; 40–69 y at baseline	2007–2014/5	263 540	1110/496	Incidence, mortality	3%/NA/NA	0.54 (0.33 to 0.88)	Short ‡	Long ‡
Matthews *et al*[25]	Prospective cohort/ Shanghai Women's Health Study/ China	Commuter	Women; Aged 40–70 y at baseline	1997–2004/5.7	67 143	NA/251	Mortality	NA/19%/5%	0.72 (0.42 to 1.23)	0–1–3.4 METh/day	>3.5 METh/day
Besson *et al*[26]	Prospective cohort/ EPIC-Norfolk/ United Kingdom	Commuter	Men, women; Aged 45–79 y at baseline	1993–2006/7	14 903	NA/370	Mortality	NA/NA/NA	0.77 (0.51 to 1.15)	<30 min/wk	>30 min/wk
Oja *et al*[27]	Prospective cohort/ HSE & SHeS/ England, Scotland	Any	Men, women; Aged 30–98 y at baseline	1991–2008/9.2	75 014	NA/1909	Mortality	10%/5%/5%	0.93 (0.76 to 1.16)	min/wk low §	min/wk high §
Sahlqvist *et al*[28]	Prospective cohort/ EPIC-Norfolk/ United Kingdom	Commuter, Total	Men, women; Aged 40–79 y at baseline	1993–2011/15.3	22 450 Commuter; 13 346	NA/1639	Mortality	Total: 30%/NA/NA Commuter: NA/4%/2%	0.86 (0.74 to 1.00)	1–59 min/wk	>60 min/wk
Grøntved *et al*[29]	Prospective cohort/ Västerbottens Health Survey/Sweden	Commuter	Men, women; Aged 43.5 y at baseline	1990–2011/10	23 732		Risk factors ¶**†† ‡‡	24%/NA/NA	1; 0.85 (0.73 to 0.99) 2; 0.87 (0.79 to 0.95) 3; 0.85 (0.76 to 0.94)		
Laverty *et al*[30]	Cross sectional/ Understanding society/ United Kingdom	Commuter	Men, women; Aged 16–65 y	NA	20 458		Risk factors ¶**	3%/NA/NA	1; 0.63 (0.53 to 0.75) 2; 0.76 (0.56 to 1.01)		
Wen *et al*[31]	Cross-sectional/ New south Wales Adult Health Survey/ Australia	Commuter	Men, women; Aged≥16 y	NA	6832		Risk factors¶¶	3%–10%/NA/NA	1; 0.34 (0.13 to 0.89)		
Østergaard *et al*[32]	Cross sectional/ NA/ Denmark	Commuter	Men, women; Aged 12–16 y		3847		Risk factors¶¶	62%/NA/NA	1; 0.55 (0.42 to 0.72)		
Bere *et al*[33]	Longitudinal/ ENDORSE and Youth in Balance/ The Netherlands, Norway	Commuter	Men, women; Aged 13.2 y at baseline	2005–2008/2	890		Risk factors¶¶	48%/NA/NA	1; 0.44 (0.21 to 0.88)		

Continued

Table 2 Continued

Study	Design/cohort /countries	Type of cycling	Population	Dates/years of follow up	Total N	Incidence /death	Outcome	Prevalence of cycling (%) Total/low/high	RR/OR (95% CI)	Dose	
										Low	High
Sahlqvist *et al*[34]	Cross-sectional/ Bicycle Victoria/ Australia	Commuter	Men, women; Aged≥18 y	NA	1813		Risk factors¶	100%/NA/NA	1; 0.67 (0.50 to 0.90)		
Millett *et al* [35]	Cross-sectional/ Indian Migration Study/ India	Commuter	Men, women; Aged≥18 y	NA	3902		Risk factors¶**	45%–68%/NA/NA	1; 0.66 (0.55 to 0.77) 2; 0.51 (0.36 to 0.71)		
Berger *et al*[36]	Cross-sectional/ TCCS/ United States	Commuter	Men, women; Aged 20–64 y	NA	1450		Risk factors¶**††‡‡	100%/NA/NA	1; 0.69 (0.58 to 0.82) 2; 0.67 (0.50 to 0.90) 3; 0.72 (0.59 to 0.88) 4; 0.85 (0.67 to 1.07)		
Evenson *et al*[37]	Cross-sectional/YRBS/ United States	Commuter	Men, women; Youth in 6th–12th grades	NA	4448		Risk factors¶	13%/NA/NA	1; 0.71 (0.52 to 0.98)		
Hu *et al*[38]	Cross-sectional/ NA/China	Commuter	Men, women; Aged 20–49 y	NA	3708		Risk factors††‡ ‡	11%–19%/NA/NA	3; 0.71 (0.52 to 0.98) 4; 0.90 (0.66 to 1.23)		
Ramirez-Velez *et al*[39]	Cross-sectional/ FUPRECOL/Colombia	Commuter	Men, women; Aged 9–17.9 y	NA	1568		Risk factors††‡‡	23%/NA/NA	3; 1.06 (0.81 to 1.37) 4; 1.03 (0.83 to 1.23)		

Risk factors:
*States that cycling is infrequent in this cohort.
†Commuter cycling: Low dose=0–1.5 hour/week; High dose >1.5 hour/week
‡Split into groups according to distance.
§Groups defined by using the sex-specific medians.
¶) Body mass index (BMI), overweight ≥25, and obesity ≥30 according to the WHO.[43]
** Hypertension (self-reported or doctor-diagnosed[30 36] or systolic blood pressure or diastolic blood pressure >140 and>90 mm Hg, and/or use of antihypertensive medications.[29]
††) Hypertriglyceridemia (>1.7 mmol/L,[29] self-reported or doctor diagnosed,[36] adverse log transformed scale,[38] or 'high triglycerides' not defined.[39]
‡‡) Low high-density lipoprotein level (self-reported or doctor-diagnosed,[36] adverse scale[38] or low high-density lipoprotein level (Friedwald formula).[39]
METh, metabolic equivalent hours.; NA, not applicable; RR, relative risk; wk, week.

the highest dose reported (table 2, characteristics of included studies). For the study by Blond *et al*,[22] low dose was generated after meta-analysis of low (>0–1 h/week) and moderately low (1–2.5 h/week) cycling. The dose-response relationship was analysed for total cycling and commuter cycling. When both CVD incidence and CVD mortality were reported,[24] CVD incidence was included in the dose-response analysis.

We reanalysed the dose-response relationship in post-hoc analysis by redefining the criteria for low and high dose. First, we redefined the cut-off for high dose as >1 h/week, then as >2 h/week and finally we analysed at three dosage levels.[21]

Statistics

In all analyses, we ensured that individuals were not analysed more than once for the same outcome, that is, 'overweight or obese' and 'obesity.' Due to this, studies were only included once for CVD incidence and CVD mortality but may have been included in different subgroup analyses or for equivalent CVD risk factors. For analyses of CVD incidence or CVD mortality, we calculated pooled RR or pooled HR. For analyses of each CVD risk factor, we calculated adjusted OR.

All analyses were performed in Stata v.12.1 (StataCorp LP, USA), using user-written commands described by Egger *et al*.[40] The estimates are presented as multivariate adjusted RR (CVD incidence and CVD mortality) or OR (CVD risk factors) with 95% CIs.

We used random effect models.[40] Dose-response relationships and differences between sexes were analysed using meta-regression and presented as β-coefficients and P values. Heterogeneity was assessed using the I^2 statistic, Q (Cochran's heterogeneity test) and P value. The I^2 statistic was calculated using Stata based on Q and df.

$I^2=100\% \times (Q-df)/Q$

As proposed by Higgins *et al*,[41] I^2 describes the percentage of total variance across studies, with values between 0% and 100%, where 0% indicates no heterogeneity. Negative values were set equal to zero.[41] Heterogeneity was tested in all analyses, but should be interpreted with caution when few studies were analysed due to the possibility of false homogeneity.[41]

Following the rule of thumb described by Sterne *et al*,[42] the test for funnel plot asymmetry was only used when there were more than nine studies in the meta-analysis (figure 2). Sensitivity analyses, tests for heterogeneity and regression analyses are presented in online supplementary table 5a-12b.

Small-study effect

The small-study effect was investigated for the total estimate CVD using the 'metabias' and 'metainf' commands as described by Egger *et al*.[40] We also performed subgroup analyses for study quality and for CVD incidence compared with CVD mortality.

Role of the funding source

There was no funding source for this systematic review.

RESULTS

In total, 38 studies fulfilled the primary inclusion criteria. As the present meta-analysis comprises dichotomous outcomes only, 17

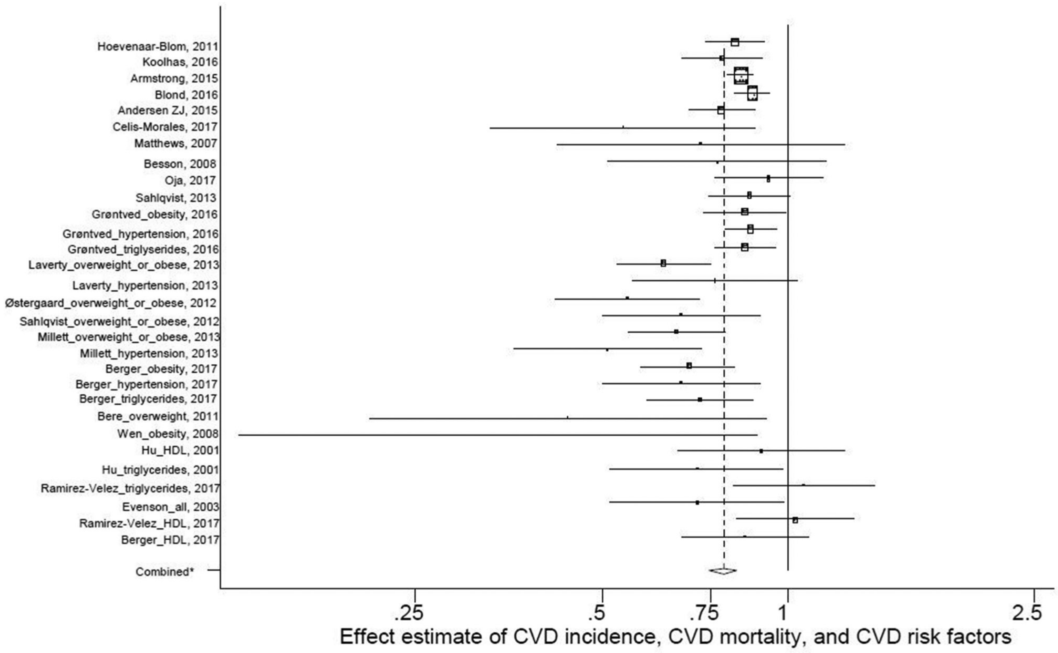

Figure 2 Forest plot of the main analysis of cycling on CVD incidence (risk ratio), CVD mortality (risk ratio), and CVD risk factors (OR). *The combined random effect estimate was 0.783 (CI: 0.744 to 0.824) for CVD incidence, CVD mortality and CVD risk factors combined, indicated by the diamond in the bottom of the diagram. The combined estimate was statistically significant, but were moderately heterogeneous (I^2=58%). From the top, the first ten studies are either CVD incidence or CVD mortality estimates, and the latter studies are CVD risk factors. See table 2 details of included studies.

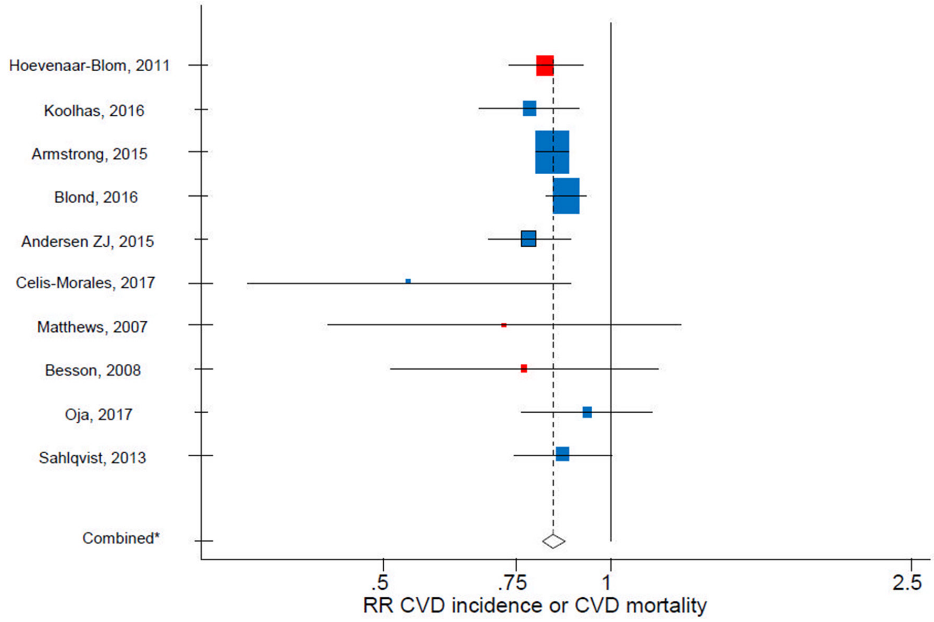

Figure 3 Forest plot of sensitivity analysis of main analysis on CVD incidence and CVD mortality. Total cycling is indicated by blue colour, and commuter cycling is indicated by red colour. *The combined random RR was 0.840 (CI: 0.812 to 0.868, I^2=0%) for CVD Incidence and CVD mortality, indicated by the diamond in the bottom of the diagram. For CVD incidence the combined RR was 0.837 (0.797–0.880, I^2=30%), and for mortality the combined RR was 0.827 (0.761–0.899, I^2=0%). The inconsistent result of homogeneity is most likely due to few studies in the separate analysis.

studies with outcomes presented only as continuous variables were excluded. Thus, the present meta-analysis included 21 studies (figure 1). Data were reanalysed of high-density lipoprotein (HDL)-cholesterol and triglyceride levels from the study of Ramírez-Vélez *et al*[39] due to lack of clarity.

In total, 1,069,034 individuals from eight different cohorts and four different countries were included in the analysis of CVD incidence and CVD mortality. The estimates were based on 12,382 incidents and 5950 deaths during a follow-up time of 9.8±4.9 years. Further, 72,648 individuals from 10 countries were analysed for one or more CVD risk factors. figure 1 presents detailed information regarding the review process and exclusions. table 2 summarises the characteristics of the 21 included studies.[19–39]

Main analysis of outcome

For the overall analysis of CVD incidence, CVD mortality and CVD risk factors, there was a significant total effect estimate of 0.78 (95% CI: 0.74 to 0.82, P<0.001; I^2=58%, Q P<0.001) (figure 2). The RR for CVD incidence was 0.84 (0.80–0.88, P<0.001; I^2=30%, Q P=0.22). The RR for CVD mortality was 0.83 (0.76–0.90; P<0.001; I^2 <0%, Q P=0.58). The OR for CVD risk factors was 0.75 (0.68–0.82; P<0.001; I^2=64%, Q P<0.001).

Sensitivity analysis of total cycling and commuter cycling in the main analysis

For total cycling, there was a RR of 0.80 (0.71–0.90, P<0.001; I^2=45%, Q P=0.16) for CVD incidence and a RR of 0.84 (0.71–0.99, P=0.037; I^2=53%, Q P=0.14) for CVD mortality (figure 3). For commuter cycling, there was a RR of 0.86 (0.85–0.91, P<0.001; I^2 <0%, Q P=0.33) for CVD incidence, a RR of 0.84 (0.74–0.97, P=0.014; I^2 <0%, Q P=0.73) for CVD mortality and an OR of 0.75 (0.69–0.82, P<0.001; I^2=66%, Q P<0.001) for CVD risk factors (figure 3).

Subgroup analysis of total cycling

CVD incidence and CVD mortality

When performing subgroup analysis of total cycling, we found a RR of 0.806 (0.741–0.877, P<0.001; I^2=41%, Q P=0.132) for combined CVD incidence and CVD mortality. Subgroup analysis showed similar results when CVD incidence was analysed separately, with a RR of 0.800 (0.712–0.899, P<0.001; I^2=45%, Q P=0.162). Matthews *et al*[24]analysed women only, and no studies analysed men separately. No studies reported results for combined or single risk factors of total cycling, and thus, all analyses of risk factors were derived from commuter cycling; see online supplementary table 10a-12b for sex differences.

CVD risk factors only

No study reported total cycling and CVD risk factors.

Subgroup analysis of commuter cycling

CVD incidence, CVD mortality and CVD risk factors

A total of 46 different estimates were reported for commuter cycling. When CVD incidence, CVD mortality and CVD risk factors were combined, there was a RR of 0.77 (0.73–0.82, P<0.001; I^2=53%, Q P<0.001). Subgroup analysis including only CVD incidence gave a RR of 0.859 (0.814–0.907, P<0.001; I^2 <0%, Q P=0.465); see online supplementary table 12a-b.

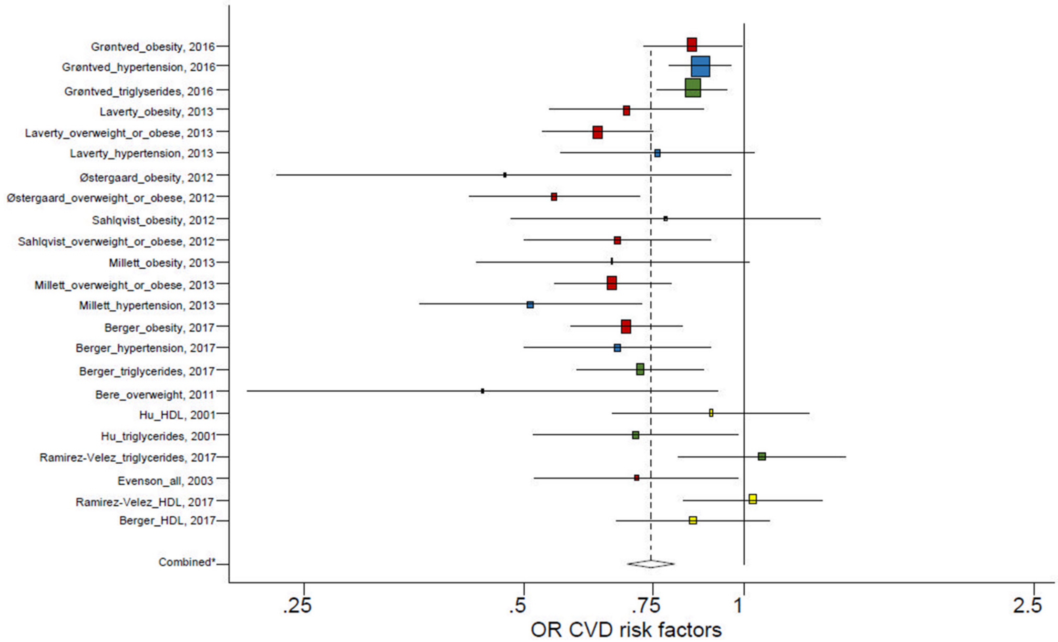

Figure 4 Forest plot of sensitivity analysis of CVD risk factors for commuter cycling. *Combined OR was 0.749 (0.689–0.815, I^2=54%) indicated by the diamond in the bottom. Red boxes indicates overweight or obese, blue box indicates hypertension, green box indicates triglycerides and yellow box indicates HDL. All risk factors independently beside HDL were significant. For detailed information of each outcome see table 6a-b in online supplementary tables.

CVD risk factors only

CVD risk factors were reported for commuter cycling. Overweight and obesity were the most commonly reported risk factors (figure 4), and were classified according to WHO.[43] In total, 'overweight or obese' or 'obesity' were reported 14 times. When analysing 'overweight or obese' and 'obesity,' there was an OR of 0.633 (0.574–0.669, P<0.001; I^2 <0%, Q P=0.814) and OR 0.722 (0.631–0.826, P<0.001; I^2=29%, Q P=0.204), respectively. There was an OR of 0.714 (0.566–0.900, P=0.004; I^2=72%, Q P=0.014) for hypertension, 0.827 (0.712–0.961, P=0.013; I^2=52%, Q P=0.098) for triglyceride level and 0.983 (0.822–1.176, P=0.855; I^2 <0%, Q P=0.502) for HDL-cholesterol level. Triglyceride level remained significant only when analysing men and women combined. HDL-cholesterol was the only risk factor not significant for men, women, or combined.

There was no dose-response relationship for total cycling, commuter cycling or combined total and commuter cycling (online supplementary table 7a-9b). All post-hoc analyses remained nonsignificant (coefficient = −0.010–0.002, P=0.648–0.909).

Small study effects

There was a significant small study effect, indicating possible publication bias (online supplementary figure 1-2).

DISCUSSION

Cycling was associated with a 16% lower risk of CVD incidence, 17% lower risk of CVD mortality and a 25% lower risk of CVD risk factors. When CVD incidence and mortality were combined, cycling was associated with a 22% lower risk. However, the main analysis was heterogeneous (I^2=58%), possibly because we included cross-sectional and prospective studies of populations of children and adults. To assess CVD incidence and CVD mortality, we analysed prospective cohort studies of adult populations.

Our results support those of a previous study of approximately 173,000 adults – that active transportation, especially cycling, reduces CVD risk.[15] We analysed an almost 10-fold larger population and included only cycling as an activity. Our results were slightly more consistent, and we found a stronger association for cycling compared with studies combining walking and cycling. Our results should be of interest for policy-makers and politicians, since they provide evidence of the protective effect of cycling on CVD.

CVD risk factors

In our systematic review, the most commonly reported and most frequently reduced risk factor was overweight or obesity. In a scoping review, Brown *et al*[16] found a small but significant reduction in body mass index with active transportation, but concluded that the effect might be smaller than indicated in the literature. However, in contrast, we found a 36% lower risk in cyclists for both overweight and obesity (OR 0.64, CI: 0.58 to 0.70, I^2=0%) combined, and a 27% lower risk for obesity (OR 0.73, CI: 0.57 to 0.94, I^2=66%). The relatively low heterogeneity could be erroneous, due to a smaller number of studies.[41] Therefore, it is possible that our results overestimate the risk reduction associated with cycling. However, our main analysis is supported by our subgroup analysis of commuter cycling and CVD risk factors (online supplementary table 12a-b), adding strength to our conclusions.

Hypertension was the second most reduced risk factor (OR 0.71, CI: 0.57 to 0.90). Two studies[30 36] defined hypertension based on a self-reported diagnosis by a physician, while Grøntved *et al*[29] used systolic and diastolic blood pressure of >140 and >90 mm Hg, respectively, or usage of antihypertensive medications. Further, risk of high triglyceride level was reduced by 18% for commuter cycling compared with that of passive commuters. Finally, HDL-cholesterol level was the only non-significant, homogeneous risk factor. Cycling therefore seems to be associated with an enhanced CVD profile and thus cycling may be able to prevent CVD incidence or CVD mortality.

Sex differences

In contrast to a previous meta-analysis,[15] we found no evidence that women experienced a greater effect from cycling compared with that of men. In our systematic review, CVD incidence and CVD mortality results were mainly presented in both sexes combined, whereas CVD risk factor results more often included a sex-specific analysis. There was a tendency for women to have greater risk reduction for both high triglyceride and HDL-cholesterol levels compared with men (online supplementary table 10a-12b).

Dose-response relationship

In contrast to previous suggestions,[11 12] we found no difference between low-dose and high-dose cycling. Increased cycling dose was associated with lower CVD risk, especially for commuter cycling and CVD mortality. This is in accordance with the finding of Kelly *et al*,[11] where the steepest risk reduction for all-cause mortality was for 0–101 min per week of cycling, but with further reduction in risk among those cycling >101 min per week.

When analysing the dose-response relationship, there were several challenges. First, we divided each study individually into either high or low doses based on the amount of cycling reported in each study. This resulted in heterogeneity of the definition of low and high dose: high dose in some studies[26 28] was similar to low dose in other studies (See table 2 for details). Second, there were few individuals in high-dose groups compared with those in low-dose groups; this was due to the low prevalence of cycling in general and a lower prevalence of high-dose cycling. Therefore, the results regarding the dose-response relationship should be interpreted with caution. We encourage researchers to be more consistent when creating categories for cycling doses and to report data, including that of low prevalence, in each category.

Strength and limitations

One of the greatest challenges of analysing cycling behaviour is that cycling is not a singular behaviour – often individuals engage in multiple physical activities. This means that people engaged in other forms of activities may be more likely to choose active transport as well. Even though 15 of 21 included studies adjusted for other physical activities, there may be residual confounding from leisure-time physical activity. In addition, in included studies with a low prevalence of cycling, cyclists may be a select group of individuals with superior health (and lower CVD risk profile). However, the majority of included studies adjusted for smoking status, alcohol consumption and level of education (see online supplementary Table 13 for details of adjustments).

Cycling and walking have different benefits such as an increased amount of vigorous activity[12]; therefore, cycling might be more protective than walking. Forty five studies were excluded due to merged groups of walking and cycling. This might be because few of the included studies were designed to evaluate the effect of cycling but rather aimed to register activity levels in large populations. If studies were not primarily designed to investigate the independent association of cycling and CVD, this may explain the publication bias we found in our funnel plot.

All studies used self-reported measurements of cycling and aimed to register physical activity levels. Self-report measurements may have recall bias, and social desirability bias by over-reporting of activity and underestimation of body weight. There was evidence for a small-study effect, and studies of negative results were less likely to be published.[40] This may have influenced our results by increasing the possibility that we overestimated the true association between cycling and CVD. On the other hand, the main analysis was primarily based on high-quality studies that consistently reported positive associations between cycling and reduction in CVD incidence and mortality. However, the results were less certain for the association between cycling and CVD risk factors since the studies included in those analyses were of moderate and low quality.

CONCLUSION

Cyclists had lower risk of CVD incidence, CVD mortality and some CVD risk factors. Similar lower risk of CVD were observed for men and women. Health professionals, city planners and stakeholders can recommend cycling to prevent CVD and should aim to increase the amount of any cycling.

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Contributors All authors contributed to the design of the study and reviewed the report. SN and LBA generated the hypotheses. SN and AR performed the literature search. SN, AR and LBA analysed the data. SN wrote the first draft of the manuscript. LBA, AKS and AR revised the manuscript critically for important intellectual content. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. LBA is the study guarantor.

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Competing interests None declared.

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Study II

Cycling and cardiovascular disease risk factors including body composition, blood lipids and cardiorespiratory fitness analysed as continuous variables: Part 2—systematic review with meta-analysis

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ABSTRACT

Objectives We aimed to examine the relationship between cycling (particularly commuter cycling) and risk factors associated with cardiovascular diseases (CVDs) including body composition, blood lipids and cardiorespiratory fitness. This study differed from our recent (Part 1) systematic review in that risk factors for CVD were analysed as continuous variables rather than being present or absent.

Design Systematic review and meta-analysis.

Eligibility criteria We searched four databases (Web of Science, MEDLINE, SPORTDiscus and Scopus). All quantitative studies, published until August 2017, were included when a general population was investigated, cycling was assessed either in total or as a transportation mode, and CVD risk factors were reported.

Methods We analysed body composition, physical activity (PA), cardiorespiratory fitness (CRF), blood lipids and blood pressure (BP). Skinfold, waist circumference and body mass index were analysed and prioritised in that order when more than one measure were available. PA included measures of counts per minutes, moderate-to-vigorous PA or minutes per week. CRF included results of maximal tests with or without expired air or submaximal test. For blood lipids and BP, separate analyses were run for low-density and high-density lipoprotein, triglycerides, total cholesterol, systolic BP and diastolic BP. Studies were excluded when reporting dichotomous outcomes or when cycling and walking were combined. Heterogeneity was investigated using I^2.

Results Fifteen studies were included; the majority reported commuter cycling. In total, we included 5775 cyclists and 39 273 non-cyclists. Cyclists had more favourable risk factor levels in body composition −0.08 (95% CI −0.13 to −0.04), PA 0.13 (95% CI 0.06 to 0.20), CRF 0.28 (95% CI 0.22 to 0.35) and blood lipids compared with non-cyclists. There was no sex difference in risk reduction.

Conclusion/implication Cycling mitigated the risk factor profile for CVD. A strength of this systematic review is that all the risk factors were analysed as continuous variables. These data provide evidence for practitioners, stakeholders, policy-makers and city planners to accommodate and promote cycling.

Systematic review registration PROSPERO CRD42016052421.

INTRODUCTION

Active travel is associated with reduced all-cause mortality,[1 2] and it could improve the health on a population level.[3] Active travel is inversely associated with obesity at both country[4] and individual levels.[5] Active travel has promising associations with lower levels of cardiovascular disease (CVD) risk factors,[6 7] and it is a feasible form of physical activity for those who do not enjoy sports.[8]

In the systematic review and meta-analysis of Hamer and Chida,[9] active travellers had 11% lower risk of CVD, with a potential for greater effects in women. Further, there appears to be even larger benefits of commuter cycling compared with walking.[10] Commuter cycling is often performed at a higher physical intensity compared with walking for transportation, which may explain the stronger health-enhancing effect.[10]

In our related systematic review and meta-analysis[11] (Part 1 of 2 where this is Part 2), cyclists had a 22% lower risk of CVD incidence, CVD mortality and CVD risk factors presented as dichotomous outcome.[11] To our knowledge, there exists no meta-analysis of studies examining risk factors associated with CVD assessed as continuous variables and cycling. Nevertheless, there is one meta-analysis examining the effect of active travel and CVD as a dichotomous outcome,[7] one scoping review on body weight,[12] and one literature review on cycling and health.[3]

Due to the growing number of published studies concerning active travel and the possible heterogeneity between walking and cycling, this systematic literature review and meta-analysis aimed to summarise the associations of cycling on CVD risk factors of continues outcome variables compared with non-cyclists. We hypothesised a similar dose-dependent association of cycling and risk factor associated with CVD for both men and women.

METHODS

Search strategy and selection criteria

We conducted a systematic review and meta-analysis. The protocol for this systematic literature review and meta-analysis was registered at PROSPERO on 6 December 2016, with registration number CRD42016052421, and complied with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009 guidelines.[13]

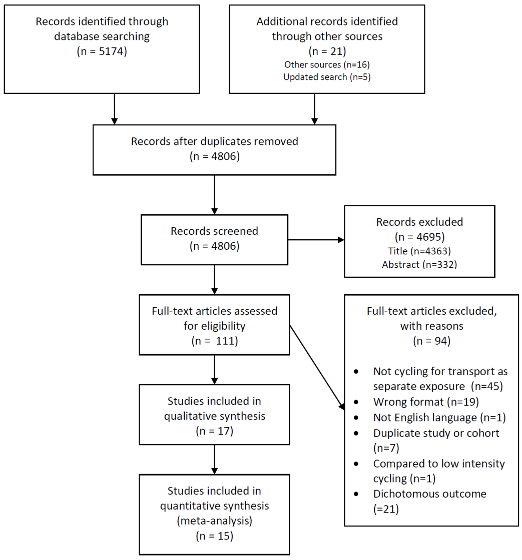

Figure 1 Flow chart of included studies as proposed by Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement 2009.

Literature search

A systematic search of published quantitative studies (prospective, retrospective, cohort, longitudinal design, cross-sectional studies and randomised controlled trials) that examined the association of cycling with CVD or CVD risk factors was performed on 1–2 December 2016. The first author (SN) performed the search in cooperation with a librarian. Published and peer-reviewed articles in English were identified from four electronic databases: Web of Science, MEDLINE, Sport Discus and Scopus. The search strategy consisted of two blocks of the terms ("cycling" OR "bicycling" OR "biking" OR "commuter cycling") AND ("CVD" OR "CVD risk factors" OR "CVD risk factor" OR "cardiovascular disease risk factors" OR "cardiovascular disease" OR "cardiovascular diseases" OR "cardiovascular disease*). In total, 5174 records were identified, from Web of Science (3525), MEDLINE (via EBSCO) (522), SPORTDiscus (41) and Scopus (1086). After elimination of duplicates, 4785 records remained (figure 1). See online supplementary table 1 for example of full search strategy.

Inclusion criteria and selection process

Two reviewers (SN and AR) independently assessed the studies for eligibility with subsequent consensus by discussion.

We included studies that (1) employed a quantitative design and studied a general population; (2) assessed cycling exposure either as a mode of transportation or as a recreational activity; (3) measured CVD incidence, CVD mortality or physiological CVD risk factors as an outcome; and (4) reported continuous outcome measures.

Studies were excluded if they measured domains other than cycling, such as stationary cycling, or if cycling was a part of a rehabilitation programme/intervention or investigated an unhealthy population. Studies that reported walking and cycling combined were excluded. We had no criteria for sample size.

Included studies

Following screening, 111 studies were selected for full-text eligibility assessment. Among the 111 full-text studies, 16 studies fulfilled the inclusion criteria, while 16 further studies were identified as eligible through the reference lists of included studies. In addition, an updated search was performed on 8 August 2017, when five more studies were included. In total, 36 studies fulfilled the primary inclusion criteria. As the present meta-analysis comprises continuous outcomes only, 21 studies with outcomes presented as dichotomous variables only were excluded. Thus, the present meta-analysis included 15 studies (see figure 1).

Study quality assessment

Included studies were assessed according to the Quality Assessment Tool of Quantitative Studies.[14] AR and SN independently assessed each study. In cases of disagreement of rating, agreement was solved by mutual consensus. For results from the study quality assessment, see online supplementary table 2.

Contact with authors

SN contacted the corresponding author when there was a lack of clarity or when additional information was needed. This resulted in reanalysis of all included outcome measures for de Geus *et al*.[15]

Analysis

Data extraction was conducted by SN based on the main exposure, which was defined in accordance with the protocol as any cycling. Main outcome was CVD risk factors. The risk factors were further categorised in seven categories after a systematic review of all risk factors reported in the included studies: body composition, physical activity, cardiorespiratory fitness (CRF), blood lipids, blood pressure, diet and other physical fitness measures than CRF. For diet[16] and physical fitness other than CRF,[17 18] both categories were excluded from meta-analysis due to too few (≤2) unique studies. In intervention studies lasting more than 6 months,[15 19] we included results from the first 6 months. All outcomes were additionally analysed stratified by design and combined to investigate possible sources of heterogeneity (online supplementary table 4).

Category 1: body composition

The risk factors covering body composition were ranked from high to low quality: (1) skinfold,[17 20 21] (2) waist circumference (WC)[22] and (3) body mass index (BMI).[23–26] To summarise the risk factors covering body composition, we included the most accurate measure in each study by the ranked quality above. In addition to body composition, each risk factor was also analysed in subgroups: skinfold, WC and BMI.

Category 2: physical activity

Physical activity was reported as either counts per minute,[20] daily moderate-to-vigorous physical activity (MVPA)[17 27] or minutes per week (min/week).[23] Physical activity was only analysed with one common analysis. However, meta-regression was used to measure the consistency of results (see table 2). Sedentary time[17] and light physical activity[17] were not meta-analysed due to interference with MVPA and the characteristics of cycling, respectively.

Category 3: cardiorespiratory fitness

CRF was analysed independently of measurement methods. Nevertheless, we ranked the measurement methods from high to low quality: (1) maximal test with analysis of expired air,[10 15 19 21 23 28] (2) maximal test without analysing expired air[22] and (3) submaximal approach.[17] Meta-regression was run to investigate relationship of measurement quality and effect (see table 2).

Category 4: blood lipids

Four risk factors from blood samples were included: high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides (TG) and total cholesterol (TC). In online supplementary table 3, we standardised the outcomes to SI units for descriptive purposes, and we recalculated HDL, LDL, TG and TC from milligrams per decilitre to millimoles per litre using the factors recommended by the Society for Biomedical Diabetes Research[29]: 0.0259 for HDL and LDL, and 0.0113 for TG, respectively. Total cholesterol was only reported as millimoles per litre. Due to the obvious heterogeneity, that is, higher HDL level indicates a better result, while a higher LDL level would be a worse result, each component was analysed separately.

Category 5: blood pressure

Both diastolic blood pressure (DBP) and systolic blood pressure (SBP) were included. DBP and SBP were analysed separately to ensure that we did not analyse individuals twice (see online supplementary table 3 for details).

Statistics

In all analyses, we ensured that individuals were not analysed more than once. Analyses were performed in Stata V.12.1 (StataCorp LP, College Station, Texas, USA) using user-written commands described by Egger *et al*[30] with random estimate models. The estimates are presented as standardised mean difference (SMD) with 95% CIs. Dose–response relationships were analysed by meta-regression and are presented as β coefficients and p values. Heterogeneity is presented as I^2 and p value. The I^2 was calculated using Stata-derived test for heterogeneity (Cohen's Q) and df:

$$I^2=100\%\times(Q-df)/Q$$

As proposed by Higgins *et al*,[31] I^2 describes the percentage of total variance across studies, with values between 0% and 100%, where 0% indicates no heterogeneity. Negative values were set equal to zero.[31] Heterogeneity was tested in all analyses. The power of the test increases with higher number of studies, and should be interpreted with caution when low number of studies, due to the possibility of false homogeneity.[31]

Small-study effect

Small-study effect was investigated by regression of effect size (ES) and SE of ES as proposed by Egger *et al*.[32] Asymmetry, which indicates a small-study effect, was defined as p value <0.1 due to limits of the statistical power.[32] As for heterogeneity, tests for small-study effect are vulnerable for type I error when few studies are included.[31 32]

RESULTS

Study characteristics

Fifteen studies were included in the meta-analysis of the present study, where the majority of the studies reported commuter cycling.[15–27] In total, the meta-analysis included 5775 cyclists and 39 273 non-cyclists. Cyclists had more favourable risk factor levels in four of five risk factor categories (body composition, physical activity, CRF and blood lipids) compared with non-cyclists (table 1). Online supplementary table 3 summarises the included studies and distribution of risk factors. Randomised controlled trial (RCT) studies showed a significant improvement for body composition and CRF with SMD −0.99 and 1.06, respectively. However, both outcomes were heterogeneous (I^2=71%–94%); see online supplementary table 4 for details.

Analysis of risk factor categories

Body composition

Cyclists had a consistently lower skinfold, WC and BMI compared with non-cyclists. The combined score of body composition was lower for cyclists, with estimates heterogeneous (figure 2 and table 1). Cycling was associated with enhanced body composition, consisting of either skinfold, BMI or WC (see table 1

Table 1 Main findings: meta-analysis for each outcome measure

Outcome	Number of reported results	Meta-analysis of each outcome: SMD	95% CI	p value	Back transfer from SMD	Test of heterogeneity: I^2*	p value	Dose–response: β	95% CI	p value
Combined score of body composition†	13	−0.08	−0.13 to −0.04	**<0.001**	NA	69%	**<0.001**	0.185	−0.46 to 0.83	0.540
Skinfold (mm)	5	−0.09	−0.17 to −0.01	**0.029**	−5.22 mm	88%	**<0.001**	0.453	−3.67 to 4.57	0.749
WC (cm)	6	−0.58	−0.64 to −0.51	**<0.001**	−9.6 cm	99%	**<0.001**	−1.588	−1.81 to −1.38	**<0.001**
BMI (kg/m^2)	12	−0.10	−0.14 to −0.05	**<0.001**	−0.45 BMI	41%	0.069	0.022	−0.11 to 0.16	0.714
Physical activity‡	7	0.13	0.06 to 0.20	**<0.001**	2.99 MVPA	80%	**<0.001**	−0.153	−0.93 to 0.63	0.635
CRF	15	0.28	0.22 to 0.35	**<0.001**	195.63 mL O_2/min	84%	**<0.001**	−0.339	−1.93 to 1.25	0.656
Total cholesterol (mmol/L)	8	−0.06	−0.12 to −0.00	**0.037**	−2.28 mmol/L	43%	0.091	0.014	−0.36 to 0.39	0.928
HDL cholesterol (mmol/L)	7	0.18	0.12 to 0.24	**<0.001**	2.95 mmol/L	24%	0.250	−0.024	−0.23 to 0.16	0.764
LDL cholesterol (mmol/L)	5	−0.15	−0.22 to −0.07	**<0.001**	−5.35 mmol/L	39%	0.161	−0.033	−0.44 to 0.37	0.809
Triglycerides (mmol/L)	8	−0.17	−0.23 to −0.11	**<0.001**	−8.62 mmol/L	20%	0.272	−0.135	−0.47 to 0.19	0.355
DBP (mm Hg)	7	0.03	−0.05 to 0.11	0.405	NA	74%	**<0.001**	0.105	−0.75 to 0.96	0.764
SBP (mm Hg)	7	−0.06	−0.14 to 0.02	0.122	NA	34%	0.172	0.030	−0.79 to 0.86	0.927

Bold font indicates significant results. Dose–response calculated from three levels of exposure (1–3).
*25%, 50% and 75% correspond to low, moderate and high I^2 values, respectively.[31]
†Sample of best measure reported. The risk factors were ranked from high to low quality: (1) skinfold,[18 20 21] (2) waist circumference[22] and (3) BMI.[23–26]
‡CPM, MVPA or min/week.
BMI, body mass index; CPM, counts per minute; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MVPA, moderate-to-vigorous physical activity; NA, not applicable; SBP, systolic blood pressure; SMD, standardised mean difference; WC, waist circumference.

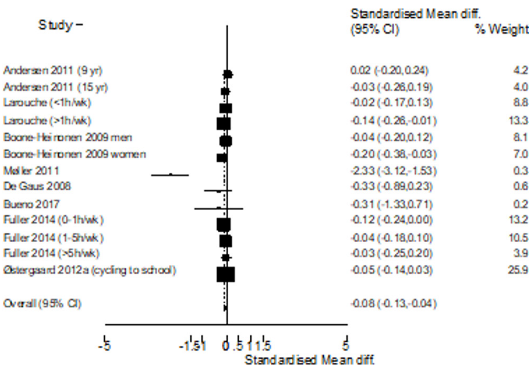

Figure 2 Forest plot of body composition, cyclists vs non-cyclists. Being a cyclist was significantly associated with more favourable body composition compared with non-cyclists, standardised mean difference −0.08 (95% CI −0.13 to −0.04), I^2=69%.

for details). The associations were similar when skinfold, WC and BMI were analysed separately. See online supplementary figures 1–3 for forest plots. Regression analysis of design and SMD showed a relationship where high-quality design (based on quality assessment) was associated with greater effect size in sum of skinfolds (see table 2 for details). Total estimate of combined score of body composition and separate analysis of BMI, skinfold and WC showed all moderate to high heterogeneity. Visually, in the analysis of combined score of body composition, Møller *et al*[21] differed from the rest of the studies. Since Møller *et al* is a RCT, we ran sensitivity analysis excluding RCTs.[10 21 23] The result became homogeneous (I^2=0%, p=0.799) and remained significant, SMD −0.7 (95% CI −0.12 to −0.03, p<0.001). For skinfold, results were also highly heterogeneous. Again, Møller *et al*[21] differed from the other results. When the analysis was run without RCT studies, including Møller *et al*,[21] cyclists no longer had lower sum of skinfold (SMD −0.07 (−0.15 to 0.01), p=0.109). Results, however, became homogeneous, I^2=0%, p=0.514. For WC, Larouche *et al*[17] >1 hour/week was considerably staggered to the left, indicating a higher effect than the rest of the studies. When Larouche *et al*[17] >1 hour/week was excluded from analysis, the result stayed significant (SMD −0.13 (−0.20 to −0.05), p=0.002) and became homogeneous, I^2=0%, p=0.616.

Physical activity

Cyclists were observed to have a significant higher level of other forms of physical activity compared with non-cyclists, with a moderate to high level of heterogeneity. See table 1 for details. We observed a positive correlation of design and observed effect of cycling, so better designed studies had a higher effect size. See table 2 for details.

Cardiorespiratory fitness

In total, 10 studies reported any CRF as a risk factor associated with CVD. Overall, cyclists had a higher CRF compared with non-cyclists (figure 3). However, the results were heterogeneous (table 1). Møller *et al*[21] showed a stronger result than the rest of the analysed studies. When performing meta-analysis excluding RCTs including Møller *et al*,[21] the result remained significant (SMD 0.23 (95% CI 0.16 to 0.29), p<0.001) and became heterogeneous (I^2=52%, p<0.001). Increased quality of design

Table 2 Regression of SMD against study design, study quality, quality of measurement, age at baseline and gender, respectively

	Design		Study quality		Measurement quality		Age at baseline		Gender	
Category	**β (95% CI)**	**p value**	**β (95% CI)**	**p value**	**β (95% CI)**	**p value**	**β (95% CI)**	**p value**	**β (95% CI)**	**p value**
Combined score of body composition*	−0.24 (−0.61 to 0.14)	0.199	0.01 (−0.54 to 0.56)	0.973	NA	NA	−0.01 (−0.04 to 0.02)	0.434	−0.07 (−0.73 to 0.58)	0.808
BMI	0.00 (−0.09 to 0.09)	1.00	0.06 (−0.48 to 0.16)	0.260	NA	NA	0.00 (−0.01 to 0.01)	0.766	0.01 (−0.13 to 0.14)	0.922
Skinfold	**−1.14 (−1.26 to −1.02)**	**<0.001**	−0.70 (−3.88 to 2.48)	0.532	NA	NA	−0.02 (−0.12 to 0.07)	0.525	†	NA
Waist circumference	†	NA	0.77 (−0.62 to 2.16)	0.200	NA	NA	−0.01 (−0.06 to 0.04)	0.584	−0.22 (−1.26; 0.82)	0.594
Physical activity	**0.71 (0.55 to 0.87)**	**<0.001**	0.10 (−1.18 to 1.39)	0.844	0.59 (−0.01 to 1.20)	0.053	0.01 (−0.02 to 0.05)	0.359	†	NA
Cardiorespiratory fitness	**0.45 (0.12 to 0.79)**	**0.012**	0.30 (−0.32 to 0.91)	0.320	**0.55 (0.10 to 1.00)**	**0.021**	0.01 (−0.12 to 0.04)	0.287	0.10 (−0.35 to 0.56)	0.631
Total cholesterol	0.02 (−0.25 to 0.30)	0.851	0.08 (−0.29 to 0.45)	0.601	NA	NA	0.00 (−0.01 to 0.02)	0.645	0.10 (−0.14 to 0.34)	0.362
HDL cholesterol	0.03 (−0.11 to 0.17)	0.653	**−0.16 (−0.29 to −0.03)**	**0.026**	NA	NA	0.00 (−0.00 to −0.01)	0.067	0.52 (−0.07 to 0.18)	0.331
LDL cholesterol	−0.08 (−0.28 to 0.13)	0.329	†	NA	NA	NA	−0.01 (−0.02 to 0.00)	0.150	−0.01 (−0.26 to 0.24)	0.919
Triglycerides	0.18 (−0.02 to 0.37)	0.065	−0.00 (−0.36 to 0.35)	0.983	NA	NA	0.00 (−0.01 to 0.01)	0.767	0.02 (−0.23 to 0.26)	0.868
DBP	−0.15 (−0.44 to 0.14)	0.242	0.09 (−0.52 to 0.69)	0.721	NA	NA	−0.01 (−0.03 to 0.01)	0.167	0.16 (−0.69 to 1.00)	0.657
SBP	−0.13 (−0.41 to 0.15)	0.290	0.02 (−0.56 to 0.61)	0.932	NA	NA	−0.01 (−0.02; 0.01)	0.367	0.03 (−0.08 to 0.87)	0.907

*Sample of best measure reported. The risk factors were ranked from high to low quality: (1) skinfold,[17 20 21] (2) waist circumference.
†Omitted due to collinearity.
‡All analysis was of combined gender.
BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; NA, not applicable; SBP, systolic blood pressure; SMD, standardised mean difference.

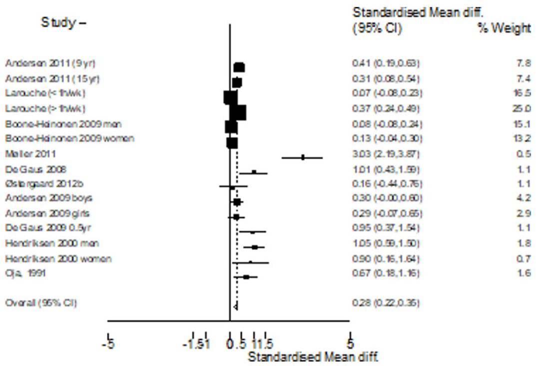

Figure 3 Forest plot of cardiorespiratory fitness, cyclists vs non-cyclists. Being a cyclist was significantly associated with improved cardiorespiratory fitness compared with non-cyclist, standardised mean difference 0.28 (95% CI 0.22 to 0.35), I^2=84%.

was significantly correlated with increased effect of cycling on CRF. Improved measurement quality (direct vs indirect VO_{2max} test) was significantly correlated with effect size. However, the total study quality (based on 'global rating' in online supplementary table 2) was not correlated with the effect size (table 2).

Blood lipids

For blood lipids, we analysed each outcome separately. TC, HDL, LDL and TG were all significantly enhanced in cyclists. TC, LDL and TG were all significantly lower and had low to moderate heterogeneity (see table 1 for details). For cyclists, HDL was found to be SMD 0.18 higher compared with non-cyclists (table 1). See online supplementary figures 4–7 for forest plots. However, the effects were small, SMD −0.06 to −0.17 for TC, LDL and TG, and 0.18 for HDL, and were all slightly heterogeneous (I^2=20%–43%).

Blood pressure

Neither DBP nor SBP were related to cycling (p=0.122 and 0.404, respectively). Low-to-moderate heterogeneity was found for SBP, whereas a high degree of heterogeneity was found for DBP. The number of studies that reported BP were approximately the same as for the other risk factor categories.

Dose–response

All exposure measures had at least two levels of cycling, but only BMI and physical activity had three levels.

WC showed a graded association with level of cycling (β −1.59, p<0.001). Andersen *et al*,[20] Boone-Heinonen *et al*[22] and Larouche *et al*[17] reported WC where only Larouche *et al*[17] reported three levels of cycling. Thus, the relationship should be interpreted with caution.

Small-study effect

A small-study effect was found among half of the outcome measurements: combined score of body composition (β=−2.50, p=0.030), BMI (β=−0.58, p=0.026), skinfold (β=−7.07, p=0.003), physical activity (β=5.98, p=0.006), CRF (β=4.72, p=0.001), total cholesterol (β=−0.92, p=0.024) and triglycerides (β=0.77, p=0.066). A small-study effect was less common among outcomes such as blood lipids and BP.

DISCUSSION

Overall, being a cyclist was associated with a reduced CVD risk compared with non-cyclists, with reductions in four out of five CVD risk factor categories. Notably, the results should be interpreted with caution as only WC and CRF had a small-to-moderate effect in accordance to Cohen's rule of thumb,[33] and the associations were mainly heterogeneous. The health effects of being a cyclist compared with non-cyclist were stronger when RCTs are only considered. Being a cyclist is associated with both improved both body composition (SMD −0.99, 95% CI −1.49 to −0.54) and improved CRF (SMD 1.06, 95% CI 0.85 to 1.28).

To our knowledge, no other studies have meta-analysed cycling and its associations on CVD risk factors such as blood lipids, body composition and fitness measured with continuous outcome variables. However, active travel has been shown to reduce all-cause mortality,[7] CVD[7 11] and CVD risk factors.[11] Although cycling has been shown to be associated with reduced rate of CVD,[11] there is uncertainty as to the effect of cycling on CVD risk factors.[11] Cycling was associated with 18%–33%lower risk of overweight, obesity, hypertension and triglycerides, but results were heterogeneous.[11] In the present study, we found a similar result for continuous variables, but BMI and blood lipids were homogeneous. For other risk factors, the degree of heterogeneity differed between 34% and 99%. Our results underpin the uncertainty of the association between cycling and CVD risk factors by continuous outcome measures.

Among the five CVD risk factor categories, the strongest association of cycling compared with non-cycling was observed for CRF (SMD −0.28, 95% CI 0.22 to 0.35). The result was heterogeneous, I^2=84%. The large degree of heterogeneity was investigated, but the reason for heterogeneity was not clear. We investigated the associations of study design and effect on CRF and found that improved study design was positively associated with the effect. This association was not observed for the global rating for study quality. This indicates an inter-relationship between study design and observed association. The challenge of meta-analysing outcomes from different designs is well known.[30] One major difference between RCT and cross-sectional designs is the possibilities of selection bias and the degree of random sampling. In addition, there is a possibility for recall bias for the cross-sectional studies due to usage of questionnaires, and selection bias for RCT.[30] When we analysed the studies of cross-sectional design separately, the result remained significant, but the degree of heterogeneity was reduced from 84% to 52%. The remaining degree of heterogeneity may be the observed positive association between effect of cycling and measurement quality and the fact that exposure is often controlled better in RCTs.

For single risk factors, the strongest association was observed in the sensitivity analysis of body composition. In our combined score of body composition, the association of cycling was significant with a moderate level of heterogeneity (SMD −0.08, 95% CI −0.13 to 0.04, I^2=69%). When we performed sensitivity analysis of each of the included risk factors, a moderate effect was observed for WC (SMD −0.58, 95% CI −0.64 to −0.51) for any cycling. The result was highly heterogeneous, I^2=99%. The chance of erroneous calculated heterogeneity increases if few studies are analysed.[31] Only six studies were analysed in the WC analysis, and thus the test of heterogeneity might be erroneous. Even though the uncertainty of consistency in analysis of WC, we found no difference between either gender or age (see table 2 for details). When we back transfer the SMD to an adult male population,[22] any cycling can be interpreted as a reduced WC of 9.5 cm.

In our present meta-analysis, cycling was associated with lower BMI compared with non-cyclists. Flint and Cummins[5] found promising results of active travel and its effect on reduction of BMI in mid-life. Our finding is in accordance with previous findings where it has been observed that the reduction may be smaller than previously expected.[12]

Dose–response relationship

We hypothesised that there was a dose–response relationship. Of the 11 outcome measures, only WC showed a dose–response relationship. This is in contrast with previous findings where both active travel[7] and cycling[3] were reported to have a dose–response relationship for health outcomes. When analysing the effect of cycling, there are several challenges. First, when risk factors are analysed by prospective cohorts, there is a great possibility of misclassification[34] and an uncertainty in results and an increased possibility of drawing an erroneous conclusion. Second, the definition of cycling and amount needed to be classified as a cyclist varied among the included studies. The majority of the included studies categorised cycling from self-reported questionnaire, where cycling is defined as the usual mode of travel,[20] mode of travel during the past 3 months,[17,26] 7-day recall about transport modes,[27] dominant mode of transport during summer months,[18] daily commute by cycling over 60 min[35] and amount of weekly recreational cycling.[16] The RCTs also had different definitions of cycling. The definitions varied between definitions of minimum daily time,[21] distances cycled,[15,23] destinations[10,28] and frequency and distance.[19] The definitions of cycling may surely influence the effect of cycling, as more and more frequent cycling is likely to increase effect. The RCT studies were the source of heterogeneity in the combined score of body composition, skinfold and CRF. When we analysed without RCT studies, the result remained significant and became homogeneous. Further, Larouche *et al*[17] seemed to be the source of heterogeneity for WC for the results of cycling more than 1 hour per week. When WC was analysed except Larouche >1 hour, the result remained significant and became homogeneous. This points in the direction that the source of heterogeneity may be the unequal definitions of cycling and that there may be a dose–response relationship even though it was only observed for WC in this meta-analysis.

Gender difference

As we hypothesised, we did not observe gender differences for any of the CVD risk factors in our meta-analysis. There were several challenges when analysing gender differences as only five studies reported separate results for men and women. We therefore recommend researchers to report gender separated data when appropriate.

Strengths and limitations

Our results confirm a previous finding.[2,36] In the present meta-analysis, all risk factors were analysed separately. This provided new and in-depth insight of the effect of cycling for the separate risk factor.

There is a well-known challenge of meta-analysing different designs and types of studies.[30] The possibility of a misleading overall estimate of an association is a problem in general with meta-analysis and bigger when different designs are combined (Egger *et al*[30]). Even though it is appropriate to review a body of data systematically, it may be inappropriate to meta-analyse all designs together. To meet these challenges, Egger *et al*[30] recommend to carefully investigate sources of heterogeneity, such as design and type of study.

The study quality of the included studies was investigated by the Quality Assessment tool of Quantitative Studies.[14] This tool consists of seven categories (selection bias, study design, confounding factors, blinding, data collection, withdraws and drop-outs, and global rating). We used both the overall rating (global rating) and the design score when we by meta-regression investigated the association between study quality and effect size between studies investigating the same outcome variable. The result of this analysis are presented in table 2.

Meta-regression analyses were performed on both design and quality based on our included tool of quality assessment.[14] In general, we did not observe any consistent pattern for systematic dependence of quality. However, we observed that design may be a source of heterogeneity. Therefore, we investigated the heterogeneity for design further (see online supplementary table 4 for details). Systematically, we observed a stronger *effect* of any cycling when RCTs were analysed separately, compared with the *association* observed when all designs were analysed together.

Our aim is to summarise the literature as broadly as possible, and therefore all quantitative studies were included. This approach has some known challenges, but through a careful investigation of heterogeneity, this approach may outweigh the disadvantages of analysis designs combined.[30]

Further, in the present meta-analysis, the population consisted of 15% cyclists. The relatively low number of cyclists may cause selection bias and residual confounding for observational studies. In our analysis, we have consequently included only the most adjusted effect estimate, where almost all included studies were adjusted for other forms of physical activity.

This meta-analysis only comprises published results and thus might be affected by publication bias since unpublished studies often differ from studies that have been published.[37] This might be why we observed a small-study effect for 7 of the 11 included outcomes, which indicated that smaller studies tend to show a greater effect.[30]

Meta-analyses of observational studies are often more distorted by confounding and selection bias than meta-analyses of randomised controlled trials,[30] but they can to a larger degree generalise the results. The inclusion criteria for the present systematic review and meta-analysis were quantitative studies. This means that the observed association might be a result of an underlying confounder due to a large range of designs.[30] Differences in design and adjusted variables may further lead to residual confounding. List of design and adjusted variables per study may be found in supplementary table 5. We are aware of this possible pitfall and therefore analysed all outcomes by regression for both study design, overall study quality and measurement quality. We found

What is already known

- ► Active travel, including cycling, is associated with increased physical activity and reduced cardiovascular risk factors.

What are the new findings

- ► Being a cyclist was associated with more beneficial risk factor levels, except for blood pressure, compared with non-cyclists.
- ► Cycling activity was associated with lower waist circumference (dose dependent).
- ► The benefits of cycling were equally prominent in women and men.

a significant association for WC, physical activity and CRF (see table 2 for details). Interestingly, better study design improved the association of cycling on physical activity and CRF, but reduced the association of skinfold. For study quality, only HDL had a significant association with effect size and study quality.

Interpretation of results

The present study, which summarises all scientific evidence, shows that known risk factors for CVD are lower in those individuals who undertake cycling. The studies with the highest quality finds the greatest associations. Surprisingly, we did not observe a dose–response relationship or gender differences, even though it is most likely that it is more beneficial to bicycle more. For policy-makers, urban planners and stakeholders, this study provides an argument for the green shift and makes a case for cycling-friendly cities. It may well be that a cycling city is a healthy city.

Conclusion

Cycling was associated with lower levels in CVD risk factors. There was no sex difference or dose-response relationship between amount of cycling and effect size.

Contributors All authors contributed to the design of the study and reviewed the report. SN and LBA generated the hypotheses. SN and AR did the literature search. SN, AR and LBA analysed the data. SN wrote the first draft of the manuscript. LBA, AKS and AR revised the manuscript critically for important intellectual content. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. LBA is the study guarantor.

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Study III

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MDPI

Article

Correlates of Commuter Cycling in Three Norwegian Counties

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Abstract: Globally, there is an increasing challenge of physical inactivity and associated diseases. Commuter cycling is an everyday physical activity with great potential to increase the health status in a population. We aimed to evaluate the association of self-reported factors and objectively measured environmental factors in residence and along commuter routes and assessed the probability of being a commuter cyclist in Norway. Our study included respondents from a web-based survey in three Norwegian counties and we used a Geographic Information Systems (GIS) to evaluate the natural and built environment. Of the 1196 respondents, 488 were classified as commuter cyclists. Self-reported factors as having access to an e-bike (OR 5.99 [CI: 3.71–9.69]), being physically active (OR 2.56 [CI: 1.42–4.60]) and good self-rated health (OR 1.92 [CI: 1.20–3.07]) increased the probability of being a cyclist, while being overweight or obese (OR 0.71 [CI: 0.54–0.94]) reduced the probability. Environmental factors, such as high population density (OR 1.49 [CI: 1.05–2.12]) increased the probability, while higher slope (trend $p = 0.020$), total elevation along commuter route (trend $p = 0.001$), and >5 km between home and work (OR 0.17 [CI: 0.13–0.23]) decreased the probability of being a cyclist. In the present study, both self-reported and environmental factors were associated with being a cyclist. With the exception of being in good health, the characteristics of cyclists in Norway, a country with a low share of cyclists, seem to be similar to countries with a higher share of cyclists. With better knowledge about characteristics of cyclists, we may design better interventions and campaigns to increase the share of commuter cyclists.

Keywords: bicycle; public employees; active travel; active commuting; adults; GIS

1. Introduction

Globally, there is an increasing challenge of physical inactivity and several environmental factors are associated with physical activity (PA) levels [1]. Low levels of PA contribute to a higher risk of diseases [2]. The World Health Organization (WHO) recommends that adults be active at least 150 min/week in order to reduce the risk of non-communicable diseases (NCDs) [3]. Furthermore, it has been observed that any level of physical activity above sedentary is associated with a lower risk of mortality [4]. Commuter cycling is an everyday PA with great potential to increase the level of PA in the population.

Already in 2000, an association of lower risk of all-cause mortality among commuter cyclists was observed [5], and commuter cycling was later reported to be associated with a reduced risk of a number of illnesses, i.e., type 2 diabetes [6], cardiovascular disease [7], cancers [8], and obesity [9]. In two recent meta-analyses, cyclists compared to non-cyclists, had a lower body mass index (BMI), and were more physically fit [10,11]. Commuter cyclists have also been observed to be happier compared to car drivers [12]. Although cyclists have a higher risk of injuries, there is convincing evidence that the health benefit of cycling far outrun the risk of injury [13]. Due to all these positive associations of commuter cycling, it is important to understand the characteristics of those who are cyclists.

In the Netherlands, a country with a high share of commuter cyclists, cyclists live closer to work and are more physically active [14]. In Australia, commuter cyclists are more likely to be male, younger, and well-educated compared to non-cyclists [15]. For built (i.e., cycle infrastructure and connectivity) and natural environment (i.e., topography) the evidence of associations of share of commuter cycling is sparse. Previous studies have observed that distance [16], time to travel by bike relatively to time by car [16] and increased cycle infrastructure seem to increase the share of cyclists [16,17].

In countries with a generally low share of commuter cyclists, like Norway, we know less about which characteristics are associated with cycling. However, those owning an e-bike seem to be more likely to use their e-bike and travel longer distances compared to those with an ordinary bike [18].

Therefore, this study aims to describe the (a) self-reported characteristics of cyclists in a country with low levels of commuter cycling, and (b) the objectively measured environmental factors in areas around residence and along commuter routes associated with commuter cycling.

2. Materials and Methods

2.1. Sample

We invited all public sector employees in three Norwegian counties (Sogn og Fjordane, and Aust-Agder, and Vest-Agder (hereafter Agder). In general, Sogn og Fjordane is more hilly, wetter and windier than Agder. The study design, recruitment, and data collection have been described previously [18]. Briefly, during spring and autumn 2017, in total, 38,297 public sector employees got access to the web-based survey. In round one (Sogn og Fjordane), the questionnaire included questions about background, travel habits, local environment, bike access and use, sickness and injuries, health (RAND-12, and quality of life), physical activity, and confidence to other people. In the second round (Agder) the questionnaire was shortened and left out some questions in all the subgroups. Questions about confidence in other people and health were fully excluded. The estimated duration of completing the questionnaire was 30 and 15 minutes in the first and second round, respectively. The study was approved by the Regional Committees for Medical and Health Research Ethics with reference 2016/1897/REK vest. Entering the survey was defined as informed consent.

In total, 3540 (9.2% of the invited) individuals entered the survey. To be included in the analysis, dependent and independent variables needed to be reported. We included individuals between 18 and 72 years and excluded 17 participants due to extreme reports (age >72, height <1.3 m or >2.40 m, income >20,000,000 NOK, weight <44 kg or >200 kg). In total, 1196 individuals where included in the present study, see Figure 1. In the sub-analysis of distance cycled, 19 cases were excluded due to distance being >35 km from residence to work.

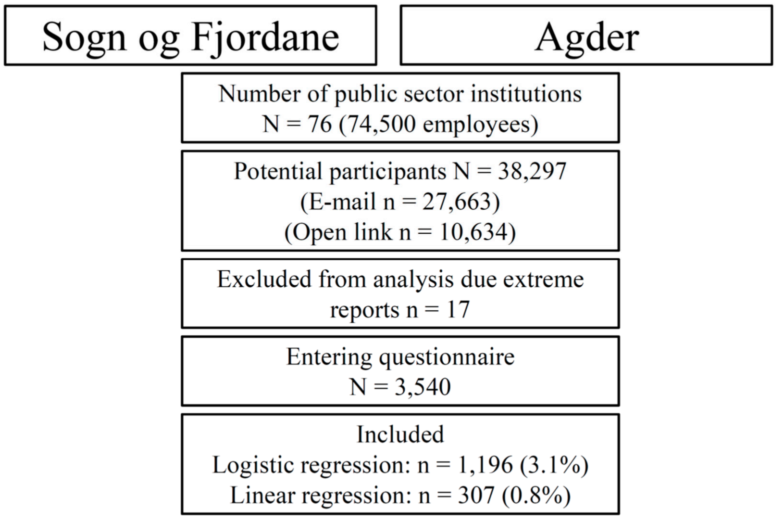

Figure 1. Flowchart and inclusion process of the Førde Active Transport study.

2.2. Being a Cyclist

Being a cyclist was defined by the Active Transport Norway-questionnaire [19]. In the present study, we only included the destination "work". Test-retest reliability among adults cycling to work has previously been reported to be 0.92 (Spearman's correlations) [19]. Those who reported one or more weekly trip(s) were classified as cyclists and the rest as non-cyclists. Distance to work was sampled by self-reported distance to work from residence.

2.3. Self-Reported Covariates

Self-reported age and perceived road safety were treated as continuous variables. Gender, type of cycle owned (e-bike or ordinary), ethnicity (Norwegian vs. non-Norwegian), self-rated health (SRH) (good or poor) and current tobacco (tobacco or non-tobacco) usage were coded binary. SRH was investigated by RAND-12's first question. This question provides relevant health information and is a strong and dose-dependent predictor of mortality [20,21]. The question was recoded from "good" (good, very good and excellent) to "poor" (poor and fair) health status. Income, BMI, education, and self-reported PA [22] were coded as categorical variables. The Saltin and Grimby question of PA [22] has previously been used in a number of cohort studies assessing health status in the Nordic countries [5], and in a Norwegian representative population, where the question was validated against aerobic fitness (correlation coefficient was 0.18 and 0.39 for men and women, respectively) [23]. Through its use in cohort studies, this question has proven to be able to distinguish health and mortality between inactive and active respondents [5]. Income was classified as either 0–399,999 NOK, 400,000–799,999 NOK, or 800,000–19,999,999 NOK. BMI was classified according to WHO's obesity classification [3]. Level of education was coded as <high school, <4 years university, and ≥4 years university. See appendix A for more details.

2.4. Geographic Information Systems (GIS) Computed Covariates

Environmental factors were investigated in a GIS (ESRI ArcGIS PRO 2.3.3, Environmental Systems Research Institute, California, CA, USA). Participants' home and work addresses (*n* = 1114) were geocoded using the address locator Environmental Systems Research Institute (ESRI) world geocode. This resulted in 1080 matched home addresses (97%), and 1053 work addresses (95 %),

Figure 2a,c. Road network and shared-path network were imported from the Norwegian Public Road Administration toolbox NVDP-API. Meter of roads (European Road, State Road, County Road, Local Road, Private road, Logging road), and shared-use path were imported for Sogn og Fjordane (Figure 2b) and Agder (Figure 2d). The population was summarized at the district level. Districts were categorized by the number of persons living within the district into low (0–199), moderate (200–599), and high (>600) density groups (Figure 2a,c). To estimate the route between home and work (home–work pairs) we used the network analysis tool "routes". This tool provides distance and travel time. For bike-route, the time-cost was estimated by calculating the time taken to travel the distance with an average speed of 15 km/h. Furthermore, we calculated the ratio between the time used when bicycling vs. driving, and the ratio between distances of the home–work route. Topography along routes for each of the original home–work-pairs was derived by cumulative absolute height gains (total elevation) and mean slopes from the Vbase data source. Elevation and slope were categorized into four groups based on percentile distribution to ensure a similar size of the groups. See appendix A for details.

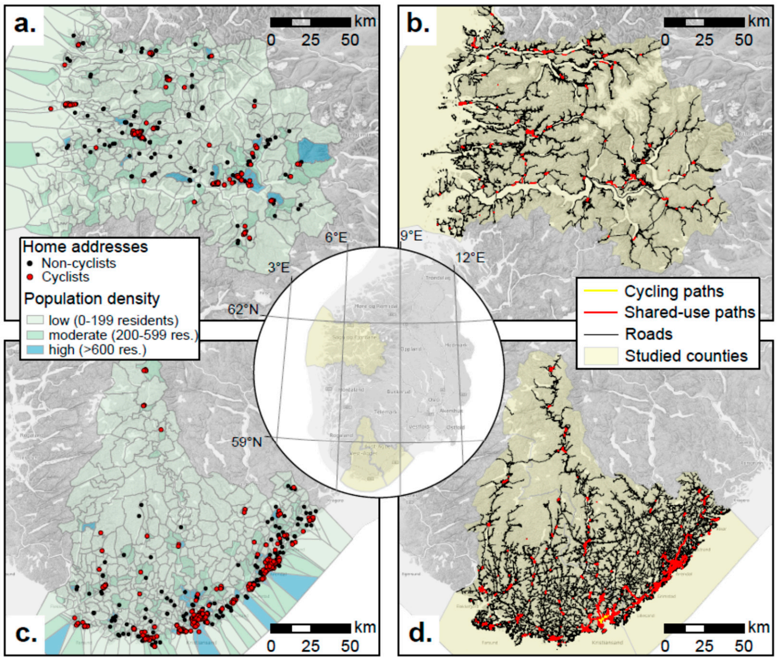

Figure 2. Geographic Information Systems (GIS)-derived information. (**a**) Population density and location of home addresses in Sogn og Fjordane; (**b**) Roads, cycling paths and shared-use paths in Sogn og Fjordane; (**c**) Population density and location of home addresses in Agder; (**d**) Roads, cycling paths and shared-use paths in Agder.

2.5. Statistics

2.5.1. Cyclists vs. Non-Cyclists

An independent samples Mann–Whitney U test was used to investigate possible differences between cyclists and non-cyclists for non-normally distributed variables. Logistic regression was performed to assess the association between independent variables and being a cyclist. Model 1 contained 12 independent variables (age, distance, gender, income, health status, BMI, e-bike, education, migration, perceived traffic safety, tobacco and PA levels) from the questionnaire. The categorical variables were coded with ascending rank. The lowest group was used as a reference. Women and men were coded 0 and 1, respectively. Both bivariate and multivariate analyses were performed. Model 2 contained eight GIS-generated variables. As for model 1, categorical variables were coded with ascending rank. Stratified analyses were run for gender and counties (Sogn og Fjordane and Agder). See appendix A for details.

2.5.2. Distance Cycled

Correlates of self-reported distance to work (0–35 km) among cyclists were explored by linear regression. Distance to work was skewed (skewness = 2.07) and was therefore log-transformed by natural logarithm to ensure normal distribution (skewness ln(distance) = 0.25). The dependent variable was distance to work for cyclists, while the independent variables were all the variables for models 1 (questionnaire) and 2 (GIS variables). In total, 307 respondents were included. Stratified analyses were run for gender and counties (Sogn og Fjordane and Agder).

All analyses were run in IBM SPSS Statistics v. 25.0 (IBM Corp., Armonk, NY, USA). Descriptive analyses are presented as mean (SD) or median (min–max). Logistic regression is presented as odds ratio (OR) with a 95% confidence interval [CI], or with trend *p*-value for variables with more than two categories (education, income, and PA). The results of linear regression are presented as standardized beta (β), and *p*-value (*p*).

3. Results

Descriptive statistics are presented in Table 1. The multivariate model including survey data was able to distinguish between cyclists and non-cyclists, $p < 0.001$. The model explained 30% (Negelkerke R Square) of the variance of cycling behavior and correctly classified 74% of all cases. The multivariate model containing GIS data was able to distinguish between cyclists and non-cyclists $p < 0.001$. The model explained 14.9% of the variance of being a cyclist, and correctly classified 68.5% of all cases.

3.1. Being a Cyclist

Compared to non-cyclists, cyclists travelled significantly shorter ($p < 0.001$) (7.6 [10.7] vs. 21.1 [19.8] km) distances, perceived lower road safety ($p < 0.001$) (7.3 [2.2] vs. 6.6 [2.4]), and were slightly older ($p = 0.043$) (48.7 [10.6] vs. 47.4 [10.6] years). Those owning an e-bike or having an active lifestyle were six and two-fold more likely to be cyclists, respectively. Furthermore, higher level of education and good SRH were also associated with increased odds of being cyclist, whereas being overweight/obese reduced the odds of being a cyclist. Those living ≥5 km from work were unlikely to be cyclists. See Table 2 for details. The associations were similar for summer and winter, but SRH was more prominent during winter (OR 1.83 [1.15–2.93] vs. 2.42 [1.41–4.14]). Between the counties, SRH was significant for Sogn og Fjordane but not for Agder, while owning an e-bike was significant in Agder, but not Sogn og Fjordane. See Table A1 for details.

Among the environmental factors (GIS model, Table 3) all the factors were significantly associated with being a cyclist in the bivariate analysis. In the multivariate analysis of environmental factors, living in areas with higher population density and taking more time when cycling decreased the odds of being a cyclist.

Table 1. Descriptive table of characteristics of participants, *n* = 1196.

Characteristics	Sogn og Fjordane and Agder		County	
	Cyclists	**Total**	**Sogn og Fjordane Total (% cyclist)**	**Agder Total (% cyclist)**
n	488	1196	441 (35%)	755 (41%)
Distance (*n* = 1196)				
0.1–5.0 km	301	467	183 (62%)	284 (66%)
5.0–145 km	187	729	258 (16%)	471 (31%)
Age (median (min-max))	49 (19–70)	49 (72–19)	48 (23–72) [a] 49 (67–24) [b]	49 (19–70) [a] 49 (19–70) [b]
Gender (*n*)				
men	204	468	155 (38%)	313 (46%)
women	284	728	286 (33%)	442 (42%)
Income (*n*)				
0–399,999 NOK	69	266	92 (30%)	174 (40%)
400,000–799,999 NOK	371	868	321 (38%)	547 (46%)
800,000–19,999,999 NOK	21	62	28 (25%)	34 (41%)
Self-reported health status * (*n*)				
Poor	38	138	44 (18%)	94 (32%)
Good	450	1058	397 (37%)	661 (46%)
BMI (*n*)				
Underweight or normal weight	282	627	246 (40%)	381 (48%)
Pre-obesity or Obesity class 1–3	206	569	195 (29%)	374 (40%)
Tobacco (*n*) *				
Non-tobacco	484	1188	438 (35%)	750 (44%)
Any usage of snuff or tobacco	4	8	3 (66%)	5 (40%)
Cycle type (*n*)				
other	408	1083	432 (39%)	651 (39%)
e-bike	80	113	9 (33%)	104 (74%)
Ethnicity (*n*)				
Self and parents born in Norway	428	1080	401 (34%)	679 (43%)
Self or parents not born in Norway	60	116	40 (48%)	76 (54%)
Education (*n*)				
<high school	50	157	50 (30%)	107 (33%)
University <4 years	98	273	103 (29%)	170 (40%)
University ≥4 years	340	766	288 (38%)	478 (48%)
Road safety (median (min-max))	8 (1–10)	8 (1–10)	7 (1–10) [a] 8 (1–10) [b]	8 (1–10) [a] 8 (1–10) [b]
PA level ** (*n*)				
inactive	20	95	40 (22%)	55 (20%)
Activity class 1	246	602	209 (33%)	393 (45%)
Activity class 2 or 3	222	499	192 (40%)	307 (47%)
Population density (*n* = 730)				
1	94	230	55 (18%)	175 (48%)
2	96	241	86 (38%)	155 (41%)
3	129	259	143 (43%)	116 (58%)
Mean slope route *n* = 730				
<25% 0–3.8%	83	170	94 (43%)	76 (57%)
25–50%, 3.8–5.6%	71	187	119 (34%)	68 (44%)
50–75%, 5.6–14.0%	68	179	49 (37%)	130 (38%)
>75%, >14.0%	97	194	22 (27%)	172 (53%)
Sum elevation home-work-home *n* = 730				
<25%, 0–132.7 m	119	172	69 (70%)	103 (69%)
25–50%, 132.7–555.9 m	72	188	75 (29%)	113 (44%)
50–75%, 555.9–1509.6 m	66	194	50 (16%)	144 (40%)
>75%, >1509.6 m	62	176	90 (30%)	86 (41%)

* Tobacco included both snuff and smoke. Non-tobacco included those who are non-users. ** Based on the four activity categories by Saltin and Grimby [22]: "Almost completely inactive: reading, TV watching, movies, etc." [inactive], "Some physical activity during at least 4 hours per week, riding a bicycle or walk to work, walking or skiing with the family, gardening'' [1], "Regular activity, such as heavy gardening, running, calisthenics, tennis, etc." and "Regular hard physical training for competition in running events, soccer, racing. European handball, etc. several times per week." [2]. [a] cyclists; [b] non-cyclists.

Table 2. Likelihood of being a cyclist, survey data, n = 1196. Presented as bivariate and multivariate analyses. Significant associations are written in bold.

Characteristics	**Bivariate All seasons OR (95% CI)**	**Multivariate All seasons OR (95% CI)**
Age	**1.01 (1.00–1.02); 0.043**	1.01 (0.99–1.02); 0.100
>5 km vs. <5 km distance	**0.19 (0.15–0.25); <0.001**	**0.17 (0.13–0.23); <0.001**
Gender (women vs. men)	1.21 (0.95–1.53); 0.116	**1.45 (1.09–1.92); 0.010**
Income	**Trend p = 0.082**	Trend p = 0.086
Income (0–399.999NOK)	Ref.	Ref.
Income (4–799.999)	1.32 (1.00–1.76); 0.054	1.09 (0.77–1.53); 0.632
Income (>800.000)	0.91 (0.51–1.63); 0.743	0.54 (0.28–1.067); 0.077
SRH poor vs. good	**1.95 (1.31–2.89); 0.001**	**1.92 (1.20–3.07); 0.007**
Normal weight vs. Pre-obesity or Obesity class 1–3	**0.69 (0.55–0.88); 0.002**	**0.71 (0.54–0.94); 0.017**
E-bike	**4.01 (2.63–6.13); <0.001**	5.99 (3.71–9.69); <0.001
Education	**Trend p = 0.003**	**Trend p = 0.023**
Education< high school	Ref.	Ref.
<4 years university	1.20 (0.79–1.81); 0.395	1.33 (0.82–0.2.15); 0.246
≥4 year university	**1.71 (1.19–2.46); 0.004**	**1.75 (1.14–2.70); 0.011**
Ethnicity	**1.63 (1.11–2.40); 0.012**	**1.69 (1.08–2.64); 0.021**
Perceived Road safety	**1.13 (1.08–1.19); <0.001**	1.05 (0.99–1.12); 0.081
Tobacco	1.46 (0.36–5.84); 0.597	0.69 (0.12–4.02); 0.675
Activity class *	**Trend p < 0.001**	**Trend p = 0.002**
Activity class 1	Ref.	Ref.
Activity class 2	**2.59 (1.54–4.36); <0.001**	**2.56 (1.42–4.60); 0.002**
Activity class 3	**3.01 (1.78–5.08); <0.001**	**2.90 (1.60–5.26); <0.001**

*Based on the four activity categories by Saltin and Grimby [22], "Almost completely inactive: reading, TV watching, movies, etc." [inactive], "Some physical activity during at least 4 hours per week, riding a bicycle or walk to work, walking or skiing with the family, gardening'' [1], "Regular activity, such as heavy gardening, running, calisthenics, tennis, etc."[2] and "Regular hard physical training for competition in running events, soccer, racing. European handball, etc. several times per week." [3]. SRH, self-rated health status.

Table 3. Likelihood of being a cyclist. Environmental factors (GIS data). n = 1009. Presented as bivariate and multivariate analyses. Significant associations are written in bold.

	Bivariate All seasons OR (91% CI); *p*	**Multivariate All seasons OR (91% CI); *p***
N	1009	1009
500m home buffer		
Ratio shared-path/road buffer home	**3.62 (1.29–10.19); 0.015**	1.79 (0.42–7.69); 0.435
Car junction home	**1.01 (1.00–1.01); <0.001**	1.00 (0.99–1.01); 0.598
Bike junction home	**1.00 (1.00–1.01); <0.001**	1.00 (0.99–1.01); 0.869
Population density home	**Trend *p* < 0.001**	Trend *p* = 0.058
Low (0–199 persons)	Ref.	Ref.
Moderate (200–599 persons)	1.11 (0.80–1.54); 0.551	1.09 (0.77–1.55); 0.626
High (<600 persons)	**1.81 (1.32–2.47); <0.001**	**1.49 (1.05–2.12); 0.026**
Route		
Ratio minutes home-work bike */car route	**0.55 (0.47–0.63): <0.001**	**0.72 (0.56–0.93); 0.013**
Ratio meter bike/car route	**0.04 (0.01–0.18); <0.001**	0.83 (0.15–4.65); 0.831
Percentiles of mean slope route	**Trend *p* = 0.042**	**Trend *p* = 0.020**
<25% 0–3.8%	Ref.	Ref.
25–50%, 3.8–5.6%	0.76 (0.53–1.10); 0.143	0.91 (0.60–1.36); 0.636
50–75%, 5.6–14.0%	**0.60 (0.41–0.86); 0.006**	0.75 (0.49–1.13); 0.162
>75%, >14.0%	0.87 (0.61–1.24); 0.439	1.44 (0.91–2.28); 0.125
Percentiles for elevation t/r route	**Trend *p* < 0.001**	**Trend *p* = 0.001**
<25%, 0–132.7 m	Ref.	Ref.
25–50%, 132.7–555.9 m	**0.32 (0.22–0.46); <0.001**	**0.43 (0.28–0.67); <0.001**
50–75%, 555.9–1509.6 m	**0.26 (0.18–0.37); <0.001**	**0.37 (0.21–0.64); <0.001**
>75%, >1509.6 m	**0.27 (0.19–0.39); <0.001**	**0.44 (0.23–0.84); 0.013**

* estimated 15 km/h.

The odds of being cyclist was similar for women and men when summer and winter were analysed combined. However, when gender was stratified per season, we observed that SRH during summer was more strongly associated among men (OR 2.54 [1.23–5.23]) than among women (OR 1.45 [0.77–2.72]), while level of PA was more strongly associated among women (p for trend = 0.010), compared to men (p for trend =0.179). For winter, e-bike increased the chances of being a cyclist more for women than it did for men (OR 7.55 [3.99–14.03] vs. 3.61 [1.73–7.54]). For environmental factors (model 2), there were similar results for men and women and between counties. See Table A2 for the results of environmental factors at the county level.

Distance from residence to work was observed to correlate with frequency of cycling, and thus, the average weekly distance cycled. Most of those who were cyclist had a short distance (0.1–20 km) to travel to work and thus had a low to moderate dose (10–60 km) of distance cycled in an average week. It seems like those living 5–10 km from work cycled more often than others and gained a larger weekly average compared to both shorter and longer distances.

3.2. Distance Cycled

Among cyclists, we observed that distance cycled was associated with being male, a lower level of perceived road safety, having a more beneficial ratio of shared-use path/roads at home buffer, and a low total elevation and mean slope. See Table 4 for details. The negative association between perceived road safety and distance cycled indicates that those cycling shorter distances are more affected by road safety compared to those cycling longer distances. This was investigated further and a significant correlation was found (chi-square = 0.013) for high perceived road safety reported among those cycling short distances (1–2 km). For summer and winter separately, associations were similar, with the expectations of winter SRH, which was significantly associated with longer cycling distances (β = 0.13 p = 0.031).

Table 4. Linear regression of distance * cycled. $n = 307$. Significant associations are written in bold.

	All seasons	
	β	*p*-Value
Survey		
Age	0.039	0.454
Gender (women vs. man)	0.109	**0.035**
Income (ascending)	−0.038	0.469
SRH (poor vs. good)	0.087	0.100
Normal weight vs. overweight/obesity	−0.054	0.312
E-bike (regular vs. e-bike)	0.041	0.443
Years of education (ascending)	0.014	0.794
Perceived road safety (ascending)	**−0.220**	**<0.001**
Ethnicity (ethnic Norwegian vs. not ethnic Norwegian)	0.017	0.744
PA level (ascending)	0.046	0.388
GIS		
500 m home buffer		
Population density home	−0.025	0.637
Bike junction home	0.063	0.700
Car junction home	−0.338	0.062
Ratio shared-path/road buffer home	**0.184**	**0.007**
Route		
Ratio minutes home-work bike **/car route	0.035	0.713
Ratio meter bike/car route	0.071	0.272
Percentiles of mean slope route	**0.188**	**0.004**
Percentiles for elevation t/r route	**0.232**	**0.013**

* Distance is log-transformed; ** Estimated 15 km/h; β, Standardized beta; SRH, self-rated health status; PA, physical activity; GIS, geographic information systems.

4. Discussion

The present study aims to describe the association between commuting by bicycle, self-reported characteristics and objectively measured environmental factors. Among the 1196 included participants, 488 were cyclists. Owning an e-bike, being active, and with good health increased the probability of being a cyclist by almost six-, three- and two-fold-larger odds, respectively, compared to non-cyclists. On the other hand, living >5 km from work reduced the probability of being a cyclist by 83%, and being overweight or obese reduced the probability by 29%. For the environmental factors, living in more populated areas increased the odds by almost 50%, while having a total elevation of more than 133 m reduced the odds of being a cyclist by almost 50%.

In the self-reported data, we observed that men were more likely to be cyclists. This is a similar finding to countries with a higher share of cyclists [15,24,25]. Owning an e-bike gave a six-fold increase in the probability of being a cyclist and has been discussed elsewhere [18]. Furthermore, we observed that those with higher education were more often cyclists. This is also in accordance with observations from Australia [15], Europe [24], and North America [25]. In accordance with previous findings in Europe [14], those being categorized as physically active were up to three times more likely to be cyclists. This indicates that those who cycled for transportation may often be engaged in other forms of physical activity. Interestingly, there was an almost two-fold likelihood of being a cyclist among those reporting good health status. This is in contrast to observations in Brussels where SRH was not related to commuter cycling [24]. In both studies, the proportions of respondents with good health were high (~90%). This may indicate that health status is one of the few factors that differs in a country with a low share of cyclists compared to countries with a higher share of cyclists. In the study, those who were cyclists may be a selected group of individuals who are highly educated, physically active, normally weighted and in good health. However, a lower incidence of CVD and death was observed in a meta-analysis of more than 1 million individuals [10] even when most of the included studies were adjusted for physical activity and education.

Cyclists travelled one third of the distance compared to non-cyclists, whilst those living >5 km from work were rarely cyclists. Barton at al. [26] observed that the distance between locations had to be short (500–2500 m) for active travel in the UK. Our findings confirm that commuter cycling is more typical when the commuting distance is relatively short (<5 km), albeit twice as long as the UK findings [26]. In Norway, the average travel distance between home and work is 16.3 km, and only seven percent are undertaken by bike [27]. Independent of mode of transportation, 39% of all journeys are <5 km [27]. In our study, 39% lived less than 5 km from work. The included respondents thus seem to be fairly representative for the whole of Norway concerning living less than 5 km from work. It may be that Norwegian commuter cyclists are willing to travel longer distances compared to those in the UK. However, the willingness to travel longer might also be affected by the exclusive focus on cycling in our study, whereas Barton et al. [26] considered active travel in general, including walking and cycling. In the UK, walking is twice as common as cycling [28]. Interestingly, short distances have been reported to be of greater importance than safety when it comes to choices of route among cyclists [29]. This may be why we observed that longer distances were associated with lower perceived safety, as the cyclist may choose a more unsafe route to reduce the travel distance.

Another important observation in our study, the positive association between population density and probability of being a cyclist, is in accordance with previous reports of commuter cycling [16], active travel [26], and a higher level of physical activity [1]. In more populated areas, the distance between home and work is often shorter [16]. If there is a 5 km threshold for trips to be conducted by bike, it follows that there is a higher potential for trips to be made by bike in such areas. However, in Norway, large areas have scattered settlements (Figure 2a,c)), and this may be why Norwegian cyclists cycle longer distances compared to the abovementioned observations from the UK. The scattered settlement in Norway is also a factor that cannot easily be changed, and may be one of the main reasons why the share of cyclist has not increased [27] despite raised focus in the Norwegian transport plan and cycle strategy [30].

When the travel time by bike is shorter relative to time travelled by car, more people are likely to cycle. This is in accordance with findings from British cities and towns [16] and other interventions on bicycle infrastructure [29]. The present ratio is based on distance between home and work, and the route is estimated by the GIS-tool routes, choosing the most likely route for bike and car. We used an average speed of 15 km/h for cyclists, while car was set to default by the tool. This means that the commuting route may differ between the one by bike compared to the one taken by car. Interestingly, we did observe a positive association for the ratios of shared-use path/roads at home, but not for either car or bike junctions along routes. This is in contrast to the observations by Cervero et al. [16], who observed that increased connectivity increased the share of cyclists. However, our ratio included shared-use path, not exclusively cycle infrastructure. Exclusive cycle infrastructure in Norway is sparse and much rarer than shared-use paths (Figure 2b,d).

In the bivariate results of the model containing GIS-generated variables, we observed a significant negative trend for both mean slope and elevation on commuting route (p < 0.001–0.042). Only for elevation along the route, the trend remained significant in the multivariate model. This indicated that a commuter who travelled with a total elevation of 133 vertical meters was 57%–63% less likely to commute by bike. Our finding is in accordance with previous observations where vertical displacement along commuter route was negatively associated with the probability of being a cyclist [16,31].

The present study cannot conclude on causality, but there seems to be a relationship between the level of PA, population density and the ratio of shared-use path and roads at home and the distance cycled. Our findings are in accordance with observations for Vancouver city where built and natural environments were associated with the share of cyclists [31]. Thus, it seems likely that the built and natural environment affect the level of commuter cycling.

4.1. Strengths and Limitations

The use of geographical data provided a direct measure of the environment in the investigated area. Together with the self-reported information, we were able to see a large picture of which factors were associated with commuter cycling. This is important information for politicians, policy makers and city planners.

The main strength of this study is the combination of a relatively large sample and the inclusion of GIS-measures of population and the environment. The sample is from two large geographical areas of Norway (Figure 2a–d). The broad requirement strategy seems to have succeeded for geographical distribution, i.e., travel distance to work, but the sample is more active, less obese, more highly educated and has a higher income than the general population in Norway. However, our aim was to describe the characteristics of cyclists, which is possible to do based on a sample consisting of 41% cyclists. For the commuting route, we observed that mean slope in the >75% percentile data gave non-logic results, where the highest group of slope increased the odds of being a cyclist. This is likely due to errors in the dataset. However, we chose to include total elevation change and mean slope derived from the TIN in the analysis since topography is likely to be one of the main factors associated with cycling [31]. Unfortunately, we had a very low response rate of only 3%. However, analysis of associations is quite robust to selection bias, and response rate is therefore of less importance. The sample of this survey was selected and not representative of the general population. However, associations between cycling and other parameters may still be valid. It is usually seen that physical activity has a preventive effect in all groups independent of age, sex and other parameters. Similarly, it is likely that the responders may choose or not choose to cycle, similarly to the total population.

4.2. Interpretation

We interpreted the result to identify and understand both personal, natural and built environment factors. With more knowledge about the characteristics of cyclists, we may design better interventions and campaigns to increase the share of commuter cyclists. The present study identified a number of factors, such as population density, elevation along commuting route, level of PA and gender that were significantly associated with commuter cycling. There seems to be no single factor affecting people's choice of transportation mode [1,16]. However, adaptions in the built environment in areas with a high population density and a likely lower distance between home and work may increase the share of cyclists.

5. Conclusions

In the present study, both self-reported and environmental factors were associated with odds of being a cyclist. Owing an e-bike, being active and in good health increased the odds of being a cyclist, while living more than 5 km from work and being overweight or obese reduced the probability of being a cyclist. With the exception of being in good health, the characteristics of cyclists in a county with a low share of cyclists seems to be similar to countries with a higher share of cyclists. Adaption of the built environment in areas with a high population density and shorter distances between home and work may increase the share of cyclists. Future studies should investigate which changes in the environment may increase the share of cyclists and aim to better understand hampers for changing transit from car to bike.

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Appendix A

Extended Methods

Self-reported age and perceived road safety, assessed by the question "On a scale of 1 (dangerous) to 10 (very safe) how will you describe your road to work?" were treated as continuous variables. Gender (women, men), type of cycle owned (other bike, e-bike), ethnicity (ethnic Norwegian, self or one of parents born in other country), current tobacco usage (non-tobacco, usage of snuff or smoke), and self-reported health, were coded binary.

Self-rated health was investigated by RAND-12's first question: "In general, would you say your health is: Poor, Fair, Good, Very good, Excellent." This question provides relevant health information, and is a strong and dose-dependent predictor of mortality [20,21]. The question was dichotomized into "good" (good, very good and excellent) and "poor" (Poor and fair) health status.

Leisure time PA was coded categorically by self-reported PA [22]: "Almost completely inactive: reading, TV watching, movies, etc.", "Some physical activity during at least 4 hours per week, riding a bicycle or walk to work, walking or skiing with the family, gardening", "Regular activity, such as heavy gardening, running, calisthenics, tennis, etc.", and "Regular hard physical training for competition in running events, soccer, racing, European handball, etc. several times per week." Those reporting to be "almost inactive" were coded as inactive and the rest were coded as activity class 1, 2, and 3. Later, class 2 and 3 three were merged (hereafter class 2), as used elsewhere [5,23]. The Saltin and Grimby question [22] has previous been used in a number of cohort studies assessing health status in the Nordic countries [5], and in a Norwegian representative population, where the question was validated against aerobe fitness (correlation coefficient was 0.18 and 0.39 for men and women respectively) [23]. Through the usage in cohort studies the question has proven to be able to distinguish health and mortality between inactive and active respondents [5]. BMI was classified according to WHO's obesity classification [3]: underweight and normal weight (BMI 11–24.9), pre-obesity (BMI 25.0–29.0), and obesity class 1–3 (BMI 30–39.9).

GIS

The graphical information was downloaded from www.kartkatalog.geonorge.no.

Population density

Population was summarized at district level. Population was based on the "Population at district level 2017". The dataset was generated by the Norwegian Mapping Authority's dataset "statistical units districts" and was linked to statistics from Statistics Norway. Districts were categorized by number of persons living within the district into low (0–199), moderate (200–599), and high (>600) density groups. See Figure 2b,d for distribution.

Route

To estimate the route between home and work (home–work pairs), we used the network analysis tool "routes" network tool at arcgis.com. The route estimated provided a best-guess route choice based on low time-cost for the individual and were run for both bike and car. The tool provides distance and travel time. For bike-route, we recalculated the time-cost. The time-cost was estimated by calculating the time taken to travel the distance with an average speed of 15 km/h. Furthermore, we calculated the ratio between time used when bicycling vs. driving (minutes_bike/minutes_car), and a ratio between distances of the home-work route (distance_bike/distance_car).

Topography along Routes

In order to receive an estimate of elevation change along commuter routes, the following workflow was applied:

Using the tool *Interpolate Shape* (Environmental Systems Research Institute, California, CA, USA), z-coordinates were added to all car routes for home–work-pairs within Sogn og Fjordane and Agder counties.

By applying the tool *Split Line at Vertices* (Environmental Systems Research Institute, California, CA, USA) to the resulting 3D polylines, information in the attribute table encompasses one record per polyline segment.

With the help of *Add Geometry* and *Field Calculator* (Environmental Systems Research Institute, California,CA, USA), absolute height differences, gain and slope were calculated for each polyline segment.

Finally, by applying the tool *Summarize Statistics* (Environmental Systems Research Institute, California, CA, USA), cumulative absolute height differences and gains as well as maximum and mean slopes were derived for each of the original home–work-pairs.

These steps were repeated several times with elevation information extracted from following surfaces: digital terrain models (DTM) and digital surface models (DSM) at 1 and 10 meter resolutions as well as a triangulated irregular network (TIN) based on the vbase dataset provided by the Norwegian Public Road Administrations. Information of roads and shared-use path was summarized within a 500 meter buffer around home address and around home–work-routes.

Statistics

An independent samples Mann–Whitney U test was used to investigate possible differences between cyclists and non-cyclists for non-normally distributed variables. Direct logistic regression was performed to assess the association between independent variables and being a cyclist. Model 1 contained 12 independent variables (age, distance, gender, income, health status, BMI, e-bike, education, migration, perceived traffic safety, tobacco and PA levels). The categorical variables (distance [<5 km vs. >5km], income, self-reposted health status, and education, and PA) were coded with an ascending rank. The lowest group was used as reference. Both bivariate and multivariate analyses were performed. Model 2 contained eight GIS-generated variables (population density home, bike junction home, car junction home, ratio shared-path/road buffer home, ratio minutes home-work bike/car route, ratio meter bike/car route, percentiles of mean slope route, and percentiles for elevation t/r route). As for model 1, categorical variables were coded with ascending rank. Stratified analyses were run for both gender (men and women) and counties (Sogn og Fjordane and Agder).

Distance Cycled

Correlates of self-reported distance to work (0–35 km) among cyclists were explored by linear regression. Distance to work was skewed (skewness = 2.07) and was therefore log-transformed by a natural logarithm to ensure normal distribution (skewness ln(distance) = 0.25). The dependent variable was distance to work for cyclists, while independent variables were age, gender, income, self-reported health status, BMI, e-bike, education, migration, perceived traffic safety, tobacco, PA levels, population density home, bike junction home, car junction home, population density home, ratio shared-path/road buffer home, ratio minutes home-work bike/car route, ratio meter bike/car route, percentiles of mean slope route and percentiles for elevation t/r route. In total, 307 respondents were included in the analysis. Stratified analyses were run for both gender (men and women) and counties (Sogn og Fjordane and Agder).

Table A1. Likelihood of being a cyclist, survey data, n = 1196. Presented as bivariate and multivariate analyses. Significant associations are written in bold.

Characteristics	**Bivariate** Sogn og Fjordane and Agder All seasons OR (95% CI)	Sogn og Fjordane and Agder n = 1196 All seasons OR (95% CI)	**Multivariate** Sogn og Fjordane n = 441 All seasons OR (95% CI)	Agder n = 755 All seasons OR (95% CI)
Age	**1.01 (1.00–1.02); 0.043**	1.01 (0.99–1.02); 0.100	1.00 (0.98–1.03); 0.701	1.02 (1.00–1.03);0.054
>5 km vs. <5 km distance	**0.19 (0.15–0.25); <0.001**	**0.17 (0.13–0.23); <0.001**	**0.12 (0.07–0.19); <0.001**	**0.19 (0.13–0.28); <0.001**
Gender (women vs. men)	1.21 (0.95–1.53); 0.116	**1.45 (1.09–1.92); 0.010**	1.18 (0.72–1.95); 0.512	**1.50 (0.06–2.13); 0.023**
Income(0–399.999NOK)	**Trend p = 0.082**	Trend p = 0.086	Trend p = 0.279	Trend p = 0.554
Income (4–799.999)	1.32 (1.00–1.76); 0.054	1.09 (0.77–1.53); 0.632	1.05 (0.57–1.95); 0.875	1.13 (0.74–1.17); 0.574
Income (>800.000)	0.91 (0.51–1.63); 0.743	0.54 (0.28–1.067); 0.077	0.46 (0.15–1.43); 0.178	0.76 (0.32–1.80); 0.527
Health poor vs. good	**1.95 (1.31–2.89); 0.001**	**1.92 (1.20–3.07); 0.007**	**2.75 (1.10–6.84); 0.030**	1.59 (0.91–2.81); 0.107
Normal weight vs. Pre-obesity or Obesity class 1–3	**0.69 (0.55–0.88); 0.002**	**0.71 (0.54–0.94); 0.017**	0.78 (0.48–1.26); 0.313	**0.66 (0.47–0.94); 0.021**
E-bike	**4.01 (2.63–6.13); <0.001**	5.99 (3.71–9.69); <0.001	0.96 (0.19–4.94); 0.957	**6.39 (3.78–10.83); <0.001**
Education< high school	**Trend p = 0.003**	**Trend p = 0.023**	**Trend p = 0.362**	Trend p = 0.051
<4 years university	1.20 (0.79–1.81); 0.395	1.33 (0.82–0.2.15); 0.246	0.99 (0.41–2.26); 0.978	1.46 (0.81–2.64); 0.21
≥4 year university	**1.71 (1.19–2.46); 0.004**	**1.75 (1.14–2.70); 0.011**	1.42 (0.66–3.09); 0.370	1.**89 (1.11–3.22); 0.019**
Ethnicity	**1.63 (1.11–2.40); 0.012**	**1.69 (1.08–2.64); 0.021**	2.05 (0.91–4.62); 0.084	1.46 (0.86–2.54); 0.160
Perceived Road safety	**1.13 (1.08–1.19); <0.001**	1.05 (0.99–1.12); 0.081	**1.00 (0.90–1.11); 0.986**	1.06 (0.99–1.15); 0.098
Tobacco	1.46 (0.36–5.84); 0.597	0.69 (0.12–4.02); 0.675	3.87 (0.12–124.79); 0.455	0.31 (0.03–3.02); 0.315
Activity class *	**Trend p < 0.001**	**Trend p = 0.002**	Trend p = 0.299	**Trend p = 0.005**
Activity class 2	**2.59 (1.54–4.36); <0.001**	**2.56 (1.42–4.60); 0.002**	1.62 (0.64–4.11); 0.307	**3.24 (1.48–7.11); 0.003**
Activity class 3	**3.01 (1.78–5.08); <0.001**	**2.90 (1.60–5.26); <0.001**	2.01 (0.80–5.08); 0.139	**3.24 (1.48–7.11); 0.003**

* Based on the four activity categories by Saltin and Grimby [22]: "Almost completely inactive: reading, TV watching, movies, etc." [inactive], "Some physical activity during at least 4 hours per week, riding a bicycle or walk to work, walking or skiing with the family, gardening'' [2], "Regular activity, such as heavy gardening, running, calisthenics, tennis, etc." and "Regular hard physical training for competition in running events, soccer, racing. European handball, etc. several times per week." [3].

Table A2. Likelihood of being a cyclist. Environmental factors (GIS data). n = 1009. Presented as bivariate and multivariate analyses. Significant associations are written in bold.

	Bivariate	**Multivariate**		
	Sogn og Fjordane and Agder All seasons OR (91% CI); *p*	**Sogn og Fjordane and Agder All seasons OR (91% CI); *p***	**Sogn og Fjordane All seasons OR (91% CI); *p***	**Agder All seasons OR (91% CI); *p***
n	1009	1009	410	599
500m home buffer				
Ratio shared-path/road buffer home	**3.62 (1.29–10.19); 0.015**	1.79 (0.42–7.69); 0.435	1.23 (0.031–49.44); 0.911	1.37 (0.26–7.29); 0.714
Car junction home	**1.01 (1.00–1.01); <0.001**	1.00 (0.99–1.01); 0.598	1.01 (0.99- 1.03); 0.380	1.01 (0.99–1.02); 0.377
Bike junction home	**1.00 (1.00–1.01); <0.001**	1.00 (0.99–1.01); 0.869	0.99 (0.98–1.01); 0.243	1.00 (0.99–1.01); 0.829
Population density home	**Trend p < 0.001**	Trend p = 0.058	Trend p = 0.098	Trend p = 0.138
0–199	Ref.	Ref.	Ref.	Ref.
200–599	1.11 (0.80–1.54); 0.551	1.09 (0.77–1.55); 0.626	1.85 (0.87–3.94); 0.109	0.92 (0.60–1.41); 0.707
>600	**1.81 (1.32–2.47); <0.001**	**1.49 (1.05–2.12); 0.026**	2.31 (1.08–4.97); 0.031	1.46 (0.92–2.31); 0.109
Route				
Ratio minutes home-work bike */car route	**0.55 (0.47–0.63): <0.001**	**0.72 (0.56–0.93); 0.013**	0.76 (0.45–1.27); 0.298	0.79 (0.57–1.09); 0.155
Ratio meter bike/car route	**0.04 (0.01–0.18); <0.001**	0.83 (0.15–4.65); 0.831	9.59 (0.70–132.09); 0.091	0.10 (0.01–1.30); 0.079
Percentiles of mean slope route	**Trend p = 0.042**	**Trend p = 0.020**	Trend p = 0.710	Trend p = 0.090
0–25%	Ref.	Ref.	Ref.	Ref.
25–50%	**0.76 (0.53–1.10); 0.143**	0.91 (0.60–1.36); 0.636	0.97 (0.56–1.69): 0.916	0.86 (0.45–1.65); 0.648
50–70%	**0.60 (0.41–0.86); 0.006**	0.75 (0.49–1.13); 0.162	0.72 (0.35–1.47); 0.369	0.68 (0.38–1.22); 0.192
75–100%	0.87 (0.61–1.24); 0.439	1.44 (0.91–2.28); 0.125	1.17 (0.43–3.18); 0.759	1.31 (0.68–2.52); 0.418
Percentiles for elevation t/r route	**Trend p < 0.001**	**Trend p = 0.001**	**Trend p = 0.021**	**Trend p = 0.024**
0–25%	Ref.	Ref.	Ref.	Ref.
25–50%	**0.32 (0.22–0.46); <0.001**	**0.43 (0.28–0.67); <0.001**	**0.39 (0.18–0.83); 0.015**	**0.41 (0.22–0.74); 0.003**
50–70%	**0.26 (0.18–0.37); <0.001**	**0.37 (0.21–0.64); <0.001**	**0.18 (0.06–0.56); 0.002**	**0.42 (0.20–0.86); 0.018**
75–100%	**0.27 (0.19–0.39); <0.001**	**0.441 (0.23–0.84); 0.013**	**0.33 (0.12–0.95); 0.40**	0.42 (0.16–1.12); 0.082

* estimated 15 km/h.

Table A3. Linear regression of distance * cycled. Significant associations are written in bold.

	Sogn og Fjordane and Agder		**Sogn og Fjordane**		**Agder**	
	All seasons		**All seasons**		**All seasons**	
n	**307**		**102**		**205**	
	β	***p*-Value**	β	***p*-Value**	β	***p*-Value**
Survey						
Age	0.039	0.454	0.014	0.888	0.058	0.331
Gender (women vs. man)	**0.109**	**0.035**	−0.099	0.322	**0.182**	**0.003**
Income (ascending)	−0.038	0.469	−0.108	0.299	0.013	0.827
Health status (ascending)	0.087	0.100	0.068	0.526	−0.009	0.888
Normal weight vs. overweight/obesity	−0.054	0.312	−0.016	0.874	−0.89	0.149
E-bike (regular vs. e-bike)	0.041	0.443	−0.306	0.760	−0.003	0.961
Years of education (ascending)	0.014	0.794	−0.040	0.706	0.003	0.968
Perceived road safety (ascending)	**−0.220**	**<0.001**	**−0.288**	**0.006**	**−0.169**	**0.005**
Ethnicity (ethnic Norwegian vs. not ethnic Norwegian)	0.017	0.744	0.052	0.615	−0.051	0.392
PA level (ascending)	0.046	0.388	0.144	0.167	0.043	0.487
GIS						
500 m home buffer						
Population density home	−0.025	0.637	0.088	0.385	−0.024	0.686
Bike junction home	0.063	0.700	0.290	0.497	**−0.522**	**0.012**
Car junction home	−0.338	0.062	−0.608	0.139	0.225	0.235
Ratio shared-path/road buffer home	0.184	**0.007**	0.069	0.586	0.144	0.058
Route						
Ratio minutes home-work bike **/car route	0.035	0.713	0.181	0.422	−0.122	0.263
Ratio meter bike/car route	0.071	0.272	0.023	0.845	0.109	0.155
Percentiles of mean slope route	**0.188**	**0.004**	−0.089	0.461	0.139	0.071
Percentiles for elevation t/r route	**0.232**	**0.013**	−0.071	0.741	**0.437**	**<0.001**

* Distance is log-transformed; β, Standardized beta; *p*, *p*-value. ** Estimated 15 km/h.

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Study IV

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Article

National Trends in Cycling in Light of the Norwegian Bike Traffic Index

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Abstract: National and international strategies and recommendations are intended to increase physical activity in the general population. Active transportation is included in interdisciplinary strategies to meet these recommendations. Cycling seems to be more health enhancing than walking for transportation since cycling seems to reduce the risk of cardiovascular disease and associated risk factors. Furthermore, the health benefits of cycling are proven to outrun the risk of injuries and mortality. Politicians seem to approve costly infrastructure strategies to increase the amount of cycling in the population to improve public health and shift to more sustainable travel habits. A linear relationship between cycle-friendly infrastructure and the amount of commuter cycling has been demonstrated. However, in Norway and on a global level, there is a lack of robust evaluations of actions and sensitive monitoring systems to observe possible change. Therefore, we aimed to develop the Norwegian bike traffic index and describe the national, regional, and local trends in counted cycle trips. We used a transparent methodology so that the index can be used, developed, and adapted in other countries. We included 89 stationary counters from the whole country. Counters monitored cycling from 2018 onward. The index is organized at local, regional, and national levels. Furthermore, the index is adjusted for population density at the counter level and presented as ratio of counted cycle trips, comparing 2018 to subsequent years. The index is presented as a percentage change with 95% confidence intervals. In Norway, counted cycle trips increased by 11% from 2018 (100, 100–100) to 2020 (111.0, 106.2–115.1), with large geographical differences. In Southern Norway, there was a significant increase of 23%, and in Northern Norway, there was a nonsignificant decrease by 8% from 2018 to 2020. The indices may indicate possible related effects of local to national cycling strategies and how the COVID-19 pandemic has affected Norwegian travel habits in urban areas.

Keywords: bicycle transport; employee commuting; monitoring bicycle employee ride; the Norwegian bike traffic index; active travel

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1. Introduction

Official Norwegian strategies and recommendations are intended to increase physical activity in the population [1,2] and highlight the necessity for interdisciplinary strategies that include active transportation (e.g., cycling). Cycling is associated with reduced risk of type 2 diabetes [3], cancer [4,5], and all-cause mortality [4,5]. Cycling further mitigates the risk factor profile for cardiovascular disease (CVD) [6] and lowers the risk for CVD incidence and CVD mortality in both men and women [7]. A dose–response relationship between cycling and all-cause mortality has been observed [8], and any cycling is recommended. The health benefits of cycling have been observed to be 21 times higher than the risk of injuries and 238 times higher than the risk of mortality alone [9], and the economic benefit is five times larger than the cost of building new cycle infrastructure [10,11].

The Norwegian Public Road Administration (NPRA) launched their national strategy for cycling in 2012 [10]. This strategy acts as a base document for the National Transport

Plan 2014–2023, highlights the need for increased use of cycling as a mode of transportation, and is continued in the latest national transport strategy [12]. The primary objective of the national strategy is to increase the number of trips by bicycle to 8% at a national level by 2023. In addition, the strategy aims to reach 80% commuter cycling for children traveling to school, promote cycling as a transportation mode choice, double the usage of bicycles in high-density cities and municipalities, and increase safety and bikeability [13]. However, since the 1990s the total number of cycling trips has decreased from 7 to 4% in Norway as reported by the national travel survey (RVU) [12]. The number of total trips is low taking into consideration that 80% of the population has access to a bicycle [12].

The national strategies for active transportation and the increased interest in and attention paid to cyclists have resulted in projects such as the Førde Package [14]. In 2012, Førde Municipality signed an agreement with the NPRA and Sogn og Fjordane County Authority to become a 'cycle city'. The aim of this agreement is to 'increase bicycle use, among other things by transferring transportation from private cars to cycling'. To increase sustainable commuting, the road network in Førde Municipality will be upgraded for EUR 154 million through the Førde Package. This package includes constructing new infrastructure for cycling and walking during a period of 8 years that began in October 2016. The Førde Package's master plan is comprised of 20 interventions, including separate bike lanes, shared lanes with walkers, shared lanes with drivers, and cycle roads.

The approval of the Førde Package underpins the fact that policymakers seem particularly keen to increase the number of cyclists since cycling allows for fast and efficient urban travel, requires minimal space for tracks and parking, and causes no air or noise pollution [15,16]. Infrastructure interventions have shown promising effects on the number of cyclists [17–19], and cycle-friendly infrastructure has a strong association with the number of cyclists with a coefficient of determination (r^2) from 0.3 to 0.8 [11,16,19]. The relationship seems to be stronger in larger cities than in smaller ones [11]. In Europe, a linear relationship between metres of cycle-friendly infrastructure per citizen and cycling has been reported [11]. Although cycle-friendly infrastructure is important when attempting to increase the number of cyclists, infrastructure alone is rarely sufficient [20]. There is a need for robust scientific evaluation of infrastructure interventions and how interventions in the built environment influence cycling habits within population groups [21,22]. A bike traffic index organized at different levels (i.e., the regional and national level), such as the Danish bike traffic index [23], may provide a reference point and be helpful for municipalities wanting to evaluate cycling-specific public health goals [24]. A bike traffic index based on bicycle counters may be more valid than surveys since it reflects the actual number of counted cycle trips independent of residence, age, or recall bias [23]. Furthermore, when the index is based on continuous counting results, the model is sensitive to actual changes [23].

Therefore, we aimed to develop the Norwegian bike traffic index and describe the national, regional, and local trends in counted cycle trips. The bike traffic index will be of local, regional, national, and even global interest since it describes the baseline number of counted cycle trips in Norway and provides a transparent method and adaptable index which monitors trends and possible related effects of local to national cycling strategies.

2. Methods and Accuracy

2.1. Bike Traffic Data

Coordinates, number of passing cycle trips, coverage (percentage of valid days for a bicycle counter), and first operative day of the bicycle counters were derived from www.trafikkdata.no; accessed on 1 August 2020, which contains data under the Norwegian license for open government data distributed by the NPRA. In addition, the indices were based on data distributed by Statistics Norway. The daily traffic is the sum of valid counted cycle trips. The daily traffic value has consecutive coverage. Coverage is a measure of the amount of data with sufficient quality (operative more than 95% of the time), where low coverage indicates low representativeness while high coverage indicates high representativeness.

2.2. Population Density

Population density was investigated in a geographical information system (QGIS version 3.10.3–A coruña, Free Software Foundation, Inc., Boston, MA, USA), which we used to investigate the number of individuals living within a 5-km grid where a counter was located. The static grid was a network of evenly spaced horizontal and vertical lines covering the whole country. The present layer was a horizontal and vertical grid network of 5 × 5 km where counters were placed at any point within the grid. Thus, we reported the total number of people living within a grid where a counter occurred. To locate the counters, we firstly recoded the coordinates of the counters as X and Y values for longitude and latitude, respectively. Second, we imported information about the population density by using Statistics Norway's 2019 defined raster file with a 5-km grid size downloaded from www.geonorge.no (accessed on 1 August 2020). To calculate the population, we summarized the number of people living in a grid with an included counter. Furthermore, we divided the proportion of individuals living in a grid and the number of individuals within a counter's grid by the total number of individuals living within a grid with a counter.

2.3. Included Counters

In total, we included 89 stationary counters in the bike traffic index (Figure 1). All included counters have been operative since 1 January 2018. We identified 25 local areas with a minimum of one operative counter. Each local area is presented as local indices. The number of counters included in the local indices ranged from 1 to 14 with a median of 2. The mean population density within the local indices ranged from 840 to 93,176 individuals (see Table 1 for the number of counters and mean population density within the local index). The local indices were further located in an appropriate region, which was either Northern, Mid, Western, Southern, or Eastern Norway. The mean population density within the regions ranged from 15,148 individuals to 29,670 individuals, and the number of counters ranged from 3 to 48 (see Table 1 for details). Eastern Norway contained 54% of the included counters and included the local index with the highest mean population density.

2.4. Missing Data

When daily traffic had coverage of less than 95%, the data was set to missing (user-missing). Throughout the years 2018, 2019, and 2020, there was a total of 6% missing data days. System- or user-missing data were replaced by linear interpolation as missing data were replaced by the mean of the last value before the missing value and the first valid value after the missing value. There were both single days and longer periods (weeks) of missing data. Reasons for system-missing data may be error on the counter, construction on site, ice on the ground, or weather. When missing data occurred in 2020 with no valid value after the period of missing values, the data were registered as missing. Following the procedure by NPRA [27], successive data were deleted in the comparable month (i.e., if there were no valid data for December 2020, data for December 2018 were deleted).

2.5. Traffic Pattern

Bike traffic may be categorized as commuter cycling or recreational cycling [24]. Commuter cycling is mainly cycling done as a mean of transportation [24]. Recreational cycling is cycling done for leisure, social, or fitness activities [24]. Miranda-Moreno et al. [24] argue that this may be oversimplified because the characteristics differ between weekdays and weekends and because the traffic volume depends on location rather than facility types. Following Minge et al.'s adapted methods [25], we calculated two indices for a random week for each counter. The first index is a relative index of weekend versus weekday traffic

(*WWI*; 1). The second index is a relative index of morning (7:00–9:00 a.m.) to midday (11:00 a.m.–1:00 p.m.) traffic (*AMI*; 2).

$$WWI = \frac{V_{we}}{V_{wd}} \tag{1}$$

where *WWI* = weekend/weekday index, V_{we} = average weekend daily traffic, and V_{wd} = average weekday daily traffic.

$$AMI = \frac{\sum_7^8 V_h}{\sum_{11}^{12} V_h} \tag{2}$$

where *AMI* = average morning/midday index, V_h = average weekday hourly count for hour (h), and hours are given as the starting time of the hour.

The traffic pattern is classified as commuter cycling when weekday traffic is higher than weekend traffic (*WWI* > 1) and the weekday hourly pattern is commuter-like with more traffic in the morning than at midday. The traffic pattern is multipurpose when weekend traffic is higher and weekday hourly patterns are not commute-like. Commute-mixed is when weekday traffic is higher than weekend traffic but weekday hourly patterns do not indicate typical commuting. Finally, a multipurpose-mixed traffic pattern is when weekend traffic is higher although weekday hourly patterns are indicative of commuting (*AMI* > 1). Among the 89 included counters, 75 (85%) were defined as 'commute', 11 (12%) as 'commute-mixed', and 3 (3%) as 'multipurpose-mixed'.

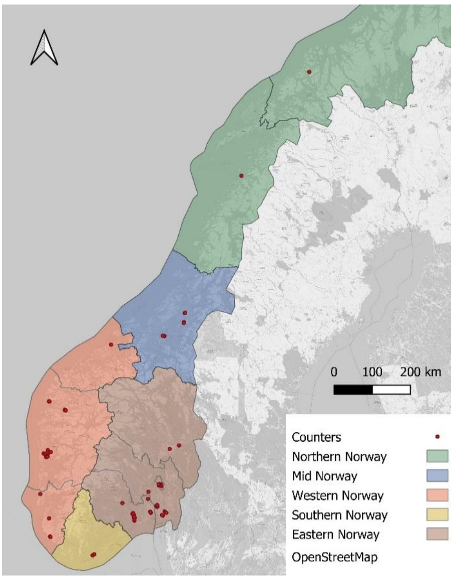

Figure 1. Location of included counters and regional areas.

Table 1. Number of counters and population density at the local and regional level.

Region	Local Area	Number of Counters	Mean Population Density
Southern Norway		3	24,780
	Kristiansand	3	24,780
Northern Norway		3	23,474
	Bodø	2	16,876
	Tromsø	1	30,073
Mid Norway		6	20,964
	Steinkjer	2	10,245
	Trondheim	2	32,547
	Verdal	2	8519
Eastern Norway		48	29,670
	Hamar	1	20,252
	Elverum	1	8012
	Oslo	6	93,176
	Sande	1	3618
	Porsgrunn	6	10,043
	Skien	14	18,195
	Tønsberg	4	16,204
	Drammen	2	25,865
	Fredrikstad	3	25,325
	Moss	5	10,512
	Sarpsborg	5	13,970
Western Norway		29	15,148
	Bergen	12	25,113
	Flora	3	4203
	Førde	8	5245
	Egersund	2	4221
	Kristiansund	1	10,982
	Bø	1	4266
	Haugesund	1	18,368
	Stavanger	1	840
Norway		89	22,631

2.6. The Counters

The included counters were either inductive loop monitors (83%) or piezoelectric counters (17%) and classified vehicles passing. An inductive loop is a detection system that senses metal objects that pass over the in-ground 'loop' [25], and piezoelectric counters generate a count when the material is physically deformed [26]. The monitors provided a timestamp, direction, and speed for the object passing. When automatic and manual observations are compared, inductive loop and piezoelectric monitors have previously demonstrated high accuracy and correlation with Pearson's r = 0.99 and 1.00, respectively [26]. A 1.7 to 2.7% underestimation of counted trips for inductive loop monitors and piezoelectric counters has previously been detected [26]. When tested, the monitor has managed on average 128 to 129 (283 to 355 maximum) counted trips per hour [26].

2.7. Principle of the Index

The inspiration for the Norwegian bike traffic index came from the Danish bike traffic index [23]. Simply put, the Norwegian index is a ratio of counted cycle trips between two successive years:

$$R = \left(\frac{Y}{X}\right) 100\ \% \tag{3}$$

where R is the ratio of Y—the year compared to the baseline year, X—multiplied by 100%. The baseline year is thus set to 100%, and we can follow a percentage change between years X and Y.

The index is organized at three different levels: local, regional, and national. The local index is adjusted for population density at the counter level. The local index is a sum of annual counted trips from each counter. By this method, the changes in the model mainly affect the local index. Separately, the local index is an uncertain measure with a large confidence interval due to the low number of counters [23] and therefore must be interpreted with caution. Furthermore, the regional indices and the national index are the weighted sum (counted trips multiplied by the proportion of residents at the counter level) of all trips in the region or country.

The indices are both presented as index based on annual counts and as monthly average daily traffic. For annual counts, 2018 is set as the baseline year, and successive years are thus compared with the baseline year.

2.8. Calculation of Confidence Intervals for Traffic Indices

We calculated confidence intervals for the traffic indices according to the directions of the NPRA [27]. This approach is based on paired sets of valid data for the period in question and for the reference year, respectively, at each site of interest and for each period (e.g., hour, day, month). We calculated a variance for all valid pairs of data. More specifically, for each site, we calculated and squared the difference between the index of the site and the average for the whole country (or region or local area). We weighted the squared difference in proportion to the traffic volume and calculated a correction to account for using estimated parameters rather than the true (but unknown) value. This last correction corresponds to dividing by (n – 1) rather than by n when calculating the common variance from n different independent values with equal weight, producing an unbiased estimate of the true but unknown variance. The standard deviation is taken as the square root of the calculated variance.

$$s_{a,p,y} = \sqrt{\sum_{i=1}^{n}\left[\frac{N_{i,p,y_0}}{N_{a,p,y_0}}\left(Q_{i,p,y} - Q_{a,p,y}\right)^2\right] \cdot \left[1 - \sum_{i=1}^{n}\left(\frac{N_{i,p,y_0}}{N_{a,p,y_0}}\right)^2\right]^{-1}} \tag{4}$$

Here, n denotes the total number of counted cycle trips, and i is a running variable for sites 1, 2, . . . , n within area a (the whole country, region, or local area). p is the period in question (hour, day, month, year), which for the present case is a full year. y is the year in question (2019 or 2020 for the present case), and y_0 is the reference year (2018 for the present case). Q denotes an index, meaning the ratio of the recorded traffic for two different years. Thus, $Q_{i,p,y}$ denotes the ratio between the counted cycle trips at site i during period p at year y and the corresponding counted trips at the same site and period in the reference year y_0. Referring to the squared term in the numerator, if the indices for all sites within an area are equal (and equal to that of the average of the whole area), the standard deviation is zero. If the indices differ much between sites, and there are thus many large deviations from the area mean index, the standard deviation will increase correspondingly.

This is the standard deviation of the index for area α during period p in year y. To calculate a confidence interval, the standard error of the mean is first calculated as

$$s_{a,p,y} / \sqrt{n} \tag{5}$$

where n is the number of recording sites. This quantity expectedly follows the t-distribution with $(n-1)$ degrees of freedom. Thus, a confidence interval of level $(1-\alpha)$ for an estimated index for year y is calculated as

$$Q_{a,p,y} \pm t_{n-1}(\alpha/2) \cdot \frac{s_{a,p,y}}{\sqrt{n}} \tag{6}$$

Here, $t_{n-1}(\alpha/2)$ is the upper $\alpha/2$ quantile of the t-distribution with $(n-1)$ degrees of freedom. The indices $Q_{a,p,y}$ and the corresponding confidence intervals may be expressed as percentages by multiplying by 100%. We consider the change significant when the confidence interval does not cross 100 since each year is compared to 2018 (100 [95% CI: 100–100]).

3. Results

From 2018 to 2020, the national index indicates a significant 11% increase in the number of counted cycle trips. The national index was 97 (94–100) in 2019 and 111 (106–115) in 2020 (see Table 2 for details). In 2020, more passing cyclists were counted during winter and autumn (Figure 2). In Norway, there seems to be a consistent seasonal pattern in which the number of counted cycle trips is threefold larger in May and June compared with January. A further drop in counted cycle trips occurs in July (summer holiday) followed by a second peak in August.

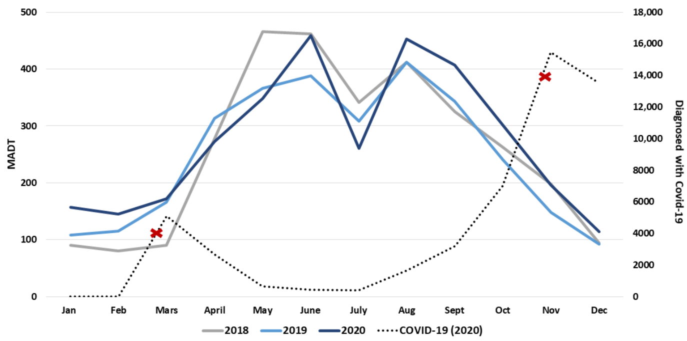

Figure 2. Monthly national bike traffic from January 2018 to December 2020 highlighting the monthly number of individuals diagnosed with COVID-19 (2020). Red crosses illustrate implementation of national strategies to combat COVID-19. MADT stands for monthly average daily traffic.

Regional and Local Trends in Bike Traffic

We found regional differences in trends of counted cycle trips. Southern and Western Norway had a continuous increase in counted cycle trips, with Southern Norway having a 23% (123, 107–140) increase over the last three years. The only region with a decrease in counted cycle trips was Northern Norway, where the number of counted cycle trips decreased by 8% from 2018 to 2020 (92, 72–112). Both Northern and Southern Norway had a 17 to 20% uncertainty mainly due to the low number of included counters (see Table 2 for details). For Western and Mid Norway, there was a statistically significant increase of 11% over the last three years, with small regional differences in patterns (Figure 3). We observed large differences in local trends over the last three years (Table 2). In Førde, Western Norway, the level of counted cycle trips increased by 4% from 2018 to 2020; however, the confidence interval indicates the uncertainty of the result. The largest local increase was observed in Drammen (Eastern Norway) and Kristiansand (Southern Norway) with 153 and 23% increases, respectively. However, the increase was only statistically significant for Kristiansand.

Table 2. National, regional, and local weighted * indices with a 95% confidence interval from 2018 to 2020.

	Number of Counters	2018	2019	2020
National	89	100	97.0 (94.1–99.8)	111.0 (106.2–115.1)
		Regional		
Southern Norway	3	100	103.5 (101.2–105.7)	123.2 (106.5–140.0)
Northern Norway	3	100	104.8 (61.3–148.4)	91.7 (71.6–111.8)
Western Norway	29	100	102.0 (96.5–107.6)	111.3 (101.4–120.9)
Eastern Norway	48	100	93.6 (89.6–97.3)	111.3 (104.5–117.0)
Mid Norway	6	100	94.2 (85.7–102.6)	103.4 (95.7–111.1)
		Local		
Kristiansand	3	100	103.5 (101.2–105.7)	123.2 (106.6–140.0)
Elverum	1	100	87.8	78.0
Hamar	1	100	91.2	108.8
Kristiansund	1	100	108.6	106.9
Bodø	2	100	106.7 (−78.9–292.2)	89.3 (24.4–154.2)
Oslo	6	100	94.3 (87.5–100.6)	118.8 (91.7–144.3)
Egersund	2	100	101.5 (79.5–123.6)	108.4 (81.7–135.1)
Tromsø	1	100	96.1	100.7
Steinkjer	2	100	91.3 (51.7–130.9)	113.6 (49.6–177.6)
Trondheim	2	100	94.2 (1.2–187.1)	100.9 (96.1–105.6)
Verdal	2	100	96.6 (95.6–97.6)	113.0 (2.5–223.5)
Porsgrunn	6	100	87.1 (80.4–93.8)	104.9 (95.0–114.9)
Sande	1	100	93.4	119.6
Skien	14	100	95.3 (90.4–100.2)	106.2 (100.6–111.8)
Tønsberg	4	100	97.1 (92.1–102.0)	109.2 (101.6–116.8)
Bergen	12	100	103.8 (92.4–115.5)	117.9 (99.8–136.1)
Kinn	3	100	95.0 (91.8–98.1)	86.5 (72.9–100.2)
Førde	8	100	104.0 (92.1–115.9)	104.6 (83.8–125.4)
Drammen	2	100	120.9 (−935.9–1177.7)	253.8 (−150.5–658.0)
Fredrikstad	3	100	68.1 (9.6–126.8)	81.4 (−12.5–175.5)
Moss	5	100	91.8 (83.0–100.5)	106.1 (88.9–123.4)
Sarpsborg	5	100	92.4 (89.7–95.2)	108.8 (101.1–116.6)
Stavanger	1	100	84.0	120.8
Haugesund	1	100	93.2	96.0
Bø	1	100	96.1	98.7

* Weighted for population density.

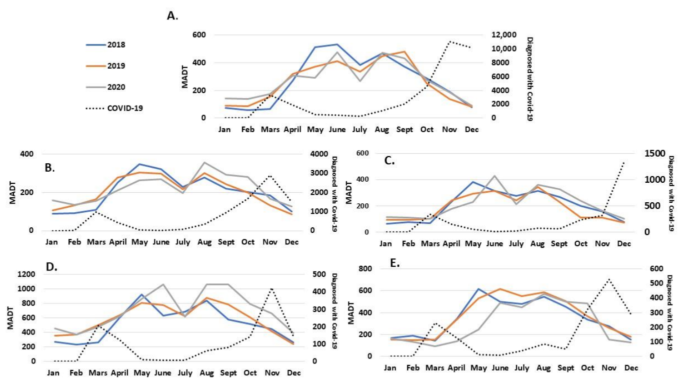

Figure 3. Regional monthly average daily traffic from 2018 to 2020 highlighting the monthly number of individuals diagnosed with COVID-19 (2020). (**A**) Eastern Norway, (**B**) Western Norway, (**C**) Mid Norway, (**D**) Sothern Norway, (**E**) Northern Norway. MADT stands for monthly average daily traffic.

4. Discussion

The national bike traffic index suggests that the number of cycle trips in Norway increased significantly by 11% from 2018 to 2020. However, we observed regional and local differences. The differences between regions and local areas highlight the advantages of indices of smaller geographical areas. Furthermore, most interventions are local, and a local index is a valuable tool to evaluate these interventions. At a national level, we observed seasonal differences with the highest level of counted cycle trips occurring from May to August, with a consistent period of fewer trips in the autumn and winter months. Ninety-three per cent of the included counters have a commuter or a commuter-mixed traffic pattern. Therefore, the index mainly describes the trends of commuter cycling, and thus the index may be defined as an index of commuter cycling. The Norwegian government is continuing the strategy of increasing the level of commuter cycling in highly populated areas [12]. The present national index and local indices may directly evaluate the national, regional, and local strategies and measures.

The aim of the present study was to develop a bike traffic index and describe the national, regional, and local trends in counted cycle trips in Norway. From a short, random sample for all counters, the calculation of traffic patterns indicates that a majority of counters describe trends in commuter cycling. The results must be integrated with knowledge of local, regional, and national strategies and actions to promote cycling to more precisely describe factors possibly affecting the trend. However, the national trend in counted cycle trips was a small national decrease in counted cycling trips in 2019 followed by a rather large increase in 2020. We are not aware of any national campaigns in the last years to increase commuter cycling, but there is a small yet steady increase in cycling-friendly infrastructure in accordance with the national transport plans [1,13]. In 2018, 199 km of new cycle-friendly infrastructure (including cycle paths and combined pedestrian and cycle paths) was finalized, while the corresponding numbers for 2019 and 2020 were 173 and 322 km, respectively [28]. Due to a national reorganization of municipalities and counties in 2020, data below the national level cannot be derived from Statistics Norway. Several studies [19,29–32] have observed positive associations and effects between cycling-friendly infrastructure and commuter cycling [11,16,19]. In 13 European cities with low to medium cycling levels, a linear relationship (R^2 = 0.8) has been observed between metres of cycle-friendly infrastructure per citizen and bike mode share [11]. Others have found that cycle-friendly infrastructure explains one-third of the variation in commuter cycling rates [17,33]. However, even with perfect conditions for commuter cycling, some individuals will still choose a mode of transportation other than a bicycle [11]. It is plausible that the significant increase in counted bicyclists is a result of more cycling-friendly infrastructure, but no causal conclusion can be drawn from the present study [34]. Since the importance of the built environment (i.e., cycle-friendly infrastructure) is likely mediated by personal factors, infrastructure alone is not sufficient to increase cycling rates [20]. Furthermore, building new cycle-friendly infrastructure is expensive. However, from a 25-year perspective, the health benefits are more than five times larger than the cost of building the cycle-friendly infrastructure [10,11]. In terms of health benefits at a population level in a country with cycle-friendly infrastructure, increased rates of cycling are 21 and 238 times higher than the risk of injuries and mortality caused by cycle accidents, respectively [9]. From a socioecological perspective, changes in behaviour (in this context, cycling) are more likely to occur when interventions implement actions on multiple levels, from the individual level to community and policy levels [34]. Due to the complexity of behaviour change, increased counted cycle trips in Norway during the last three years may be led by other factors than changes in the built environment.

Another factor that may have affected travel habits in Norway in 2020 is the COVID-19 pandemic. In Norway, there was a national lockdown during spring 2020 and a second lockdown in late autumn 2020. Although the second lockdown was a national strategy, the local implementation varied. The national lockdown included closure of preschools, and all levels of schools provided remote learning. All shops, restaurants, and services were closed, and remote work was standard for all citizens whenever possible. Social contact was guided towards an absolute minimum. After the lockdown, Norwegian citizens were encouraged to minimize the use of public transport (i.e., bus, train, and tram), only travel when needed, keep social contact at a minimum, and work remotely when possible. The promotion of not using public transport may have led to an increase in the use of micro mobilities [35] and private cars [35,36]. The national index indicates that a higher volume of counted cycle trips may be a result of reduced use of public transport as observed in both European and American cities [37]. However, the national index only describes total cycling. The calculated traffic pattern indicates that included counters mainly count commuter traffic; however, the increase may also have been an increase in recreational cycling. In European cities, a total increase of 8% from 2019 to 2020 has been observed [37], while in a worldwide cross-sectional study, the proportion of cyclists has increased from 8 to 26% [36]. Some studies report that the largest increase is seen on weekends, indicating an increase in recreational cycling [37,38].

4.1. The Present Bike Traffic Index Compared to the National Travel Survey

The bike traffic index supplements the Norwegian travel survey. Together they provide reliable data to evaluate strategies at the local, regional, or national level. From 1985 to 2014, the travel survey was conducted every fourth year. Since 2016, the travel survey has been published annually and conducted by NRPA. While the travel survey is conducted annually, the index provides monthly and annual data with a much larger sample size. The last two travel surveys have had 47,806 and 110,672 respondents, with a 5% share of cyclists [39,40]. The present bike traffic index covers an area of more than 1.2 million people and thus is likely to be more sensitive regarding changes in cycling habits.

4.2. Sensitivity Analyses

The present index is weighted for population density in accordance with the Danish bike traffic index [23]. The index could possibly be weighted for other factors, such as type of road, weather, type of day, traffic pattern, and cycle infrastructure [40]. For the present model, multiple models built on parameters conserving mean counts, population density, distance between counters, and a counter's number of operative days were tested. The variance between the models was 4.1% (see Appendix A). Therefore, the present index was only weighted only for population density around the counter.

4.3. Strengths and Limitations

The present bike traffic index is a measure of counted passings over a stationary counter and does not necessarily have the same trend as travel surveys where one examines either the proportion of cycle trips out of the total number of trips or the proportion of cyclists. The present bike traffic index describes the trends in counted cycle trips where an increased number of trips may reflect that more people are cycling or that a person cycles more frequently. Given the ecological design of the present study, one should be aware of the possibilities of ecological fallacy since the study is not based on individual data. The present index describes counted trips with indications of cycling mode based on calculation of traffic pattern forming a short, random period and thus describing total cycling with *indications* of commuter cycling before the COVID-19 pandemic. If Norwegian travel patterns follow European and American mobility trends during the COVID-19 pandemic [37], it is possible that the observed increase in counted cycle trips is reflecting more recreational cycling rather than commuter cycling.

It has been argued that bike traffic indices must have at least one of each day of the week in each month to have sufficient data quality [40]. Furthermore, the error may be minimized by using factors that take weather into account [40]. In the present bike traffic index, we handled missing data at a daily level by interpolating by linear regression, where the missing value was set to the mean of the nearest valid values next to the missing value. Furthermore, only pairs of months with valid data were included in the index.

Unfortunately, the present national bike traffic index is mainly based on counters in urban areas. However, in Norway there are large areas with rural populations. The index has the limitation of not describing rural bike traffic trends due the lack of counters in rural areas. For urban areas, the present bike traffic index has several advantages for detecting changes. Moltved et al. [23] highlight three specific advantages for bike indices with similar methods as the present index. First, the bike counters include the actual number of passing cyclists independent of residence, age, or recall bias. Second, the counter's location is precisely described, and third, continuous counting results in a model which is sensitive to actual changes. Furthermore, the present bike traffic index is a robust yet dynamic model. The present bike traffic index uses the sum of counted trips from local indices in both national and regional indices. We have therefore developed a model which enables the inclusion of both new counters and local indices when more counters are operative.

5. Conclusions

The present study describes the methods of a sensitive bike traffic index at local, regional, and national levels from 2018 to 2020 and was intended to follow trends in counted trips for years. The bike traffic index of counted cycle trips has described the 2018 level and trends in Norway over subsequent years. Nationally, we observed a significant 11% increase in counted cycle trips. However, local and regional indices indicate local differences. The indices may indicate the possible related effects of local to national cycling strategies and constitute a sensitive tool for monitoring changes in cycling habits. Calculations indicate that most counters are mainly passed by commuter cyclists, but the index itself only describes trends in total counted trips. No conclusion regarding possible explanations of the significant increase in counted trips can be drawn from this study. However, the trend observed is in accordance with the literature regarding the increased metres of cycle-friendly infrastructure and how the COVID-19 pandemic affected travel habits globally in 2020.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: www.trafikkdata.no (accessed on 7 June 2021).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Sensitivity Models of the National Bike Traffic Index

Table A1. Sensitivity mdels * of the national bike traffic index.

Year	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
2018	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2019	95.4	94.6	95.4	94.7	93.9	97.2	93.1	94.5

* All models are based on 79 counters operative from 1 July 2017.

Model 1: The model is the mean of all counts (C) divided by the total number of counters: 79 (T).

$$= \frac{C_1 + C_{2\ldots} + C_n}{T_n} \tag{A1}$$

Model 2: Mean of annual average daily trips ($AADT$) per local index (l) divided by the number of indices (l_n).

$$= \frac{\overline{AADTl_1} + \overline{AADTl_{2\ldots}} + \overline{AADTl_n}}{l_n} \tag{A2}$$

Model 3: Weighted number of counters within the local index. When there are one or two counters, the local $AADT$ is multiplied by 1; when there are three or four counters, the local $AADT$ is multiplied by 2; and with more than five counters, the index is multiplied by 3.

Model 4: Weighted percentage of volume $AADT$ per local index.

$$= \frac{\overline{AADTl_1}}{AADTl_1 + AADTl_{2\ldots} + AADTl_n} + \frac{\overline{AADTl_{2\ldots}}}{AADTl_1 + AADTl_{2\ldots} + AADTl_n} + \frac{\overline{AADTl_n}}{AADTl_1 + AADTl_{2\ldots} + AADTl_n} \tag{A3}$$

Model 5: Weighted population density per municipality, where Pm = total population, pm = population in local index.

$$= \frac{pm\,\overline{AADTl_1}}{Pm} + \frac{pm\,\overline{AADTl_{2\ldots}}}{Pm} + \frac{pm\,\overline{AADTl_n}}{Pm} \tag{A4}$$

Model 6: Weighted population in 5-km grid per counter, where Pg = total population in all grids with counter, Pg = population in grid with counter, and C = counter.

$$= \frac{pg\,\overline{AADTC_1}}{Pg} + \frac{pg\,\overline{AADTC_{2\ldots}}}{Pg} + \frac{pg\,\overline{AADTC_n}}{Pg} \tag{A5}$$

Model 7: Weighted population in 5-km grid per local index, where Pg = total population in all grids with counter, Pg = population in grid with counter, and l = local index.

$$= \frac{pg\,\overline{AADTl_1}}{Pg} + \frac{pg\,\overline{AADTl_{2\ldots}}}{Pg} + \frac{pg\,\overline{AADTl_n}}{Pg} \tag{A6}$$

Model 8: Weighted distance (> or <4.9 km; Average length of daily trips in Norway) between counters in local index, where d = average distance between counters > 1 = 1.

$$= \frac{\overline{d\,AADTl_1}}{l_1} + \frac{\overline{d\,AADTl_{2\ldots}}}{l_{2\ldots}} + \frac{\overline{d\,AADTl_n}}{l_n} \tag{A7}$$

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APPENDIX I

Approval from the Regional Committee for Medical and Health Research Ethics

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK vest	Camilla Gjerstad	55978499	01.03.2017	2016/1897/REK vest
			Deres dato:	
			13.01.2017	

Vår referanse må oppgis ved alle henvendelser

Lars Bo Andersen
Avdeling for lærarutdanning og idrett

2016/1897 Førde Aktiv Transport (FACT) Studie

Forskningsansvarlig: Høgskulen i Sogn og Fjordane
Prosjektleder: Lars Bo Andersen

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK vest) i møtet 09.02.2017. Vurderingen er gjort med hjemmel i helseforskningsloven (hfl.) § 10, jf. forskningsetikkloven § 4.

Prosjektomtale
Vegnettet i Førde vil fra 2016 bli oppgradert gjennom Førdepakken. 1,0 milliarder kr skal brukes på ny infrastruktur for sykling og gåing. Førde Active Transport (FACT) Study har som mål å evaluere effekten på sykling i Førde med å implementere Førdepakken, og å vurdere hvordan implementeringen kan påvirke folkehelse og miljøfaktorer. Naturlige eksperiment for økt sykkelbruk har vist positive verknader, men vitenskapelige evalueringer mangler og vil derfor bli gjennomført i FACT-studien. Alle mellom 13–65 år i Førde og Sogn og Fjordane inviteres til å svare på et web-basert spørreskjema våren 2017 og etter hvert som tiltakene ferdigstilles for å analysere endringer i sykkeladferd og medbestemmende faktorer. Stasjonære tellinger i Førde vil vurdere sykkeladferd fra høst 2016. Kohorten kobles til norske registre for å undersøke årsaksspesifikk dødelighet, sykdom, sykehusinnlegging og medisinbruk. I tillegg gjennomføres en RCT, kvalitative intervjuer, litteraturgjennomgang og casestudie

Komiteen behandlet saken første gang i møtet 24.11.16 og ba om tilbakemelding

- Datainnsamling og valg av variabler må begrunnes.
- Frafallsanalysen må begrunnes eller tas bort.
- Håndteringen av kontrollgruppen må belyses.
- Den kvalitative delen må beskrives mer inngående. Dette kan eventuelt gjøres i fremtidige prosjektendringer.
- Delstudie WP2 må sendes som egen prosjektsøknad til REK.

Tilbakemelding fra prosjektleder
Forskningsprotokollen er revidert på grunn av manglende finansiering
Det søkes kun godkjenning for arbeidspakkene WP1 og WP4. Utvalget i WP1 er endret til offentlige ansatte og videregående elever fra Sogn og Fjordane og Agder-fylkene. Deltakerne oppgir personnummeret i spørreskjema og på den måten vil man senere kunne koble til de omsøkte registrene.

Datainnsamling og begrunnelse for variabler
Studien vil innhente data om medisinforbruk og bruk av helsetjenester til å vurdere økonomiske byrde av

sykling, gange og passiv transport. Data om deltakere i studien innhentes fra følgende kilder:

-Dødsårsaksregister: Dødstidspunkt, diagnose, dødsårsak.
-Kreftregisteret: Krefttyper.
-Norsk pasientregister: Bruk av helsetjenester. Innleggelsesdager og bruk av fastlege.
-Reseptbasert legemiddelregister: Kostnader knyttet til legemiddelbruk.
-Nasjonal register over hjerte- karlidelser: Diagnose og dato.
-HELFO/KUHR: kontakttidspunkt og takster, diagnose (ICPC, ICD10).

Datasikkerhet
Komiteen ba om en redegjørelse fra forskningsansvarlig om grep for å styrke datasikkerheten i prosjektet. Dette er vedlagt.

Frafallsanalye
Studien vil gå bort fra den opprinnelig planen om å gjennomføre en frafallsanalyse, og velger i stedet å sammenholde studieutvalget med generell populasjonsstatistikk fra fylkene.

Kontrollgruppen
Komiteen ba om tilbakemelding om informasjonsskriv til kontrollgruppen. Kontrollgruppen (utvalget i Agder) deltar i samme spørreskjemaundersøkelse og vil få et tilsvarende informasjonsskriv som utvalget i Sogn og Fjordane.

Kvalitativ del av studien
WP2, WP3, og WP5 inneholder kvalitative deler. For WP2 (El-sykkel) vil det bli sendt separat søknad til REK. WP3 og WP5 omhandler ikke helsespørsmål. Prosjektleder foreslår derfor at WP3 og WP5 isteden meldes til NSD. WP5 vil undersøke forhold i sosiale, politiske og fysisk miljø som kan identifisere faktorer for suksess eller fiasko av intervensjonene i Førde. WP3 vil undersøker reisevaner og holdninger til sykling og hva som kan være barrierer for å bruke sykkel.

Vurdering av tilbakemeldingen i møtet 09.02.17
Komiteen mener at WPI, som beskrevet i tilbakemeldingen, er spisset nok til at det kan anses å være et konkret prosjekt. REK vest har ingen innvendinger til at WP3 og WP5 isteden vurderes av NSD. Tilbakemeldingen besvarer de fleste av komiteens spørsmål og merknader på en god måte. REK vest har likevel noen spørsmål/merknader:

- *Om WP4:* komiteen synes det er vanskelig å få oversikt over WP4 og hva slags datakilder som inngår. REK vest ber om at denne delstudien sendes til vurdering via en endringssøknad når beskrivelsen og finansieringen er mer konkret.
- *Datasikkerhet i WP1:* I den opprinnelige søknaden står det at prosjektleder, arbeidspakkelederne og stipendiat vil ha tilgang til koblingsnøkkelen. Komiteen er opptatt av at færrest mulig skal få tilgang til koblingsnøkkelen, og ber om at tilgangen kun gis til prosjektleder.
- *Informasjonsskriv til WP1*: Komiteen har følgende merknader:

    Det må fremgå hva slags helseregistre og andre offentlige registre det er snakk om å koble, og det må komme tydeligere frem at det er snakk om kobling av registerdata om den enkelte deltaker.

    Det må informeres om at data blir slettet ved prosjektslutt i 2027.

    Det må informeres i skrivet om at kun en person (data manager) har tilgang til koblingsnøkkel. Det må også fremgå hvem som har tilgang til koblingsnøkkelen etter at de ulike registerdata er koblet til.

Vilkår:

- Komiteen ber om at informasjonsskrivet revideres og sendes til REK vest til

post@helseforskning.etikkom.no.
- WP4 må vurderes senere når protokollen er mer konkret.

Vedtak
REK vest godkjenner prosjektet på betingelse av at ovennevnte vilkår tas til følge.

Sluttmelding og søknad om prosjektendring
Prosjektleder skal sende sluttmelding til REK vest på eget skjema senest 30.06.2028, jf. hfl. § 12. Prosjektleder skal sende søknad om prosjektendring til REK vest dersom det skal gjøres vesentlige endringer i forhold til de opplysninger som er gitt i søknaden, jf. hfl. § 11.

Klageadgang
Du kan klage på komiteens vedtak, jf. forvaltningsloven § 28 flg. Klagen sendes til REK vest. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK vest, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Med vennlig hilsen

Marit Grønning
Prof. dr.med
Komiteleder

Camilla Gjerstad
rådgiver

Kopi til: post@hisf.no; post@hvl.no

APPENDIX II

Study information to participants

Fysisk aktivitet og transport i Sogn og Fjordane

Bakgrunn og formål

Det har vorte innvilga store summar for oppgradering av gang- og sykkelvegar i Sogn og Fjordane. FACT studien vil i tilknyting til dette gjennomføre ei spørjeundersøking. Målet med studien er å evaluere effekten av oppgraderinga på sykling, og å vurdere korleis oppgraderinga kan påverke folkehelse og miljøfaktorar. Studien vil analysere moglege direkte og indirekte helsefordelar og tilhøyrande miljøfordelar ved å fremme sykling gjennom arealplanlegging og investeringar i ny infrastruktur. Forskingsgruppa består av forskarar frå Høgskulen på Vestlandet (tidligare Høgskulen i Sogn og Fjordane), Helse Førde, Vestlandsforsking, Universitetet i Agder og Norges idrettshøgskole. Alle offentleg tilsette i Sogn og Fjordane inviterast til å delta i studien, og du mottek denne invitasjonen då arbeidsgjevar har gjort e-postadressa di tilgjengeleg for studien. NSD er databehandlar og ansvarleg for den tekniske utføringa av undersøkinga.

Kva inneberer deltaking i studien?

Som deltakar i studien vil du svare på eit web-basert spørjeskjema våren 2017 og ved eit seinare tilhøve når fleire av gang- og sykkelvegtiltaka er ferdigstilt. Spørjeskjemaet tar ca. 25 minutt å fylle ut. Spørjeskjemaet omhandlar transportvanar, sykkeleigarskap, generell fysisk aktivitet, røykevaner, helsetilstand, og bakgrunnsvariablar som kjønn, alder, etnisitet, utdanning og arbeidssituasjon etc. Vi ønsker å kople data om den enkelte deltakar frå spørjeskjema opp mot nasjonale helseregistre (Dødsårsaksregistret, Kreftregistret, Norsk pasientregister, Reseptbasert legemiddelregister, Nasjonalt register over hjarte- og karlidingar og HELFO/KUHR) og Statens Helseundersøkingar for å undersøke samanhengar mellom transportvanar og helse. Mindre utval vil også bli spurd om å delta på intervju vedrørande sykling. Personane dette gjeld vil få ein eigen invitasjon. Alle deltakarar i undersøkinga vil vere med i trekking av ein iPad.

Det er enkelt å besvare spørjeskjemaet via Internett. Du treng berre å klikke på lenka nedanfor for å komme i gong.

https://resp.nsd.uib.no/survey?id=2872&pin=8889

Venlegast ikkje bruk tilbake-tasten i weblesaren. Merk at innloggingsdata er personlege, og ikkje må overlatast til andre.

Dersom du ikkje kjem inn på skjemaet ved å klikke på den oppgitte lenka, kan du gå til: **https://resp.nsd.uib.no**
Bruk din personlege innloggingsinformasjon: BrukerId "2872" og pinkode "8889"

Kva skjer med informasjonen om deg?

Informasjonen som registrerast om deg skal kunn brukast slik som forklart i hensikta med studien. Alle opplysningane vil bli behandla utan namn eller andre direkte eller indirekte gjenkjennande opplysningar. Ein ID-kode knyter deg til dine opplysningar gjennom ei koplingsliste. Koplingslista lagrast åtskilt frå andre data og vil berre vere tilgjengelig for data manager i FACT. Besvarte spørjeskjema vil oppbevarast på sikra server hos NSD. Det vil ikkje være mogleg å gjenkjenne deltakarane i publikasjonar. Prosjektleiar har ansvar for den daglige drifta av forskingsprosjektet og at opplysningar om deg blir behandla på ein sikker måte. Informasjon om deg vil bli avidentifisert, men beheldt for framtidige koplingar mot helseregistre. Kunn data manager vil ha tilgang til koplingsnøkkel etter at dei ulike registerdata er kopla til. All data vert sletta ved prosjektslutt i 2027.

Frivillig deltaking

Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke utan å oppgje nokon grunn. Dersom du trekker deg, vil alle opplysningar om deg bli sletta.

Studien er godkjent av Regional komite for medisinsk og helsefaglig forskningsetikk (REK) med referanse 2016/1897/REK vest.

Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med prosjektkoordinator Ane K. Solbraa (tlf: 57676081, e-post: **ane.solbraa@hvl.no**) eller PhD-stipendiat Solveig Nordengen (tlf: 57676197, e-post: **solveig.nordengen@hvl.no**). Professor Lars Bo Andersen er prosjektleder.

APPENDIX III

Questionnaire Sogn og Fjordane (Study III)

Bakgrunnsdata

Kjønn:

- Kvinne
- Mann

Personnummer

Personummer blir kunn nytta til kopling til helseinformasjon og vil bli lagra adskilt frå denne informasjonen

Vennligst skriv personnummer (11 siffer): [ ]

Fødselsdato

Dag:

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31

Måned:

- Januar
- Februar
- Mars
- April
- Mai
- Juni
- Juli
- August
- September
- Oktober
- November
- Desember

År:

Vennligst noter: ____

Kor høg er du? (utan sko)

cm: ____

Kva er vekta di? (utan klede og sko)

kg: ____

Er du fødd i Noreg?

- Ja
- Nei

Kvar er du fødd? ____

Er begge foreldra dine fødd i Noreg?

- Ja
- Nei

Mor er fødd i: ____

Far er fødd i: ____

Kva er din bustadsadresse?

Gatenamn: ____

Husnummer: ____

Postnummer: ____

Poststed: ____

Kva er din sivile status?

- Gift
- Sambuar
- I eit forhold (bur aleine)
- Separert
- Skilt
- Enkje/enkjemann
- Einsleg
- Annan

Kva var bustaden si samla bruttoinntekt i fjor?

NOK:

Kor mange bur i din bustad?

Barn:

- 0
- 1
- 2
- 3
- 4
- 5 eller fleir

Kor mange bur i din bustad?

Vaksne:

- 0
- 1
- 2
- 3
- 4
- 5 eller fleir

Har du barn i barnehagealder?

- Ja
- Nei

Har du barn i skulealder?

- Ja
- Nei

Kva for ein utdanning er den høgaste du har fullført?

Sett eitt kryss

- ○ Mindre enn 7 år grunnskule
- ○ Grunnskule 7-10 år, framhaldsskule eller folkehøgskule
- ○ Realskule, middelskule, yrkesskule, 1-2 vidaregåande skule
- ○ Artium, økonomisk gymnas, allmennfagleg retning i vidaregåande skule
- ○ Høgskule/universitet, mindre enn 4 år
- ○ Høgskule/universitet, 4 år eller meir

Kva er din hovudsyssel?

Sett eitt kryss

- ○ Yrkesaktiv heiltid
- ○ Yrkesaktiv deltid

Tal timar per veke: ☐

Har du skiftarbeid, nattarbeid eller går vaktar?

- ○ Ja
- ○ Nei

Vennligst spesifiser:

- ☐ Skift
- ☐ Turnus
- ☐ Nattarbeid
- ☐ Anna ordning

Røykjer du?

- ○ Nei, eg har aldri røykja fast
- ○ Nei, eg har slutta

Årstal da du slutta: ☐

- ○ Ja, men ikkje dagleg
- ○ Ja, dagleg

Tal: ☐

Snuser du?

- ○ Nei, eg har aldri snust fast
- ○ Nei, eg har slutta

Årstal da du slutta: ☐

- ○ Ja, men ikkje dagleg
- ○ Ja, dagleg

Tal: ☐

Har du vore sjukemeldt siste 6 månadene?

- Ja

Noter tal veker:

Gjennomsnitt % sjukmelding:

- Nei

Transportvaner

Dei neste spørsmåla handlar om dine vanar knytt til transport og omfattar dine vanlege måtar å kome frå ein stad til ein annan.

Har du månadskort for kollektivtransport (buss eller tog)?

- Ja
- Nei

Har du førarkort?

- Ja
- Nei
- Har hatt tidligare

Kor mange bilar/motorsyklar råder din bustad over?

- Ingen
- 1
- 2
- 3
- 4
- 5 eller fleir

Har du tilgang til parkeringsplass for bil på arbeidsplassen?

- Ja, gratis
- Ja, må betale
- Nei

Ranger trafikktryggleiken på arbeidsvegen din fra 1 (særs farleg veg) til 10 (heilt trygg veg).

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Kor einig eller ueinig er du i følgjande utsegn:

	Særs ueinig	Litt ueinig	Verken/eller	Litt einig	Særs einig
Totalt sett meiner eg det er fint å bruke bil i kvardagen	○	○	○	○	○
Det er lett for meg å bruke bilen i kvardagen	○	○	○	○	○
Eg meiner det er godt å bruke bilen i kvardagen	○	○	○	○	○
Eg kan køyre bil	○	○	○	○	○
Folk rundt meg støttar meg i å bruke bilen i kvardagen	○	○	○	○	○
Eg reknar med å bruke bilen i kvardagen	○	○	○	○	○
Eg kjem sannsynlegvis til å køyre bil i kvardagen framover	○	○	○	○	○

Har du en funksjonshemming som snevrar inn dine transportmulegheiter?

○ Ja

Kva for nokon: [ ]

○ Nei

Kor mange dagar i ei vanleg veke reiser du med motorisert transportmiddel som buss eller bil i minst 10 minuttar for å komme deg frå ein stad til ein anna?

Dagar per veke om sommaren: [ ]

Dagar per veke om vinteren: [ ]

På ein vanlig dag kor du reiser med motorisert transportmiddel, kor lang tid brukar du då totalt på transportmiddelet?

Om sommaren:

Timar [ ]

Minuttar [ ]

Om vinteren:

Timar [ ]

Minuttar [ ]

Kor mange dagar i ei vanleg veke syklar (vanleg sykkel eller el-sykkel) du minst 10 minuttar samanhengande for å komme deg frå ein stad til ein anna?

Dagar per veke om sommaren [ ]

Dagar per veke om vinteren [ ]

På ein vanlig dag kor du syklar (vanleg sykkel eller el-sykkel) for å komme deg frå ein stad til ein anna, kor lang tid brukar du då totalt på å sykle?

Om sommaren:

Timar

Minuttar

Om vinteren:

Timar

Minutter

Kor mange dagar i ei vanleg veke går du minst 10 minuttar i strekk for å komme frå ein stad til ein annan?

Dagar per veke om sommaren

Dagar per veke om vinteren

På ein vanleg dag kor du går for å komme deg frå ein stad til ein annan, kor lang tid brukar du då totalt på å gå?

Om sommaren:

Timar

Minuttar

Om vinteren:

Timar

Minuttar

Spørsmåla under omhandlar ditt nærmiljø.

Med nærmiljø meiner vi det fysiske miljøet rundt der du bur. Kva som oppfattast som nærmiljø er individuelt. Nærmiljøet omfattar blant anna bustadområder, parkar, plassar, vegar, gater, leikeplassar og natur- og friområde.

Kor stort er ditt nærmiljø?

Meter (diameter):

Kor einig eller ueinig er du i følgjande utsegn om ditt nærmiljø:

	Særs ueinig	Ueinig	Verken/eller	Einig	Særs einig
Det er fint å gå i mitt nærmiljø	◯	◯	◯	◯	◯
Vegane er farlege for syklistar i mitt nærmiljø	◯	◯	◯	◯	◯
Det er godt tilrettelagt kollektivtransport i mitt nærmiljø	◯	◯	◯	◯	◯
Det er godt tilrettelagt for sykling i mitt nærmiljø	◯	◯	◯	◯	◯
Det er lite trafikk i mitt nærmiljø	◯	◯	◯	◯	◯
Det er ikkje godt tilrettelagt for gåande i mitt nærmiljø	◯	◯	◯	◯	◯
Det er trygt å krysse vegane i mitt nærmiljø	◯	◯	◯	◯	◯

Dersom du brukar kollektivtransport til arbeid, kor langt er det frå der du bur til haldeplass/stasjon?

Meter: ______

Dersom du tek kollektivtransport, korleis kjem du deg som regel til haldeplass/stasjon?

- ◯ Går
- ◯ Syklar
- ◯ El-sykkel
- ◯ Køyrer bil
- ◯ Anna

Vennligst spesifiser: ______

Vi vil nå spørje om ALLE reiser du føretok i går. Du vil få moglegheit til å svara for kvar enkelt reise. Når det ikkje er fleire reiser å rapportere, kryssar du av for «ingen fleire reiser».

Kvar starta du gårsdagen?

- ◯ Min bustadsadresse
- ◯ Annan stad

Gatenamn: ______

Husnummer: ______

Postnummer: ______

Poststed: ______

- ◯ Hadde ikkje nokon reiser i går

Etter du forlot denne staden, kor reiste du då?

Gatenamn:

Husnummer:

Postnummer:

Poststed:

Omtrent kor lang var denne reisa i kilometer?

km:

Kva var formålet med denne reisa?

- Eigen heim
- Innkjøp
- Sosial/helse (besøk hos lege, sjukehus, jobbsenter osv.)
- Anna ærend (bank, bibliotek, bilverkstad osv.)
- Hente/bringe person
- Hente/bringe ting
- Besøkje familie/venner
- Fornøyelse (idrettsarrangement, kafé, restaurant osv.)
- Møter i privat samanheng
- Fritidsaktvitetar
- Gåtur, løpetur, sykkeltur, køyretur (turen var formål i seg sjølv)
- Reise tilknytt arbeid
- Skule
- Arbeid
- Sommarhus/hytte
- Anna

Vennligst spesifiser:

Når reiste du dit?

hh:

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15
- ○ 16
- ○ 17
- ○ 18
- ○ 19
- ○ 20
- ○ 21
- ○ 22
- ○ 23

---

mm:

- ○ 05
- ○ 10
- ○ 15
- ○ 20
- ○ 25
- ○ 30
- ○ 35
- ○ 40
- ○ 45
- ○ 50
- ○ 55

---

mm:

- 05
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Kva var transportmiddelet på denne turen?

- Bil

Kva for eit bilmerke? (la stå blankt om du ikkje veit)

Kva årsmodell var bilen? (la stå blankt om du ikkje veit)

Kva type drivstoff bruker bilen? (la stå blankt om du ikkje veit)

Kor mange personar var det i bilen?

- Sykkel
- El-sykkel
- Moped/scooter/motorsykkel
- Gange
- Buss
- Anna

Vennligst spesifiser:

- Sett kryss her om dette var siste reisa denne dagen

Under følger nokon spørsmål om kvardagsreiser

Kor langt er det frå heimen din til...?

Fyll inn tal km

Arbeidsplassen

Barnehagen/Skulen (dersom du har barn i barnehage/skule)

Nærmaste matvarebutikk

Nærmaste sentrum

Oftast besøkte fritidsaktivitet-stad (eks: treningssenter, kino, familie)

Kva er adressa til arbeidsplassen din?

Gatenamn:

Husnummer:

Postnummer:

Poststed:

Kva er adressa til barnehagen/Skulen (dersom du har barn i barnehage/skule)?

Gatenamn:

Husnummer:

Postnummer:

Poststed:

Kva er adressa til nærmaste matvarbutikk?

Gatenamn:

Husnummer:

Postnummer:

Poststed:

Kva er adressa til nærmaste sentrum?

Gatenamn:

Husnummer:

Postnummer:

Poststed:

Kva er adressa til oftast besøkte fritidsaktivitet-stad (eks: treningssenter, kino, familie)?

Gatenamn:

Gatenummer:

Postnummer:

Korleis kjem du deg vanlegvis (tenk på det siste året) til og frå arbeid utanfor heimen. Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar årstid (jobbar du 5 dagar/veke utanfor heimen skal summen for kvar årstid verte 5, jobbar du 3 dagar utanfor heimen/veke skal summen verte 3).

Haust (sept-nov)

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv-transport

Totalt

Vinter (des-feb)

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv-transport

Totalt

Vår (mars-mai)

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv-transport

Totalt

Sommar (jun-aug)

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv-transport	
Totalt	

Om du køyrer bil, køyrer du sjølv eller er du passasjer?

- ○ Køyrer sjølv
- ○ Passasjer

Kor langt tid brukar du normalt på denne turen?

Minuttar	

Om du skulle nytta anna framkomstmiddel som hovudtransportmiddel, kva for eit ville du nytta:

- ☐ Til fots
- ☐ Sykkel
- ☐ El-sykkel
- ☐ Bil/motorsykkel/moped/scooter
- ☐ Kollektivtransport
- ☐ Ikkje aktuelt

Kor mykje lenger hadde du vore villig til fortsatt å sykle til arbeidsplassen?

Tid (minuttar):	
Avstand (km):	

Kor ofte leverar eller hentar du vanlegvis barn i barnehage/på skulen?

Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar linje (leverar eller hentar du 5 dagar/veke skal summen for kvar linje verte 5, leverar eller hentar du 3 dagar/veke skal summen verte 3, leverar du OG hentar du kvar dag vert det 10).

Haust (sept-nov)

Til/frå barnehage/skule:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vinter (des-feb)

Til/frå barnehage/skule:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vår (mars-mai)

Til/frå barnehage/skule:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Sommar (jun-aug)

Til/frå barnehage/skule:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Om du køyrer bil, køyrer du sjølv eller er du passasjer?

- ○ Køyrer sjølv
- ○ Passasjer

Kor langt tid brukar du normalt på denne turen?

Minuttar	

Om du skulle brukt anna framkomstmiddel som hovudtransportmiddel, kva for eit ville du nytta:

- ☐ Til fots
- ☐ Sykkel
- ☐ El-sykkel
- ☐ Bil/motorsykkel/moped/scooter
- ☐ Kollektivtransport
- ☐ Ikkje aktuelt

Kor mykje lenger hadde du vore villig til fortsatt å sykle til barnehage/skule?

Tid (minuttar)	
Avstand (km)	

Korleis kjem du deg vanlegvis til næraste matvarebutikk?

Skriv inn tal dagar du handlar i ei normal veke ved dei ulike årstidene. Summer for kvar linje (handlar du 5 dagar/veke skal summen for kvar linje bli 5, handlar du 3 dagar/veke skal summen bli 3).

Haust (sept-nov)

Til/frå matvarebutikk:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vinter (des-feb)

Til/frå matvarebutikk:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vår (mars-mai)

Til/frå matvarebutikk:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Sommar (jun-aug)

Til/frå matvarebutikk:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Om du køyrer bil, køyrer du sjølv eller er du passasjer?

- ○ Køyrer sjølv
- ○ Passasjer

Kor langt tid bruker du normalt på denne turen?

Minuttar	

Om du skulle brukt anna framkomstmiddel som hovudtransportmiddel, kva for eit ville du nytta:

- ☐ Til fots
- ☐ Sykkel
- ☐ El-sykkel
- ☐ Bil/motorsykkel/moped/scooter
- ☐ Kollektivtransport
- ☐ Ikkje aktuelt

Kor mykje lenger hadde du vore villig til fortsatt å sykle til næraste matvarebutikk?

Tid (minuttar)	
Avstand (km)	

Korleis kjem du deg vanlegvis til næraste sentrum?

Skriv inn tal dagar i en normal veke ved dei ulike årstidene du reiser til sentrum. Summer for kvar linje (er du i sentrum 5 gangar/veke skal summen for kvar linje bli 5, 3 gangar/veke skal summen bli 3).

Haust (sept-nov)

Til/frå sentrum:

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vinter (des-feb)

Til/frå sentrum:

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv- transport

Totalt

Vår (mars-mai)

Til/frå sentrum:

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv- transport

Totalt

Sommar (jun-aug)

Til/frå sentrum:

Går

Syklar

Køyrer bil (motorsykkel e.l.)

Kollektiv- transport

Totalt

Om du køyrer bil, køyrer du sjølv eller er du passasjer?

- ○ Køyrer sjølv
- ○ Passasjer

Kor langt tid brukar du normalt på denne turen?

Minuttar

Om du skulle brukt anna framkomstmiddel som hovudtransportmiddel, kva for eit ville du brukt:

- ☐ Til fots
- ☐ Sykkel
- ☐ El-sykkel
- ☐ Bil/motorsykkel/moped/scooter
- ☐ Kollektivtransport
- ☐ Ikkje aktuelt

Kor mykje lenger hadde du vore villig til fortsatt å sykle til næraste sentrum?

Tid (minuttar)	
Avstand (km)	

Korleis kjem du deg vanlegvis til fritidsaktivitetar?

Skriv inn tal dagar i en normal veke ved de forskjellige årstidene. Summer for kvar linje (er på fritidsaktivitetar 5 dagar/veke skal summen for kvar linke bli 5, er du på fritidsaktiviteter 3 dagar/veke skal summen bli 3).

Haust (sept-nov)

Til/frå fritidsaktivitet

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vinter (des-feb)

Til/frå fritidsaktivitet

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Vår (mars-mai)

Til/frå fritidsaktivitet

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Sommar (jun-aug)

Til/frå fritidsaktivitet

Går	
Syklar	
Køyrer bil (motorsykkel e.l.)	
Kollektiv- transport	
Totalt	

Om du køyrer bil, køyrer du sjølv eller er du passasjer?

- Køyrer sjølv
- Passasjer

Kor langt tid brukar du normalt på denne turen?

Minuttar	

Om du skulle brukt anna framkomstmiddel som hovudtransportmiddel, kva for eit ville du brukt:

- ☐ Til fots
- ☐ Sykkel
- ☐ El-sykkel
- ☐ Bil/motorsykkel/moped/scooter
- ☐ Kollektivtransport
- ☐ Ikkje aktuelt

Kor mykje lenger hadde du vore villig til fortsatt å sykle til oftast besøkte fritidsaktivitet-stad?

Tid (minuttar)	
Avstand (km)	

Sykkel

Har du tilgang til sykkel?

- Ja
- Nei

Kva for type syklar har du?

(tal før kvar kategori)

Racer

Terrengsykkel

Hybrid

Bysykkel

Transport-/lastesykkel (utan motor)

Transport-/lastesykkel (el-sykkel)

El-sykkel

Anna

Vennligst spesifiser:

Har du tenkt å kjøpe sykkel til deg sjølv i løpet av dei neste 12 mnd.?

- Ja
- Nei

Kva for ein type?

(Fleire kryss mogleg)

- ☐ Racer
- ☐ Terrengsykkel
- ☐ Hybrid
- ☐ Bysykkel
- ☐ Transport-/lastesykkel
- ☐ Transport-/lastesykkel (el-sykkel)
- ☐ El-sykkel
- ☐ Anna

Vennligst spesifiser:

Tenk på ei vanleg veke. Kor mange dagar brukar du vanlegvis sykkel som trening/rekreasjon i dei ulike årstidene?

Tal dagar haust (sept-nov):

Tal dagar vinter (des-feb):

Tal dagar vår (mars-mai):

Tal dagar sommar (jun-aug):

Kor einig eller ueinig er du i følgjande utsegn?

Eg går/syklar sjeldan til arbeid om det er dårlig vær

- Helt ueinig
- Litt ueinig
- Verken einig eller ueinig
- Litt einig
- Helt einig

Nedanfor er ei liste med faktorar som kan motivere til sykling. Kor viktig er kvar av faktorane for din motivasjon til å sykle?

	1 Ikkje viktig i det heile teke	2	3	4 Veldig viktig
Vedlikehalde/forbetre den fysiske formen				
For gleda/fornøyelsens skyld				
Avkopling/redusere stress				
Få tid til fysisk aktivitet i ein travel kvardag				
Være ute i frisk luft				
Ei positiv utfordring				
Ein aktivitet med låg miljø påverknad				
Tid for meg sjølv				
Bra for helsa				
Ein aktivt eg kan gjere samen med andre				
Trafikal fridom/komfort				
Omtanke for miljøet				
Tru på eigne sykkelferdigheter				
Billeg transportform				
Sjå andre personer sykle				
Delta i kampanjar som «Sykle til jobben»				
Oppmuntring frå familie, vener og arbeidskollegaer				
Oppmuntring frå ledar eller arbeidsgjevar				

Nedanfor er ei liste med faktorar som kan forhindre sykling. Kor mykje forhindrar desse faktorane din sykling?

	1 Forhindrar ikkje	2	3	4 Forhindrar i stor grad
Føler meg utrygg i trafikken	◯	◯	◯	◯
Aggressive bilistar	◯	◯	◯	◯
Regn og vind	◯	◯	◯	◯
Tidsnaud	◯	◯	◯	◯
Manglande sykkelparkering på endestasjon	◯	◯	◯	◯
Luftforureining	◯	◯	◯	◯
Manglande fasilitetar som dusj/garderobe på endestasjon	◯	◯	◯	◯
Vanskelig å ta med sykkelen inn på kollektiv transport som buss/tog	◯	◯	◯	◯
Lite dagslys i vinterhalvåret	◯	◯	◯	◯
Varmt vær	◯	◯	◯	◯
For lang avstand til dei stadane eg ønsker å sykle til	◯	◯	◯	◯
Kaldt vær	◯	◯	◯	◯
For mange bakkar	◯	◯	◯	◯
Manglar kunnskap om lokale sykkelruter	◯	◯	◯	◯
For dyrt (sykkel, utstyr, kler)	◯	◯	◯	◯
For dårlig form	◯	◯	◯	◯
Manglande tru på egen evne til sykkelvedlikehald/reparasjonar (eks. slangeskift ved punktering)	◯	◯	◯	◯
Manglande tru på sykkelferdighetene mine	◯	◯	◯	◯
Manglande støtte frå familie/venner/kollegaer	◯	◯	◯	◯
Manglande bagasjeplass	◯	◯	◯	◯

Sjukdom og skader

Brukar du medisinar permanent?

◯ Ja

Kva for nokon?

◯ Nei

Eig du ein sykkelhjelm?

◯ Ja

◯ Nei

Brukar du sykkelhjelm?

◯ Ja

◯ Av og til

◯ Nei

Har du i løpet av det siste året vore utsett for ei ulykke som syklist?

- ○ Ja
- ○ Nei

Skjedde ulykka på...

- ○ Gang- og sykkelveg
- ○ Fortau
- ○ Veg

Kva slags ulykke var dette?

Fleire svar mulig.

- ☐ Velt
- ☐ Kollisjon med bil
- ☐ Kollisjon med anna syklist
- ☐ Kollisjon med fotgjengar
- ☐ Kollisjon med moped/motorsykkel
- ☐ Anna ulykke

Har legen din diagnostisert deg med:

(sett gjerne fleire kryss)

- ☐ Astma
- ☐ Kronisk bronkitt/emfysem/KOLS
- ☐ Hjerteinfarkt
- ☐ Angina Pectoris (hjertekrampe)
- ☐ Allergi
- ☐ Psykiske plager
- ☐ Diabetes type I (sukkersjuke)
- ☐ Diabetes type II (sukkersjuke)
- ☐ Kreft
- ☐ Revmatiske lidingar
- ☐ Hypertensjon
- ☐ Eteforstyrring
- ☐ Anna

Vennligst spesifiser: ______

Spørsmåla under handlar om korleis du oppfattar helsa di. Desse opplysningane vil hjelpe oss å forstå korleis du føler deg og kor godt du er i stand til å utføre dine vanlege aktivitetar.

Stor sett, vil du si at helsa di er:

Utmerka	Veldig god	God	Nokså god	Dårleg
○	○	○	○	○

Dei neste spørsmåla handlar om aktiviteter som du kanskje utfører i løpet av ein vanleg dag.

<u>Er helsa di slik at den forhindrar deg</u> i utføring av desse aktivitetane no?

	Ja, forhindrar meg mykje	Ja, forhindrar meg litt	Nei, forhindrar meg ikkje i det hele teke
Moderate aktiviteter som å flytte eit bord, støvsuge, gå ein spasertur eller drive med hagearbeid	○	○	○
Gå opp trappa fleire etasjar	○	○	○

I løpet av <u>dei siste fire vekene,</u> har du hatt nokon av de følgande problema i arbeidet ditt eller i andre daglege aktivitetar <u>på grunn av di fysiske helse?</u>

	Ja	Nei
Fått gjort mindre enn du ønska	○	○
Vore forhindra i type arbeidsoppgåver eller andre aktiviteter	○	○

I løpet av <u>dei siste fire vekene,</u> har du hatt nokon av dei følgande problema i arbeidet ditt eller i andre daglege aktivitetar på <u>grunn av følelsesmessige problem</u> (som å føle seg engsteleg eller deprimert)?

	Ja	Nei
Fått gjort mindre enn du ønska	○	○
Utført arbeidet eller andre aktivitetar mindre grundig enn vanleg	○	○

I løpet av <u>dei siste fire vekene</u>, kor mykje har <u>smerter</u> påverka det vanlege arbeidet ditt (gjelder både arbeid utanfor heimen og husarbeid)?

Ikkje i det heile teke	Litt	Moderat	Ganske mye	Ekstremt mye
○	○	○	○	○

Dei neste spørsmåla handlar om korleis du føler deg og korleis du har hatt det <u>i løpet av dei siste fire vekene.</u> For kvart spørsmål, ber vi deg velje det svaret som best beskriver korleis du har følt det.

Kor ofte i løpet av <u>dei siste fire vekene:</u>

	Heile tida	Mesteparten av tida	Ein god del av tida	Noko av tida	Litt av tida	Aldri
Har du følt deg roleg og avslappa?	○	○	○	○	○	○
Har du hatt mykje overskot?	○	○	○	○	○	○
Har du følt deg nedfor og deprimert?	○	○	○	○	○	○

I løpet av <u>dei siste fire vekene,</u> kor mykje av tida har den <u>fysiske helsa di eller følelsesmessige problem</u> påverka dine sosiale aktivitetar (som å besøke venner, slektningar, osv.)

Heile tida	Mesteparten av tida	Ein del av tida	Litt av tida	Aldri
○	○	○	○	○

Fysisk aktivitet

<p>Når du svarer på dei neste spørsmåla:</p>
<p>Veldig anstrengande – er fysisk aktivitet som får deg til å puste mykje meir enn vanlig.</p>
<p>Middels anstrengande – er fysisk aktivitet som får deg til å puste litt meir enn vanlig.</p>
<p>Det er kunn aktiviteter som varer i minst 10 minuttar i strekk som skal rapporterast.</p>

Kor mange dagar i løpet av dei siste 7 dagane har du drevet med *veldig anstrengande* fysiske aktivitetar som tunge løft, gravearbeid, aerobics eller sykle fort?

Tenk berre på aktivitetar som varer i minst 10 minuttar i strekk.

Dagar per veke: ☐

På ein vanlig dag kor du utfører *veldig anstrengande* fysisk aktivitetar, kor lang tid brukte du da på dette?

Timar ☐

Minuttar ☐

○ Veit ikkje/hugsar ikkje

Kor mange dagar i løpet av dei siste 7 dagane har du drevet med *middels anstrengande* fysiske aktivitetar som å bære lette ting, sykle eller jogge moderat tempo eller mosjonstennis?

Ikkje ta med gange, det kjem i neste spørsmål.

Dagar per veke: ☐

På ein vanleg dag kor du utførte *middels anstrengande* fysiske aktivitetar, kor lang tid brukte du då på dette?

Timar ☐

Minuttar ☐

○ Vet ikkje/hugsar ikkje

Angi bevegelse og kroppsleg anstrenging i di fritid. Om aktiviteten varierer mykje f.eks. mellom sommar og vinter, så ta eit gjennomsnitt.

Spørsmåla gjeld berre det siste året (sett et kryss i den ruta som passar best)

○ Lese, ser på fjernsyn eller anna stillesittande aktivitet

○ Spaserar, syklar eller beveger deg på en anna måte minst 4 timar i veka? (Her skal du regne med gang eller sykling til arbeidsstaden, søndagstur mm)

○ Driver mosjonsidrett, tyngre hagearbeid e.l? (Merk at aktiviteten skal vere minst 4 timar i veka

○ Trener hardt eller driv konkurranseidrett regelmessig og fleire gangar i veka

Dette spørsmålet omfattar all tid du tilbringar i ro (sittande) på jobb, heime, på kurs, og på fritida. Det kan være tida du sitter ved arbeidsbord, hos vener, mens du leser eller ligger for å sjå på TV.

I løpet av dei siste 7 dagane, kor lang tid brukte du vanlegvis totalt på å sitte <u>på ein vanleg kvardag?</u>

Timar ☐

Minuttar ☐

- ○ Veit ikkje/hugsar ikkje

Kor mange timar søv du vanlegvis om natta på kvardagane?

Timar: ☐

Kor mange timar søv du vanlegvis om natta i helgene?

Timar: ☐

Tillit

Generelt sett, vil du seie at dei fleste menneske er til å stole på, eller må ein vere svært forsiktig i forhold til andre?

- ○ Dei fleste er til å stole på
- ○ Ein må vanlegvis vere svært forsiktig

Overordna livskvalitet

Her er ein skala der 10 står for best mogleg livet for deg, og 0 det verst moglege livet for deg.

<p>Generell sett kor synes du at du står på skalaen for tida?</p>

- ○ 10 Best mogeleg liv
- ○ 9
- ○ 8
- ○ 7
- ○ 6
- ○ 5
- ○ 4
- ○ 3
- ○ 2
- ○ 1
- ○ 0 Verst mogeleg liv

Kva er di epostadresse?

Vennligst noter:

☐

Tusen takk for hjelpa!

APPENDIX IV

Questionnaire Agder (Study III)

Fysisk aktivitet og transport (FACT) i Agderfylka

"" ""

0 [V0_inst]

Institusjon

- ○ Lillesand kommune
- ○ Sjøfartsdirektoratet
- ○ Havforskningsinstituttet
- ○ UiA ansatt
- ○ UiA student
- ○ Birkenes kommune

1 [B0]

Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student.

Sett kryss:

- ○ Offentleg tilsett
- ○ Student
- ○ Anna

Bakgrunnsdata

2 [B1]

Kjønn:

- ○ Kvinne
- ○ Mann

---

3 [B2]

Personnummer

Personnummer blir kun nytta til kopling til helseinformasjon og vil bli lagra adskilt frå denne informasjonen

Vennligst skriv personnummer (11 siffer): [ ]

4 [B3_dd]

Fødselsdato

Dag:

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15

○ 16
○ 17
○ 18
○ 19
○ 20
○ 21
○ 22
○ 23
○ 24
○ 25
○ 26
○ 27
○ 28
○ 29
○ 30
○ 31

5 [B3_mm]

Måned:

○ Januar
○ Februar
○ Mars
○ April
○ Mai
○ Juni
○ Juli
○ August
○ September
○ Oktober
○ November
○ Desember

---

6 [B3_yyyy]

År:

Vennligst noter: [ ]

---

7 [B4]

Kor høg er du? (utan sko)

cm: [ ]

---

8 [B5]

Kva er vekta di? (utan klede og sko)

kg: [ ]

9 [B6]

Er du fødd i Noreg?

○ Ja
○ Nei
Kvar er du fødd? [ ]
Skal bare besvares hvis du har krysset av for Nei

10 [B7]

Er begge foreldra dine fødd i Noreg?

○ Ja
○ Nei

Mor er fødd i: [ ]
Skal bare besvares hvis du har krysset av for Nei
Far er fødd i: [ ]
Skal bare besvares hvis du har krysset av for Nei

11 [B8_student]

Kva er din bustadsadresse?

Med bustad meiner me der du bur når du studerer (altså ikkje kor du er registrert i folkeregisteret eller kor dine foreldre bur)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Gatenamn: [ ]
Husnummer: [ ]
Postnummer: [ ]
Poststed: [ ]

12 [B8_student_oppfolg]

Kor bur du?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

- ○ Heime hjå foreldra mine
- ○ Eigen hybel/leilegheit/hus
- ○ Bufellesskap/studentbustad

13 [B8]

Kva er din bustadsadresse?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Gatenamn: [ ]
Husnummer: [ ]
Postnummer: [ ]
Poststed: [ ]

14 [B9]

Kva er din sivile status?

- ○ Gift
- ○ Sambuar
- ○ I eit forhold (bur aleine)
- ○ Separert
- ○ Skilt
- ○ Enkje/enkjemann
- ○ Einsleg
- ○ Annan

---

15 [B10]

Kva var bustaden si samla bruttoinntekt i fjor?

Om du ikkje er gift eller sambuande regnar du di eiga inntekt som bustadens inntekt

NOK: [ ]

16 [B11]

Kor mange bur i din bustad?

Barn:

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ 0
○ 1
○ 2
○ 3
○ 4
○ 5 eller fleir

17 [B12]

Kor mange bur i din bustad?

Vaksne:

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ 0
○ 1
○ 2
○ 3
○ 4
○ 5 eller fleir

18 [B13]

Har du barn i barnehagealder?

○ Ja
○ Nei

19 [B14]

Har du barn i skulealder?

○ Ja
○ Nei

20 [B15_student]

Kva for eit studium går du på?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

○ Årsstudium/enkeltemner
○ Bachelor
○ Master

21 [B15]

Kva for ein utdanning er den høgaste du har fullført?

Sett eitt kryss

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ Mindre enn 7 år grunnskule
○ Grunnskule 7-10 år, framhaldsskule eller folkehøgskule

○ Realskule, middelskule, yrkesskule, 1-2 vidaregåande skule
○ Artium, økonomisk gymnas, allmennfagleg retning i vidaregåande skule
○ Høgskule/universitet, mindre enn 4 år
○ Høgskule/universitet, 4 år eller meir

22 [B16]

Kva er din hovudsyssel?

Sett eitt kryss

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ Yrkesaktiv heiltid
○ Yrkesaktiv deltid
Tal timar per veke: [ ]
Skal bare besvares hvis du har krysset av for Yrkesaktiv deltid

23 [B17]

Har du skiftarbeid, nattarbeid eller går vaktar?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ Ja
○ Nei

24 [B18]

Vennligst spesifiser:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du skiftarbeid, nattarbeid eller går vaktar?" har verdien "Ja".

☐ Skift
☐ Turnus
☐ Nattarbeid
☐ Anna ordning

25 [B19]

Røykjer du?

○ Nei, eg har aldri røykja fast
○ Nei, eg har slutta
Årstal da du slutta: [ ]
Skal bare besvares hvis du har krysset av for Nei, eg har slutta
○ Ja, men ikkje dagleg
○ Ja, dagleg
Tal: [ ]
Skal bare besvares hvis du har krysset av for Ja, dagleg

26 [B20]

Snuser du?

○ Nei, eg har aldri snust fast
○ Nei, eg har slutta
Årstal da du slutta: [ ]
Skal bare besvares hvis du har krysset av for Nei, eg har slutta
○ Ja, men ikkje dagleg
○ Ja, dagleg
Tal: [ ]
Skal bare besvares hvis du har krysset av for Ja, dagleg
Transportvaner

Dei neste spørsmåla handlar om dine vanar knytt til transport og omfattar dine vanlege måtar å kome frå ein stad til ein annan.

27 [Q2]

Har du førarkort?

- ○ Ja
- ○ Nei
- ○ Har hatt tidligare

28 [Q3_student]

Har du tilgang på bil i kvardagen?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

- ○ Ja
- ○ Nei

29 [Q3]

Kor mange bilar/motorsyklar råder din bustad over?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

- ○ Ingen
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 eller fleir

30 [Q5_student]

Har du tilgang til parkeringsplass for bil på studiestaden?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

- ○ Ja, gratis
- ○ Ja, må betale
- ○ Nei

31 [Q5]

Har du tilgang til parkeringsplass for bil på arbeidsplassen?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

- ○ Ja, gratis
- ○ Ja, må betale
- ○ Nei

Ranger trafikktryggleiken på studievegen din frå 1 (særs farleg veg) til 10 (heilt trygg veg).

	1	2	3	4	5	6	7	8	9	10	
32 [Q6_student]	○	○	○	○	○	○	○	○	○	○	Betinget visning

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Ranger trafikktryggleiken på arbeidsvegen din fra 1 (særs farleg veg) til 10 (heilt trygg veg).

	1	2	3	4	5	6	7	8	9	10	
33 [Q6]	○	○	○	○	○	○	○	○	○	○	Betinget visning

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

34 [Q8]

Har du en funksjonshemming som snevrar inn dine transportmulegheiter?

○ Ja
Kva for nokon: [ ]
Skal bare besvares hvis du har krysset av for Ja
○ Nei
Spørsmåla under omhandlar ditt nærmiljø.

Med nærmiljø meiner vi det fysiske miljøet rundt der du bur. Kva som oppfattast som nærmiljø er individuelt. Nærmiljøet omfattar blant anna bustadområder, parkar, plassar, vegar, gater, leikeplassar og natur- og friområde.

Kor einig eller ueinig er du i følgjande utsegn om ditt nærmiljø:

	Særs ueinig	Ueinig	Verken/eller	Einig	Særs einig
35 [Q19a] Det er fint å gå i mitt nærmiljø	○	○	○	○	○
36 [Q19b] Vegane er farlege for syklistar i mitt nærmiljø	○	○	○	○	○
37 [Q19c] Det er godt tilrettelagt kollektivtransport i mitt nærmiljø	○	○	○	○	○
38 [Q19d] Det er godt tilrettelagt for sykling i mitt nærmiljø	○	○	○	○	○
39 [Q19e] Det er lite trafikk i mitt nærmiljø	○	○	○	○	○
40 [Q19f] Det er ikkje godt tilrettelagt for gåande i mitt nærmiljø	○	○	○	○	○
41 [Q19g] Det er trygt å krysse vegane i mitt nærmiljø	○	○	○	○	○

Under følger nokon spørsmål om kvardagsreiser

42 [Q22_student]

Kor langt er det frå heimen din til...?

Fyll inn tal km

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Studiestaden [ ]
Barnehagen (dersom du har barn i barnehage) [ ]
Skulen (dersom du har barn i skulealder) [ ]

43 [Q22]

Kor langt er det frå heimen din til...?

Fyll inn tal km

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Arbeidsplassen
Barnehagen (dersom du har barn i barnehage)
Skulen (dersom du har barn i skulealder)

44 [Q23]

Kva er adressa til arbeidsplassen din?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Gatenamn:
Husnummer:
Postnummer:
Poststed:

45 [Q23_student]

Kva er din studiestad?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

- ○ Grimstad
- ○ Kristiansand
- ○ Anna

46 [Q24a]

Kva er adressa til barnehagen?

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Gatenamn:
Husnummer:
Postnummer:
Poststed:

47 [Q24b]

Kva er adressa til skulen?

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Gatenamn:
Husnummer:
Postnummer:
Poststed:
Korleis kjem du deg vanlegvis (tenk på det siste året) til og frå studiestaden. Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar årstid (studerer du 5 dagar/veke utanfor heimen skal summen for kvar årstid verte 5, studerer du 3 dagar utanfor heimen/veke skal summen verte 3).

48 [Q28AUT_student]

Haust (sept-nov)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv-transport
Totalt

49 [Q28WIN_student]

Vinter (des-feb)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Går [ ]
Syklar [ ]
Køyrer bil (motorsykkel e.l.) [ ]
Kollektiv-transport [ ]
Totalt [ ]

50 [Q28SPR_student]

Vår (mars-mai)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Går [ ]
Syklar [ ]
Køyrer bil (motorsykkel e.l.) [ ]
Kollektiv-transport [ ]
Totalt [ ]

51 [Q28SUM_student]

Sommar (jun-aug)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Går [ ]
Syklar [ ]
Køyrer bil (motorsykkel e.l.) [ ]
Kollektiv-transport [ ]
Totalt [ ]

52 [Q28c_student]

Kor langt tid brukar du normalt på denne turen når du nyttar hovudtransportmiddelet?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

Minuttar [ ]

53 [Q28f_student]

Korleis kom du deg til studiestaden i dag (om du ikkje var der i dag, svar for førre gang du var der?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." har verdien "Student".

○ Gjekk
○ Sykla på vanleg sykkel
○ Sykla på el-sykkel
○ Køyrte bil
○ Køyrte motorsykkel/moped/scooter
○ Tok kollektiv-transport

Korleis kjem du deg vanlegvis (tenk på det siste året) til og frå arbeid utanfor heimen. Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar årstid (jobbar du 5 dagar/veke utanfor heimen skal summen for kvar årstid verte 5, jobbar du 3 dagar utanfor heimen/veke skal summen verte 3).

54 [Q28AUT]

Haust (sept-nov)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv-transport
Totalt

55 [Q28WIN]

Vinter (des-feb)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv-transport
Totalt

56 [Q28SPR]

Vår (mars-mai)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv-transport
Totalt

57 [Q28SUM]

Sommar (jun-aug)

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv-transport
Totalt

58 [Q28c]

Kor langt tid brukar du normalt på denne turen når du nyttar hovudtransportmiddelet?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

Minuttar

59 [Q28f]

Korleis kom du deg til arbeidsplassen i dag (om du ikkje var der i dag, svar for førre gang du var der)?

Dette spørsmålet skal bare besvares hvis spørsmålet "Undersøkinga rettar seg mot offentleg tilsette i Agderfylka, samt studentar ved Universitetet i Agder. For at spørsmåla skal passe best mogleg til din kvardag, må vi først vite om du er offentleg tilsett eller student." **ikke** har verdien "Student".

○ Gjekk
○ Sykla på vanleg sykkel
○ Sykla på el-sykkel
○ Køyrte bil
○ Køyrte motorsykkel/moped/scooter
○ Tok kollektiv-transport
Kor ofte leverar eller hentar du vanlegvis barn i barnehagen?

Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar linje (leverar eller hentar du 5 dagar/veke skal summen for kvar linje verte 5, leverar eller hentar du 3 dagar/veke skal summen verte 3, leverar du OG hentar du kvar dag vert det 10).

60 [Q29AUT]

Haust (sept-nov)

Til/frå barnehage:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

61 [Q29WIN]

Vinter (des-feb)

Til/frå barnehage:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

62 [Q29SPR]

Vår (mars-mai)

Til/frå barnehage:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

63 [Q29SUM]

Sommar (jun-aug)

Til/frå barnehage:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Går

Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

64 [Q29c]

Kor langt tid brukar du normalt på denne turen når du nyttar hovudtransportmiddelet?

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i barnehagealder?" har verdien "Ja".

Minuttar
Kor ofte leverar eller hentar du vanlegvis barn på skulen?

Skriv inn tal dagar i ei normal veke ved dei ulike årstidene. Summer for kvar linje (leverar eller hentar du 5 dagar/veke skal summen for kvar linje verte 5, leverar eller hentar du 3 dagar/veke skal summen verte 3, leverar du OG hentar du kvar dag vert det 10).

65 [Q30AUT]

Haust (sept-nov)

Til/frå skule:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

66 [Q30WIN]

Vinter (des-feb)

Til/frå skule:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

67 [Q30SPR]

Vår (mars-mai)

Til/frå skule:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Går
Syklar
Køyrer bil (motorsykkel e.l.)
Kollektiv- transport
Totalt

68 [Q30SUM]

Sommar (jun-aug)

Til/frå barnehage/skule:

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Går
Syklar

Køyrer bil (motorsykkel e.l.) [ ]
Kollektiv- transport [ ]
Totalt [ ]

69 [Q30c]

Kor langt tid brukar du normalt på denne turen når du nyttar hovudtransportmiddelet?

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du barn i skulealder?" har verdien "Ja".

Minuttar [ ]
Sykkel

70 [Q32]

Sykla du i går?

○ Ja
○ Nei

71 [Q33]

Har du tilgang til sykkel?

○ Ja
○ Nei

72 [Q34]

Kva for type syklar har du?

(tal før kvar kategori)

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du tilgang til sykkel?" har verdien "Ja".

Racer [ ]
Terrengsykkel [ ]
Hybrid [ ]
Bysykkel [ ]
Transport-/lastesykkel (utan motor) [ ]
Transport-/lastesykkel (el-sykkel) [ ]
El-sykkel [ ]
Anna [ ]
Vennligst spesifiser: [ ]
Skal bare besvares hvis du har krysset av for Anna

73 [Q35]

Har du tenkt å kjøpe sykkel til deg sjølv i løpet av dei neste 12 mnd.?

○ Ja
○ Nei

74 [Q36]

Kva for ein type?

(Fleire kryss mogleg)

Dette spørsmålet skal bare besvares hvis spørsmålet "Har du tenkt å kjøpe sykkel til deg sjølv i løpet av dei neste 12 mnd.?" har verdien "Ja".

☐ Racer
☐ Terrengsykkel
☐ Hybrid
☐ Bysykkel
☐ Transport-/lastesykkel
☐ Transport-/lastesykkel (el-sykkel)
☐ El-sykkel
☐ Anna

Vennligst spesifiser: [ ]
Skal bare besvares hvis du har krysset av for Anna

Nedanfor er ei liste med faktorar som kan motivere til sykling. Kor viktig er kvar av faktorane for din motivasjon til å sykle?

		1 Ikkje viktig i det heile teke	2	3	4 Veldig viktig
75 [Q39a]	Vedlikehalde/forbetre den fysiske formen	○	○	○	○
76 [Q39b]	For gleda/fornøyelsens skyld	○	○	○	○
77 [Q39c]	Avkopling/redusere stress	○	○	○	○
78 [Q39d]	Få tid til fysisk aktivitet i ein travel kvardag	○	○	○	○
79 [Q39e]	Være ute i frisk luft	○	○	○	○
80 [Q39f]	Ei positiv utfordring	○	○	○	○
81 [Q39g]	Ein aktivitet med låg miljø påverknad	○	○	○	○
82 [Q39h]	Tid for meg sjølv	○	○	○	○
83 [Q39i]	Bra for helsa	○	○	○	○
84 [Q39j]	Ein aktivitet eg kan gjere samen med andre	○	○	○	○
85 [Q39k]	Trafikal fridom/komfort	○	○	○	○
86 [Q39l]	Omtanke for miljøet	○	○	○	○
87 [Q39m]	Tru på eigne sykkelferdigheter	○	○	○	○
88 [Q39n]	Billeg transportform	○	○	○	○
89 [Q39o]	Sjå andre personer sykle	○	○	○	○
90 [Q39p]	Delta i kampanjar som «Sykle til jobben»	○	○	○	○
91 [Q39q]	Oppmuntring frå familie, vener og arbeidskollegaer	○	○	○	○
92 [Q39r]	Oppmuntring frå ledar eller arbeidsgjevar	○	○	○	○

Nedanfor er ei liste med faktorar som kan forhindre sykling. Kor mykje forhindrar desse faktorane din sykling?

		1 Forhindrar ikkje	2	3	4 Forhindrar i stor grad
93 [Q40a]	Føler meg utrygg i trafikken	○	○	○	○
94 [Q40b]	Aggressive bilistar	○	○	○	○
95 [Q40c]	Regn og vind	○	○	○	○
96 [Q40d]	Tidsnaud	○	○	○	○
97 [Q40e]	Manglande sykkelparkering på endestasjon	○	○	○	○
98 [Q40f]	Luftforureining	○	○	○	○
99 [Q40g]	Manglande fasilitetar som dusj/garderobe på endestasjon	○	○	○	○
100 [Q40h]	Vanskelig å ta med sykkelen inn på kollektiv transport som buss/tog	○	○	○	○
101 [Q40i]	Lite dagslys i vinterhalvåret	○	○	○	○
102 [Q40j]	Varmt vær	○	○	○	○
103 [Q40k]	For lang avstand til dei stadane eg ønsker å sykle til	○	○	○	○
104 [Q40l]	Kaldt vær	○	○	○	○
105 [Q40m]	For mange bakkar	○	○	○	○
106 [Q40n]	Manglar kunnskap om lokale sykkelruter	○	○	○	○
107 [Q40o]	For dyrt (sykkel, utstyr, kler)	○	○	○	○
108 [Q40p]	For dårlig form	○	○	○	○
109 [Q40q]	Manglande tru på egen evne til sykkelvedlikehald/reparasjonar (eks. slangeskift ved punktering)	○	○	○	○
110 [Q40r]	Manglande tru på sykkelferdighetene mine	○	○	○	○
111 [Q40s]	Manglande støtte frå familie/venner/kollegaer	○	○	○	○
112 [Q40t]	Manglande bagasjeplass	○	○	○	○

113 [Q43]

Brukar du sykkelhjelm?

- ○ Ja
- ○ Av og til
- ○ Nei

114 [Q44]

Har du i løpet av det siste året vore utsett for ei ulykke som syklist?

- ○ Ja
- ○ Nei

Spørsmåla under handlar om korleis du oppfattar helsa di. Desse opplysningane vil hjelpe oss å forstå korleis du føler deg og kor godt du er i stand til å utføre dine vanlege aktivitetar.

Stor sett, vil du si at helsa di er:

	Utmerka	Veldig god	God	Nokså god	Dårleg
115 [Q48]	○	○	○	○	○

116 [Q61]

Angi bevegelse og kroppsleg anstrenging i di fritid. Om aktiviteten varierer mykje f.eks. mellom sommar og vinter, så ta eit gjennomsnitt.

Spørsmåla gjeld berre det siste året (sett et kryss i den ruta som passar best)

- ○ Lese, ser på fjernsyn eller anna stillesittande aktivitet
- ○ Spaserar, syklar eller beveger deg på en anna måte minst 4 timar i veka? (Her skal du regne med gang eller sykling til arbeidsstaden, søndagstur mm)
- ○ Driver mosjonsidrett, tyngre hagearbeid e.l? (Merk at aktiviteten skal vere minst 4 timar i veka)
- ○ Trener hardt eller driv konkurranseidrett regelmessig og fleire gangar i veka

Overordna livskvalitet

117 [Q65]

Her er ein skala der 10 står for best mogleg livet for deg, og 0 det verst moglege livet for deg.

Generell sett kor synes du at du står på skalaen for tida?

- ○ 10 Best mogeleg liv
- ○ 9
- ○ 8
- ○ 7
- ○ 6
- ○ 5
- ○ 4
- ○ 3
- ○ 2
- ○ 1
- ○ 0 Verst mogeleg liv

118 [Q66]

Kva er di epostadresse?

Vennligst noter:

Tusen takk for hjelpa!

APPENDIX V

Data processor agreement NSD

Avtale om behandling av personopplysninger mellom Høgskulen på Vestlandet (behandlingsansvarlig) og NSD - Norsk senter for forskningsdata (databehandler)
(Jfr. personopplysningslovens §15.)

Prosjekttittel: **FACT**

Prosjektleder/daglig ansvarlig: Ane Kristiansen Solbraa

Surveynummer NSD: 287

1. I forbindelse med innsamling av forskningsdata i ovennevnte prosjekt skal databehandler behandle personopplysninger i henhold til kvittering fra Personvernombudet for forskning ved NSD (Jfr. personopplysningsloven §31 eller personopplysningsforskriften §7-27), fra tilsvarende institusjon eller fra Datatilsynet (Jfr. personopplysningsloven §33).
2. Databehandler kan bare behandle personopplysninger fra ovennevnte prosjekt i forhold til avtalt forskningsformål. Direkte identifiserende opplysninger som navn og epostadresser lagres i en database i kryptert form og brukes kun til elektronisk utsendelse av invitasjoner eller påminnelser i forbindelse med innsamling av data for prosjektet. Disse opplysningene slettes så snart det er avklart at det ikke vil bli sendt ut nye påminnelser, og senest ved utløp av avtalen.
3. Datamaterialet skal behandles i henhold til det som er spesifisert i kvittering fra personvernombudet eller i konsesjon fra Datatilsynet. Dersom personopplysninger skal oppbevares utover 31.12.2017, må behandlingsansvarlig forelegge godkjenning for dette fra personvernombudet eller fra Datatilsynet.
4. Databehandler er pliktig til å gjennomføre sikkerhetstiltak som følger av personopplysningslovens §13. Databehandler skal videre sørge for at dokumentasjon av informasjonssystemet og sikkerhetstiltakene er tilgjengelig for behandlingsansvarlig, Datatilsynet og Personvernnemnda.
5. Databehandler kan bare utlevere personopplysninger til andre enn behandlingsansvarlig etter særskilt avtale med behandlingsansvarlig og bare når det foreligger gyldig hjemmelsgrunnlag for slik utlevering samt tilrådning fra Personvernombudet for forskning ved NSD eller fra tilsvarende institusjon, eller konsesjon fra Datatilsynet.
6. Denne avtalen utløper 31.12.2017. Senest 14 dager tidligere (17.12.2017) slettes alle personopplysninger og innsamlede data fra NSDs databaser, og data overføres til behandlingsansvarlig. Data kan oppbevares offline hos NSD til avtalens utløp.
7. Data som overføres til behandlingsansvarlig skal ikke kunne kobles til personopplysningene som er brukt for å samle inn data med mindre det er eksplisitt avtalt og tillatelse foreligger.

Sogndal 21.03.2017 — Ane K. Solbraa
Sted/Dato
Ane Kristiansen Solbraa
Prosjektleder/daglig ansvarlig

Sogndal 20.03.2017 — Erik Kyrkjebø
Sted/Dato
Erik Kyrkjebø
Behandlingsansvarlig, med fullmakt til å undertegne på vegne av institusjonen

Bergen 21.3.2017
Sted/Dato
Bjørn Henrichsen
NSD (databehandler)

Solveig Nordengen // Bicycling in the right direction?