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Application of the systematic intervention mapping approach to conceptualize a school-based randomized controlled trial for the promotion of cycling to secondary school in Germany: the ACTS study

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LIST OF ABBREVIATIONS

ADAC	German Automobile Club
ADFC	German Cyclist's Club
e.g.	for example
i.e.	that is
n	number
n.p.	no page
p	*p*-value
p.	page
PICo	population, interest, context
UK	United Kingdom
USA	United States of America
v	version
vs.	versus

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1 BACKGROUND

Physical, psychosocial, and cognitive health in children and adolescents can be positively influenced by physical activity (1) and might directly, indirectly, or behaviorally persist into adulthood (2). Firstly, directly means that an active child is a healthy child and becomes a healthy adult. Conversely, indirectly means that an active child is a healthy child, becomes a healthy adolescent and a healthy adult. Finally, behaviorally means that an active child is a healthy child, becomes an active and healthy adolescent and an active and healthy adult. Based on the findings from Germany's report card on physical activity among children and adolescents in 2018, Germany received a D – in the category "overall physical activity" (3). Only the minority of children and adolescents up to 17 years of age in Germany met the World Health Organization recommendation of at least 60 minutes per day in moderate-to-vigorous physical activity across the week (4) between 2014 and 2017 (girls: 22.4%; boys: 29.4%) (5). From 2009 to 2017, a decrease of 3% in girls meeting the World Health Organization recommendation was observed in Germany (6). Consistent with previous research (7), patterns of physical activity are becoming unstable in the transition of both girls and boys from childhood to adolescence and beyond, whereby a decline of physical activity can be detected (5). Interestingly, the national recommendation for school-aged children and adolescents in Germany suggests at least 90 minutes per day in moderate-to-vigorous physical activity (8), which is even higher than the World Health Organization recommendation. Therefore, the low commitment to physical activity recommendations (5) and the lower tracking of physical activity in life changing phases (7) need to be counteracted. This is why researchers are increasingly concerned in finding evidence-based strategies to effectively promote physical activity in children and adolescents (9), possibly by active commuting to school (10).

The Institute of Medicine highly recommends active commuting to school as an additional opportunity to engage in physical activity (11). Based on the findings from Germany's report card on physical activity among children and adolescents in 2018, Germany received a C – in the category "active commuting to school" (3). One mode to actively commute to school is cycling. Previous research from England showed that 36% of 5- to 15-year-old cyclists, who actively commute to school, met the weekly physical activity recommendation in 2008, whereas this was only the case

in 25% of walkers and 22% of neither cyclists nor walkers (12). Therefore, physical activity can be promoted by increasing the rate of children and adolescents who cycle to school. Compared to other modes of active commuting to school, additional health-related benefits are expected when cycling to school. Cycling to school is positively associated with cardiorespiratory (13-15) and -vascular fitness (16) in children and adolescents, possibly because of a higher physical activity intensity (16) related to more solid health benefits (1). When living further away from school, cycling increases the mobility for active commuting in students (17, 18). Moreover, cycling to school might establish a potentially lifelong cycling habit to any other destination (12). Within five kilometers, bicycles are considered as the ideal and fastest mode of commuting, especially in congested traffic of cities (19).

In Germany, non-representative data suggests that every student attending grade 7 or 8 in secondary school is able to cycle (20, 21). Additionally, bicycle ownership is common in children and adolescents up to 17 years of age (22). Following these optimal conditions in Germany, cycling as mode of active commuting to school is cost-effective, attractive, and seems to provide equal basic requirements for all social classes. However, a nationwide representative study conducted in Germany showed that the bicycle is the least used mode of commuting to school in girls and boys overall (23). Following this, cycling to school in Germany appears to be an underused opportunity to engage in physical activity. From 2003 to 2017, the rate of cycling to school in 11- to 17-year-old girls (20.6% vs. 21.5%) was constantly below the rate of boys (23.8% vs. 25.2%) (23, 24). The reasons for this discrepancy remained as yet unknown. In addition to this gender difference, there is also a large regional difference in cycling to school between Northern (25) and Southern Germany (26), in population density of the residential region (i.e., small or medium-sized town, city) (24), and in educational level of the school attended (26). Consequently, the context where cycling to school takes place seems to influence the rate in Germany. According to the Standing Conference of the Ministers of Education and Cultural Affairs, mobility and traffic education should be taught at schools in Germany (27). However, they might not be able to fulfill this task adequately referring to the low rate of cycling to school. Therefore, a suitable cycling intervention for students at schools

in Germany, embedded in the conditions of a community setting, is warranted that considers their personal factors, social and physical environment (28).

This formed the basis of the rationale for the initiation of the European ACTS project to promote active commuting to school. Six research institutes from five countries (i.e., Germany, the Netherlands, Czech Republic, Poland, Portugal) collaborated, which provided individually different initial positions. At the Technical University of Munich, our research institute focused on the promotion of cycling to school in particular. Following this, the aim of this work was to use the intervention mapping approach to (a) conduct fundamental research help draw conclusions on how to positively influence the behavior of cycling to school needed in order to (b) conceptualize a school-based randomized controlled trial for the sustainable promotion of cycling to secondary school in Germany.

1.1 INTERVENTIONS IN THE FIELD OF STUDY

For interventions aimed at the promotion of physical activity and health, the school is regarded as an optimal setting (29-32). For example, in Germany, school attendance is compulsory until 18 years. Every student needs to commute daily to and from school in some way and spends approximately half of the waking time at school on weekdays. This is why all children and adolescents, regardless of their social background, can be easily reached when implementing an intervention. In terms of the social background, interventions should follow both a behavioral and situational approach to not further increase social inequalities (28).

The current state of research in this field of study shows that the development of interventions focusing on active commuting to school is in an early stage (33). Also, the long-term effectiveness of interventions remained unclear (33). In particular, there is a lack of interventions implemented in secondary schools (34) and targeting students who attend two levels from grade 7 upwards (35). Strong research designs providing a high evidence level, such as (randomized) controlled trials (36), are still rare (37) and have not been developed, implemented, or evaluated for cycling to school in Germany (35). The evidence for effectiveness of interventions focusing exclusively on cycling to school has not been provided until now due to weak quality (35), whereas the evidence for effectiveness of interventions focusing exclusively on

walking to school is already documented (38). This circumstance might be explained by the fact that more walking (*n*=25) than cycling to school interventions (*n*=12) have been conducted to date (39). Of those interventions focusing on cycling to school, only the minority was based on established theoretical frameworks (35).

1.2 THEORETICAL FRAMEWORKS

In general, theory-based interventions have a higher chance to change physical activity behavior effectively (9). The model of children's active travel (40) and the social-ecological model of the correlates of active transportation (41) are two theoretical frameworks, which explain influencing factors of active commuting.

1.2.1 Model of children's active travel

According to the model of children's active travel (see Figure 1), objective characteristics of the child, its parents, and family as well as objective characteristics of the physical, economic, and political-socio-cultural environment influence the perceptions of parents and its child (40). Objective characteristics of the child can be age (12, 20, 21, 23, 42, 43), gender (12, 20, 21, 24, 26, 42-44), bicycle ownership (20, 21, 45), ability to cycle (20, 21, 45), and school attended (20, 21, 26). Objective characteristics of parents can be age (20, 21), gender (20, 21, 46-48), bicycle ownership (20, 21), ability to cycle (20, 21), employment status (20, 21, 46-48) with number of working days per week (20, 21), mode and frequency of commuting to work (20, 21, 47-49). Regarding family characteristics, the size can play a role (40). Objective characteristics of the physical environment can mean population density (20, 21) and distance (18, 20, 21, 26, 45, 50). The economic environment can include costs (40). Teachers at school can be objective characteristics of the political-socio-cultural environment. However, the direction of influencing objective characteristics differs between countries, e.g., more children aged 9 to 12 than adolescents aged 13 to 17 cycle to school in Colombia (42), whereas the likelihood increases with age in Germany (i.e., from grade 5 to 12 (43); from ages 4 and 5 to 11 and 17 (23)).

The influence of these objective characteristics (e.g., gender) on perceptions of parents and its child affects attitudes (e.g., benefits or risks), the child (e.g., sense of responsibility, knowledge of road safety, cycling skills), and environment (e.g.,

favorable or unfavorable) (40). Previous research showed that the perceptions on barriers of active commuting to school differ between parents and children/adolescents and that parents identify more barriers (46).

Based on the interactions between objective characteristics and perceptions, parents decide on the child's mode of commuting to school and influence the final decision of the child to actively commute to school as outcome (40). The role and influence of the parents' decision in terms of allowance or restriction decrease with increasing autonomy, independence, and personal responsibility in the child's maturation process (40). Following the child's final decision, events occurring on the way to school (e.g., bullying) can lead to a change in habit or frequency of active commuting (45) in a feedback loop over time (40).

In conclusion, complementary and stimulating impulses of (gender-dependent) perceptions in the socialization process (51) of active commuting to school include three expert groups. The child is an expert on its own behavior (52). Parents and teachers are experts on the child's behavior considering its strengths, deficits, and stage of maturation due to their roles as educators/observers at home/school (53).

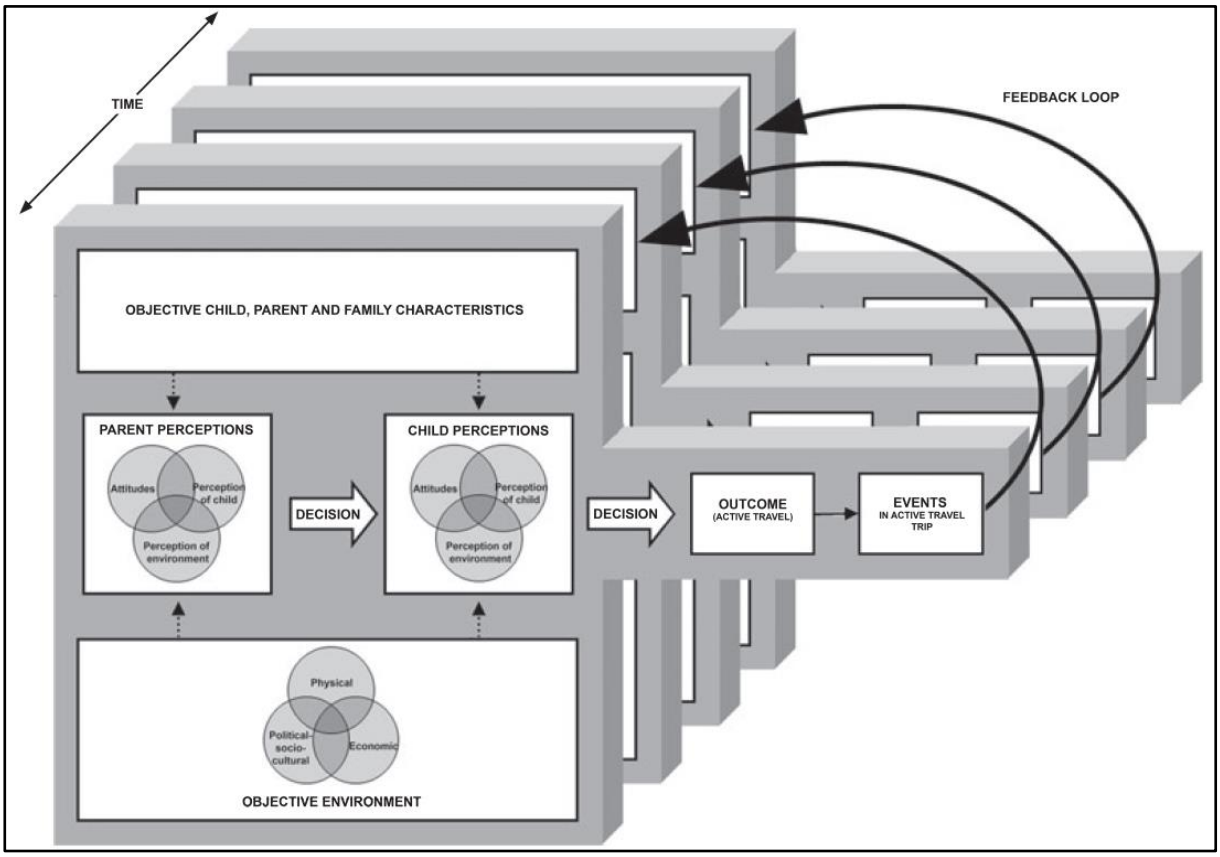

Figure 1. Model of children's active travel (40) (p. 140).

1.2.2 Social-ecological model of the correlates of active transportation

The social-ecological model of the correlates of active transportation (see Figure 2) shows the complex interaction of five influence levels considering the individual's characteristics and environmental characteristics (i.e., interpersonal, community, built environment, policy), in which the individual lives in (41). Similar characteristics as described in the previous chapter can be found in these levels. Individual characteristics include age, gender, and attitudes. Parents play a vital role in shaping the interpersonal environment. The community means for example the school and its policies. Part of the built environment is the infrastructure of the transportation system, which provides the opportunity to engage in active commuting to school. Policy could also relate to the school and its siting policies. Influences can occur both within and across these five levels, whereby proximal (i.e., individual) compared to more distal levels (i.e., policy) might have a stronger influence on the behavior of the individual but not on many individuals simultaneously over time. Interventions that consider these multiple levels are predicted to have a higher chance to change behavior effectively.

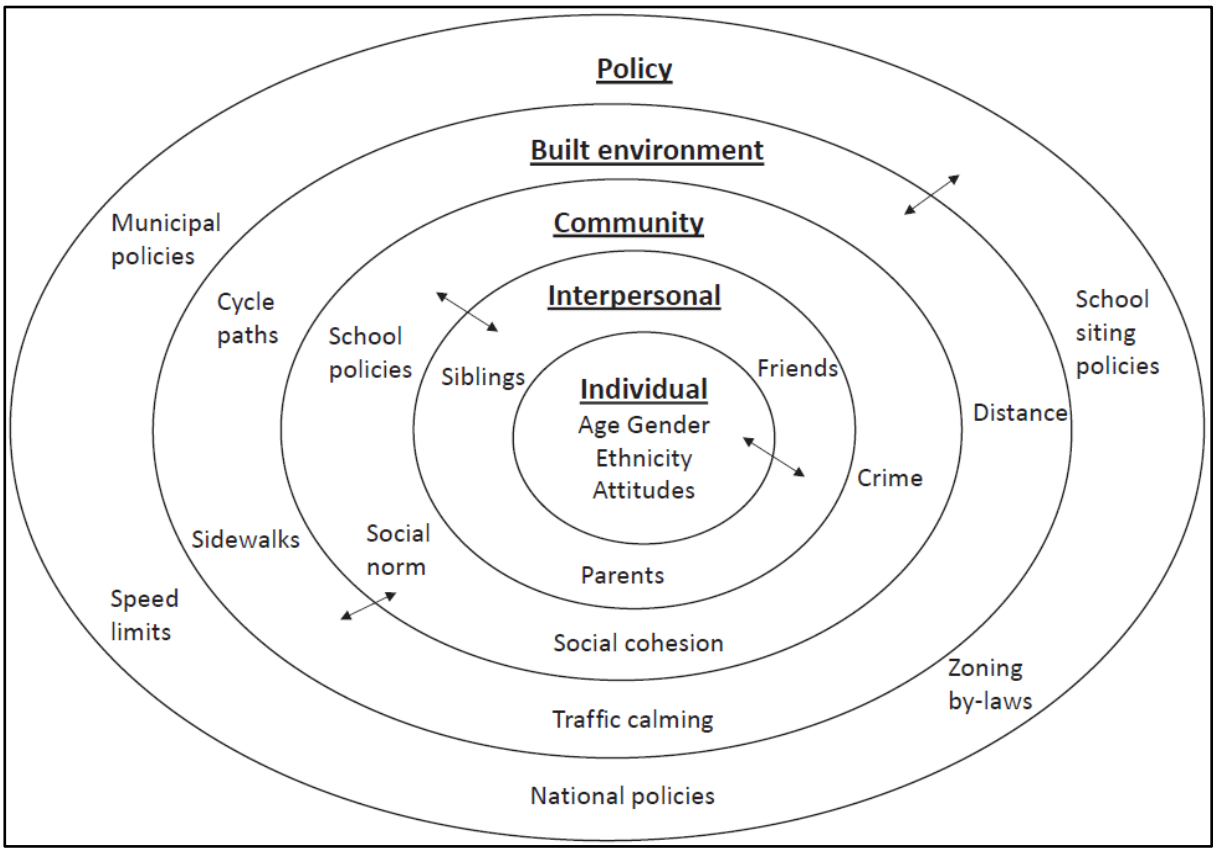

Figure 2. Social-ecological model of the correlates of active transportation (41) (p. 94).

1.3 INTERVENTION MAPPING

When developing an intervention, researchers might face the challenge of how to design a coherent program, which adequately matches the needs of the target group and the local conditions, based on diverse information sources, such as theoretical frameworks, existing literature, and collected data in the field (54). This is why a theory- and evidence-based systematic approach was developed: the intervention mapping protocol (see Figure 3).

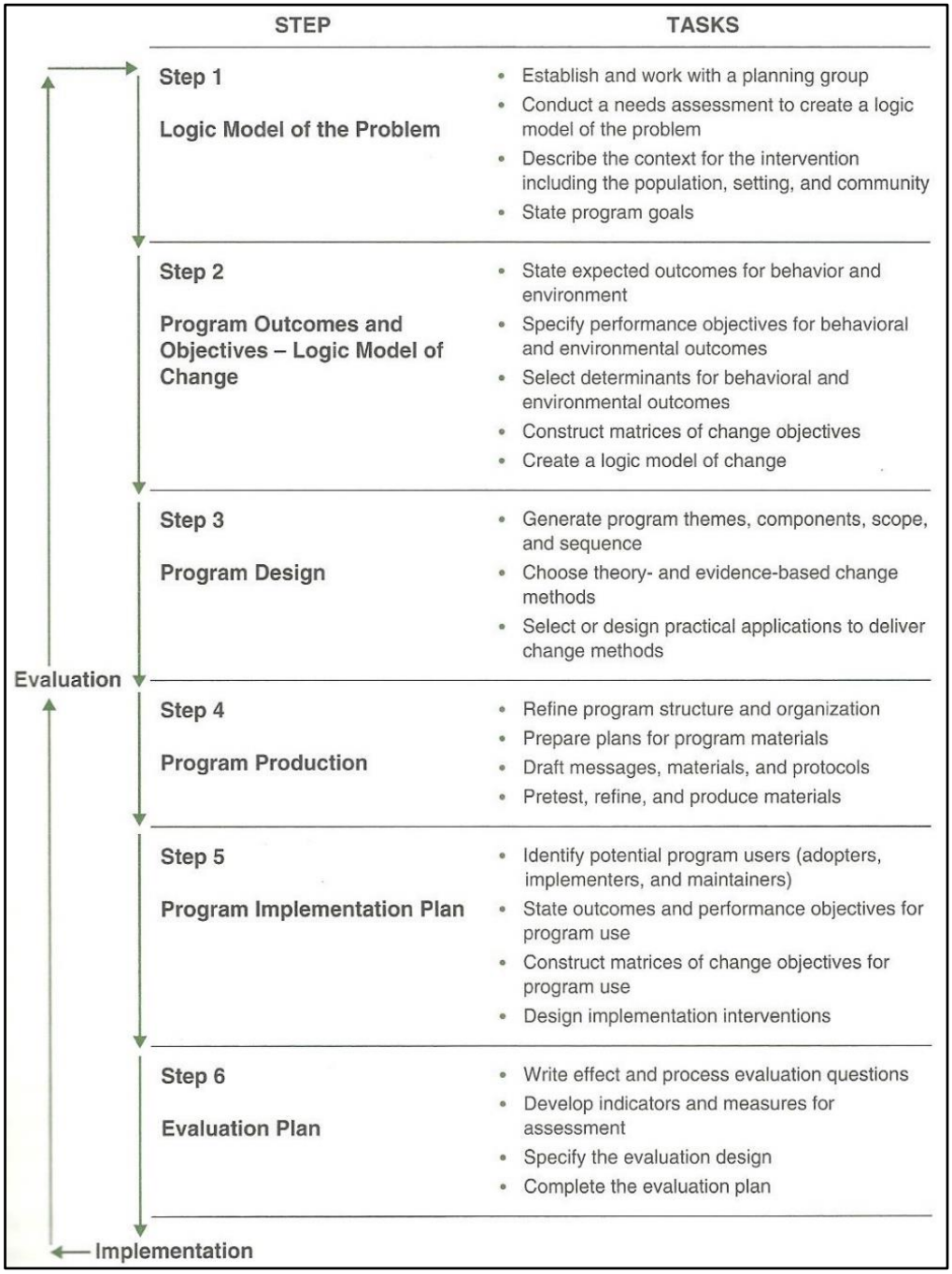

Figure 3. Steps and tasks listed in the intervention mapping protocol (54) (p. 13).

Intervention mapping defines six steps structured in several tasks needed to be considered when developing, implementing, and evaluating an intervention aimed at changing behavior: (a) logic model of the problem, (b) logic model of change, (c) program design, (d) program production, (e) implementation plan, and (f) evaluation plan. The approach consists of an iterative process, in which the completion of all tasks within one step leads to a new product to work on within the next step. In order to intervene at multiple levels, intervention mapping follows a social-ecological approach. Additionally, the protocol suggests to apply a participatory approach, which involves both the target group and relevant stakeholders (55). Thus, barriers can be identified and minimized by researchers in an early stage (54). Also, the output of a participatory approach is more transparent and may be more accepted by the target group, which could lead to a higher and long-term commitment.

1.3.1 Definition of terms

The first three steps of the intervention mapping approach include terms, which need to be defined for a clear understanding. In the first step, a needs assessment should be conducted to create a logic model of the problem (54). A needs assessment means “the collection and analysis of information that relates to the needs” (56) (p. 314) of the population to gain insights into actual and desired behavior as well as its facilitators and barriers. In the second step, matrices should be constructed that illustrate specified performance objectives, selected determinants causing a change in behavior, and change objectives (54). The term performance objectives means “observable and specific behaviors, which are judged necessary to meet the desired aim(s)” (57) (p. 3) of an intervention. Determinants are variables, which show a direct cause-and-effect relationship with another variable (41). Change objectives are the combination of both performance objectives and determinants (54). In the third step, theory- and evidence-based change methods matched to change objectives should be chosen in order to influence selected determinants. The “evidence for how change may occur” (p. 17) is provided by change methods (also techniques). Theory-based change methods are for example summarized in the behavior change technique taxonomy (v1), which includes 93 hierarchically clustered behavior change techniques (58). There is an indication in the literature that interventions using appropriate

behavior change methods may have a higher chance to change behavior effectively compared to interventions using theoretical frameworks only (59).

1.3.2 Needs assessment: Current state of research

To increase the number of children and adolescents who cycle to school, the discrepancy between their actual and desired behavior as well as perceived barriers hindering and facilitators supporting them in choosing this mode of commuting to school need to be assessed.

A literature search of existing literature on barriers and facilitators of active commuting to school showed that data on needs has not been collected separately by different modes, the local context of Germany has not been considered so far, no attention has been paid to teachers as relevant stakeholders, and previous research has rather focused on quantitative research methods (17, 46, 60-63). The identified publications in the literature search were cross-sectional studies from USA, New Zealand, Spain, Ireland, Australia, and Canada published between 2006 and 2018. Four out of these six studies included students as well as parents (46, 60, 61, 63) and three focused on elementary schools (46, 60, 63). Sample sizes in students ranged from 37 to 4013. If reported, age of students ranged from 5 to 6 years and 8 to 18 years. Sample sizes in parents ranged from 37 to 1296 if reported. As measuring instruments, focus groups (n=1) and surveys/questionnaires (n=5) were conducted. Additionally, one systematic review published in 2019 was found that summarized barriers of active commuting to school in parents (64). It included 27 studies from USA (n=18), Australia (n=4), Iran (n=2), Belgium, Canada, and the Netherlands (n=1, respectively) published between 2006 and 2016. Findings showed that perceived barriers in parents of children differ compared with parents of adolescents.

Previous studies have identified age (12, 23, 42, 43), gender (12, 24, 26, 42-44), migration background (24, 65), weight status (65-67), distance from home to school (18, 26, 50), residential area (24), socioeconomic status (23, 68), and child's (26)/parents' educational level (42) as socio-demographic correlates in cycling to school. These 13 studies were published between 2006 and 2020 and conducted in Germany (n=4), the UK (n=2), Colombia, Czech Republic, Denmark, Belgium, and Australia (n=1, respectively), Norway and the Netherlands (n=2). In Germany, age,

gender, migration background, distance from home to school, residential area, socioeconomic status, and child's educational level have been identified as socio-demographic correlates in children and adolescents.

1.4 STUDY AIMS

In summary, the conclusion of all the previous chapters are that a need for action is required to promote physical activity and health among children and adolescents. Therefore, the overarching aim of this work was to develop a school-based intervention for the sustainable promotion of active commuting to school by bicycle in Germany based on the intervention mapping approach (see Figure 4), which helps identify key components and ensures the highest chance of developing an effective intervention (55). As target population, age groups in the transitional phase from childhood to adolescence were chosen who are at high risk for potentially instable physical activity patterns with lower tracking (7), i.e., grades 7 (approximately 12 years) and 8 (approximately 13 years) at secondary school in Germany. Additionally, gender analyses were considered throughout the planning process.

Furthermore, based on conducting fundamental research for the logic model of the problem in step one (i.e., needs assessment) and for the program design in step three (i.e., identification of evidence-based change methods) of the intervention mapping approach, the current state of research on how to positively influence the behavior of cycling to school was expanded. To assess the needs, the target group (i.e., students) and relevant stakeholders (i.e., parents, teachers) were involved in a concept mapping approach in order to answer the following two research questions. (a) What do students need to cycle daily to school in Germany, perceived by students, parents, and teachers stratified by gender? (b) Which socio-demographic correlates based on a sample of students and parents influence cycling to school in Germany, is the influence positive or negative, and does gender play a role? To identify evidence-based change methods, the existing literature was systematically reviewed on effective school-based (randomized) controlled trials aimed at the promotion of cycling to school in children and/or adolescents. Based on the findings obtained after conducting this fundamental research for steps one and three of the intervention mapping approach, conclusions for the design of the intervention were drawn.

Following steps one to six of the intervention mapping approach, a school-based randomized controlled trial was developed, which provides a high evidence level (36) and combines a behavioral (i.e., personal factors) and situational (i.e., social and physical environment) approach.

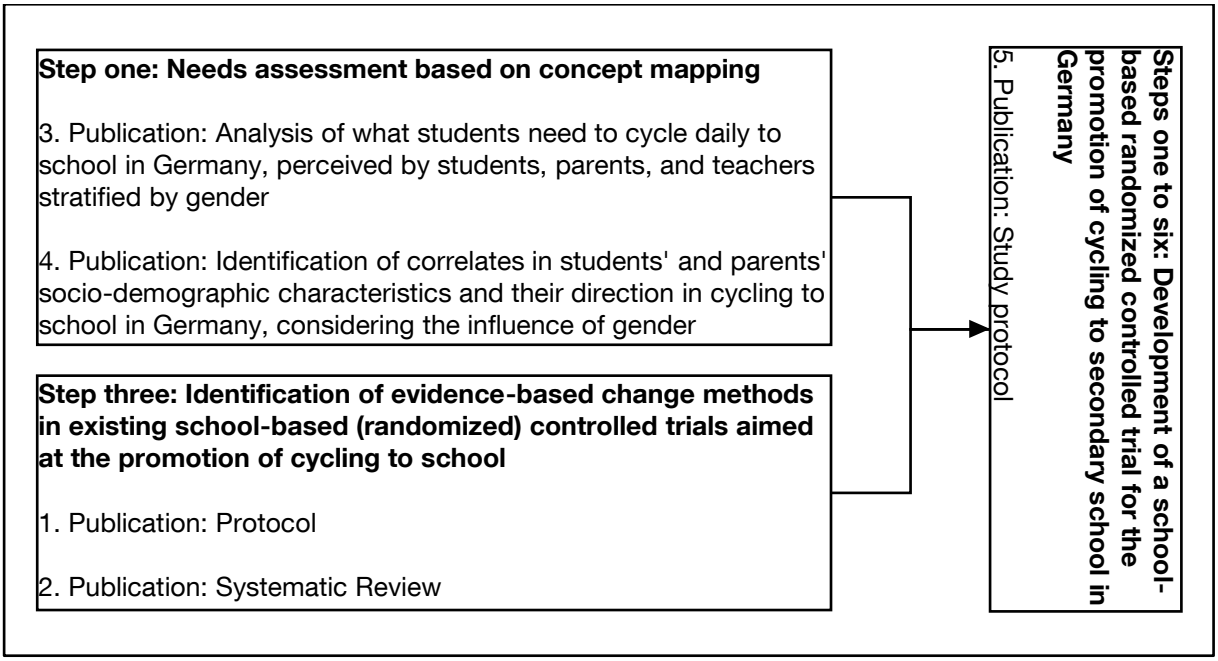

Figure 4. Overview of the process towards the intervention development using intervention mapping.

2 METHODS

This chapter describes the methods used in the five publications. Publication one described the methodological procedure of publication two, in which a qualitative method was used. Publications three and four used mixed-methods approaches. The findings of publications two, three, and four were used in publication five, which described the methodological procedure of how to develop an intervention.

2.1 PUBLICATIONS ONE AND TWO

Publication one is the protocol of the systematic review presented in publication two. Reasons for writing a protocol are the opportunity to receive feedback on the planned methodological procedure at an early stage, to prevent duplication and reporting bias by providing the possibility of comparison between the methodological procedure planned in the protocol and completed in the systematic review. In PROSPERO, the protocol for the systematic review has been registered

under the number CRD42019125192 and was updated according to discrepancies occurring later. To draft the protocol, the checklist Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols 2015 Statement (69) was followed and the checklist Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement (70) for the systematic review.

2.1.1 Literature search and study selection

The aim of the literature search was to identify effective school-based (randomized[1]) controlled trials conducted in primary and/or secondary schools, whose intervention components targeted the promotion of cycling to school in children and/or adolescents without specific health issues. The term school-based was defined as "everything that happens in or on the way to and from school" (p. 3), which does not necessarily involve school staff (e.g., teachers) (71). The control group could be either active, but without a treatment targeting the promotion of active commuting to school or physical activity and/or the reduction of sedentary behavior, or could be without any treatment. Analyses of intervention effects, i.e., a pretest-posttest comparison between intervention and control group, had to be presented.

A search strategy based on PICo (72) was developed, which stands for population, interest, and context, whereby the type of outcomes and its measures were not restricted to a predefined topic. The combination of search terms according to PICo had to be represented in the title or abstract of English publications from the years 2000 to 2019, for which a search was conducted in the electronic databases ERIC (EBSCO), PsycINFO (EBSCO), PSYNDEX (EBSCO), PubMed (NCBI), Scopus (ELSEVIER), SPORTDiscus (EBSCO), SURF (BISp), and Web of Science (Clarivate Analytics) on November 28th, 2018 (update: November 25th, 2019).

A number of 1919 publications identified in the eight electronic databases were imported into and further managed with EndNote X7.4, where 776 duplicates were removed in the first instance. Following this, two independent reviewers screened the identified 1143 publications for their relevance based on title, abstract, and full text as described in the eligibility criteria. Discrepancies during this study selection process were resolved by discussions between the two independent reviewers or by a third

[1] Randomization in terms of a cluster-randomized or parallel-group design.

independent reviewer contacted after a continued disagreement. Authors of relevant publications were contacted not more than two times via e-mail in case of unavailable full texts or missing/unclear information. In total, nine publications were identified as to be relevant for inclusion in the systematic review.

2.1.2 Data extraction and quality assessment

A spreadsheet listing all components and variables of interest (see Table 1) was prepared using Excel 2016. The spreadsheet was piloted by randomly selecting three included publications, which should ensure consistency and a systematic process during unblinded data extraction and quality assessment. Data extraction of each included publication also contained the evaluation of behavior change techniques (58). Variables, components, and global rating ranging from strong to moderate to weak was given in the quality assessment (73), which followed a common procedure (74) and was carried out at study level. The quality assessment was completed by using other related, more detailed publications (e.g., study protocol) when explicitly cited. Publications referring to the same intervention but analyzing and reporting different outcome variables were assessed independently. Discrepancies during data extraction were resolved by discussions between the two independent extractors and evaluators of behavior change techniques. The two independent quality assessors resolved discrepancies by discussions or consulted a third independent assessor in case of continued disagreement.

Table 1. Overview of the data extraction and quality assessment process.

Tasks	**Responsible Person**	**Components of Interest**	**Variables of Interest**
Data Extraction	Two independent data extractors	General study details	Author, country, year, design, aim
		Theoretical background	
		Characteristics of participants	Total/subgroup sample size(s), sample size determination, class level/age, stage of life, participant's recruitment/retention rate
		Intervention description	Name, components targeting active commuting to school, approach, task(s) of control group, duration, frequency, points of data collection
		Statistical analysis incl. confounder	
		Measuring instruments incl. outcome variables	
		Effects of intervention outcomes	

	Two independent evaluators	Behavior change techniques using the behavior change technique taxonomy (v1) (58)	93 hierarchically clustered techniques clustered in 16 main groups and two newly added strategies/groups (knowledge transfer and parental involvement (74))
Quality Assessment using the Effective Public Health Practice Project (73)	Two independent assessors	Selection bias	Representativeness of sample, percentage of recruitment rate
		Study design	(R)CT, randomization, method of randomization, appropriateness of randomization method
		Confounders	Group differences prior to intervention, potentially relevant confounders according to the model of children's active travel (40) (age, gender, previous active commuting to school experiences at baseline level, weight status, migration background, bicycle ownership, socioeconomic status, distance from home to school), quality rating of controlled confounders
		Blinding	Blinding of outcome assessor(s), blinding of participants
		Data collection methods	Validity of data collection tools, reliability of data collection tools
		Withdrawals/drop-outs	Report of drop-outs (numbers/reasons), percentage of retention rate
		Intervention integrity	Percentage of intervention delivery, measurement of intervention's consistency, contamination/co-intervention
		Analyses	Unit of allocation, unit of analysis, appropriateness of statistical methods, intention to treat

incl.=inclusive; (R)CT=(randomized) controlled trial

2.1.3 Data synthesis and analyses

A narrative synthesis was conducted. Intervention characteristics, behavior change techniques, and the quality of studies were described. Intervention effects were summarized by reporting effect sizes, e.g., Cohen's d, Odds Ratio, partial Eta-squared, and effect estimates, e.g., confidence intervals, or *p*-values ($p \leq 0.05$). Extracted data, the global and component-based quality assessment were illustrated in tables and figures. Due to the variety of outcome variables, they were grouped according to their main topic. The effectiveness in changing the outcome(s) was illustrated with symbols and abbreviations. A subgroup analysis was conducted for children (≤ 12 years) and adolescents (≥ 13 years) (75). Additionally, gender differences were considered in the analysis if mentioned.

2.2 PUBLICATIONS THREE AND FOUR

In both publications three and four, the concept mapping approach consisting of six steps (76) was used for a cross-sectional study in Germany. Contrary to methods used in previous research, concept mapping is based on mixed methods combining both quantitative as well as qualitative approaches (77, 78). As it is in line with the requirements of intervention mapping, the concept mapping approach was ideal for data collection regarding our purpose for the following reasons. Concept mapping can explicitly be used in its sixth step for planning (i.e., needs assessment) and evaluating (i.e., intervention development) further research (76). Additionally, concept mapping follows a participatory approach using group processes (77, 78) and considers the context of the intervention (i.e., population/stakeholders, school setting, community).

Publication three presented the output after completing the whole concept mapping approach analyzing needs to cycle to school perceived by students, parents, and teachers, whereas publication four presented data collected on socio-demographic characteristics of students and parents only.

2.2.1 Participants

As one part of the first step in the concept mapping approach, participants were defined (76). Southern Germany was chosen for recruiting participants as previous research among a representative local-restricted sample in Germany suggested a lower rate of students who cycle to school compared to the Northern region (25, 26). Additionally, the likelihood of cycling daily to school was lower when attending an intermediate compared to a high educational level (26). Previous research among a representative nationwide sample in Germany reported that living in a small town with 5,000 to 19,000 residents decreased (in girls) and a medium-sized town with 20,000 to 99,999 residents increased the likelihood of usually cycling to school compared to cities with more than 100,000 residents (24).

Subsequently, four secondary schools with an intermediate or a high educational level located in small or medium-sized towns (suburban school's region) and cities (urban school's region) in Southern Germany received an invitation letter in October 2019. Three schools with a total of 154 students (22 to 32 students per class)

located in a small town with 13,000 residents or medium-sized town with 21,000 residents (both intermediate educational level) or a city with 1.5 million residents (high educational level) agreed to participate in the concept mapping study. The cycling-friendliness in the small town seemed to be low due to missing bicycle lanes, whereas the medium-sized town and city received an (in)sufficient ranking in a study rating the cyclists' satisfaction in Germany (79). In each school, two classes of grade(s) 7 and/or 8 with students aged 12 to 15, their parents, and teachers were asked to participate in the study. Prior to its beginning, an information letter was sent to parents on behalf of their child and teachers. Signed consent forms of parents (for themselves and their child) and teachers were required prior to their participation. Anonymity and connection of each participant's data throughout the study were ensured by letting participants create a five-digit ID code.

Overall, 136 students, 58 parents, and 29 teachers participated in the study. The drop-out rate was 26.5% in students, 79.3% in parents, and 62.1% in teachers. Data from 134 students (girls: 51; boys: 83) were included in publication three and 121 students (girls: 49; boys: 72) in publication four. In both publications, students were aged 13.1±0.9. Data from 43 parents (mothers: 35; fathers: 8) were included in publication three and 42 parents (mothers: 34; fathers: 8) in publication four. In both publications, parents were aged 47.8±5.5. Data from 27 teachers (female teachers: 14; male teachers: 13) aged 39.4±10.9 were included in publication three.

2.2.2 Data collection

As another part of the first step in the concept mapping approach, the study's main questions were developed for each participating sample (i.e., students, parents, teachers) (76). In the second step, each participating sample answered their main question. Then, all unique answers obtained in the second step were rated on importance and feasibility by each participating sample and grouped into clusters according to similar contents in the third step. The detailed procedure of the concept mapping study for each participating sample is summarized in Table 2.

Table 2. Overview of the study's procedure of concept mapping.

Sessions		Students	Parents/Teachers
General Conditions	Where	At schools (face-to-face)	At home
	When	Two regular lessons (90 minutes)	Anytime
	Media	Printed or online	Online
	Supervisors	At least one trained researcher	No supervision but an information letter was sent prior to and a reminder during each session
Session 1	When	November/December 2019	
	Tasks	Questionnaire (printed or online via Survalyzer (80)): 1. Socio-demographic characteristics (e.g., gender)	Separate questionnaires for each sample (via Survalyzer): 1. Socio-demographic characteristics (e.g., gender)[2]
		2. Warm-up question (icebreaker): Why do or don't you cycle to school?	2. Warm-up question (icebreaker): Why does or doesn't your child cycle to school? (parents); Why do or don't your students cycle to school? (teachers)
		3. Main question: What do you need to cycle to and from school daily?	3. Main question: What does your child need to cycle to and from school daily? (parents); What do your students need to cycle to and from school daily? (teachers)
		4. Individual brainstorming phase: Each student listed as many answers as possible to the main question	4. Individual brainstorming phase: Each parent/teacher listed as many answers as possible to the main question
		5. Group brainstorming phase: Each student shared each answer to the main question one after another; answers were checked on clarity	N.a.
	Result	A final list of unique answers from each class	A list of answers from parents/teachers
	Post-processing	1. A single list of unique answers from all six classes was created and checked by a second researcher, whereby any discrepancies were resolved by discussions	1. An interim list of unique answers from parents/teachers was created and checked by a second researcher, whereby any discrepancies were resolved by discussions
		2. A final list of 98 unique answers were entered into the rating and clustering program Ariadne (81)	2. An interim list of 90/94 unique answers from parents/teachers were entered into Survalyzer and checked by a second researcher
		3. A personal link for each student was created to access Ariadne based on their individual ID code	N.a.

[2] In addition to parents' self-reported socio-demographic characteristics, they were asked proxy-report questions on their child's socio-demographic characteristics as data from students and their parents could not have been matched due to the separate data collection using two different questionnaires.

Session 2	When	January/February 2020	January 2020
	Tasks	1. Students rated each of the 98 answers on importance and feasibility using a five-point Likert scale ranging from very unimportant/unfeasible to very important/feasible (printed or online via Ariadne) 2. Students grouped each of the 98 answers into two to ten self-titled topic clusters with at least two answers in each cluster according to similar contents (printed or online via Ariadne) 3. Students named grouped clusters, whereby a miscellaneous pile was not allowed	Each parent/teacher checked unique answers on clarity in a list of parents/teachers and could add new answers to the main question if inspired by other answers
	Result	Concept maps	A final list of unique answers from parents/teachers
	Post-processing	The tasks of the printed version were entered into Ariadne	1. Answers from parents/teachers were revised and combined based on given comments if necessary; a final list of unique answers from parents/teachers was created and checked by a second researcher, whereby any discrepancies were resolved by discussions
			2. A final list of 90/94 unique answers from parents/teachers were entered into Ariadne
			3. A personal link for each parent/teacher was created to access Ariadne based on their individual ID code
Session 3	When	N.a.	February 2020
	Tasks		1. Parents/teachers rated each of the 90/94 answers on importance and feasibility using a five-point Likert scale ranging from very unimportant/unfeasible to very important/feasible (via Ariadne) 2. Parents/teachers grouped each of the 90/94 answers into two to ten self-titled topic clusters with at least two answers in each cluster according to similar contents (via Ariadne) 3. Parents/teachers named grouped clusters, whereby a miscellaneous pile was not allowed
	Result		Concept maps

e.g.= for example; n.a.=not applicable

2.2.3 Analyses

Different methods were used in publications three and four to analyze data collected in the concept mapping study.

2.2.3.1 Publication three: Mixed-methods analysis

The program IBM SPSS Statistics v25 (82) was used for two analyses. An intraclass correlation coefficient was calculated based on the within and between variance of days per week on which students cycled to the three sampled schools (83). Socio-demographic characteristics of each sample (i.e., students, parents, teachers) separated by gender (female vs. male) were described and analyzed in terms of gender differences using U- or Chi-squared tests ($p \leq 0.05$).

To be included in the analyses of perceived needs stratified by female and male gender, at least one of the three tasks conducted in the third step of the concept mapping approach (i.e., rating on importance, rating on feasibility, clustering) had to be completed by sampled participants. However, a stratified analysis in fathers was not permitted due to the small number of completed rating tasks (n=2) and clustering task (n=1). Two-dimensional concept maps for each sample stratified by gender were created and interpreted. Therefore, Ariadne was used in the fourth step of the concept mapping approach to conduct quantitative multivariate statistical analyses, i.e., a (hierarchical) cluster analysis and multidimensional scaling (76). These analyses resulted in concept maps for each sample stratified by gender. Each concept map represented the unique answers of each sample, which were obtained in step two and grouped into clusters in step three of the concept mapping approach, and arranged as dots. The frequency, with which each sample stratified by gender grouped their unique answers into clusters according to similar contents, was represented by the distance between dots (i.e., the more often, the closer; the rarer, the wider). In the fifth step of the concept mapping approach, two researchers interpreted the concept maps qualitatively (76). Therefore, a researcher defined an adequate number of relevant clusters for each concept map by looking at each created hierarchical cluster tree, illustrating all possible options of clusters, for each sample stratified by gender. Based on how each sample stratified by gender grouped their unique answers, each hierarchical cluster tree arranged them in one single cluster and suggested how to

further split it up. To ensure plausibility of answers in clusters if necessary, a researcher reallocated answers into newly (circles) or already created (arrows) clusters. A second researcher checked these decisions; any discrepancies were resolved by discussions. Finally, clusters were named according to their contents. For this purpose, suggestions of each sample stratified by gender were used. Mean cluster ratings on importance and feasibility based on the mean individual rating of all answers in each cluster of a concept map were calculated and descriptively reported for each sample stratified by gender. Differences in mean cluster ratings could not be statistically analyzed due to an inadequate provision of raw data in Ariadne.

2.2.3.2 Publication four: Quantitative analysis

The program IBM SPSS Statistics v25 was used for analyses. To be included in the analyses, participants of each sample (i.e., students, parents) needed to complete data collection on socio-demographic characteristics and report their gender as female or male. Separate binary logistic regressions were used to identify associations between independent and dependent variables in each sample (see Table 3), whereby the predicted probability was of not cycling to school sometimes and the reference group was of the low-risk group based on the current state of research. Additionally, separate binary logistic regressions were used to identify gender-specific associations between these variables in girls, boys, and mothers. A separate gender analysis in fathers was not permitted due to the small number of participants (n=8). For these statistical analyses, a sample size of at least 50 participants overall is required (84). Findings were reported by effect size (Odds Ratio), effect estimates (confidence intervals for Odds Ratio), and p-values ($p \leq 0.05$).

Table 3. Overview of the statistical design.

Samples		**Variables**		
		Independent		**Dependent**
Students	Self-reported	Age, gender, educational level/school's region, number of residents, distance from home to school		Habits of cycling to school
Parents	Self-reported	Age, gender, employment status, number of working days per week, habit/frequency/distance of cycling to work	⇨	Child's habit of cycling to school
	Proxy-reported for child	Age, gender, educational level/school's region, number of residents, distance from home to school		

2.3 PUBLICATION FIVE

In publication five, the systematic application of the six intervention mapping steps to develop a school-based randomized controlled trial for the sustainable promotion of cycling to secondary school in Germany was described. The six research institutes from the five countries, which were part of our European ACTS project, established a planning group to work on the intervention development. Findings of analyzed concept mapping data were used as needs assessment in step one of the intervention mapping approach. In step two, an integrated theoretical framework (85) combining the social-ecological model (of the correlates of active transportation (41)) with basic psychological needs (i.e., autonomy, competence, relatedness), a sub-theory of the self-determination theory (86), was selected. An evidence-based changed method identified in existing literature and the behavior change technique taxonomy (v1) (58) as theory-based change method were used in step three. The intervention was produced in step four. A plan for the implementation was drafted in step five and for the evaluation in step six.

2.3.1 Participants

The intervention should target the same population as described for publications three and four (see chapter 2.2.1), i.e., 12- to 15-year-old students attending grade 7 or 8 in secondary schools with intermediate or high educational level located in suburban regions (small and medium-sized town) or urban region (city) in Southern Germany. Secondary schools should be searched by sending random invitation letters. In each school, two classes from grade(s) 7 and/or 8 should be recruited. For the pilot study, three schools including approximately 150 students should be in the intervention group and two schools including 100 students in the control group. For the main study, five schools including approximately 255 students should be in the intervention and control group, respectively.

2.3.2 Measuring instruments

The developed intervention should lead to more days on which students cycle to school (primary outcome) and therewith to a higher amount of moderate-to-vigorous physical activity (secondary outcome). Based on these formulated aims,

appropriate measuring instruments for an effect and process evaluation were selected. For the effect evaluation, two valid self-report questions were chosen asking retrospectively for mode, frequency, and duration of active commuting to school and representing the primary outcome (87). The secondary outcome, total moderate-to-vigorous physical activity, should be assessed using accelerometers (ActiGraph wGT3X-BT). As potential moderators, certain socio-demographic characteristics (20, 40, 88, 89) using self-report questions and weather conditions (90) should be collected. Two newly developed self-report questionnaires asking for regulatory styles of motivation types and satisfaction of the three basic psychological needs in cycling to school as well as basic cycling skills assessed by a reliable practical cycling skills exam off-road (91) could be potential mediators. For the process evaluation, structured interviews among students, parents, art and physical education teachers and documentations in written form among art and physical education teachers should give information about (dis)satisfaction with and implementation dimension of the developed intervention. All data should be collected by a researcher and student assistants from the Technical University of Munich during two regular physical education lessons taking 90 minutes and by using ID codes as described in publications three and four (see chapter 2.2.1).

2.3.3 Study design

The intervention was designed as a two-arm (intervention/control group) three-level cluster (students in classes in schools) randomized controlled trial (see Figure 5), with a simple randomization method on school-level, whereby no treatment delivery of the control group was intended. For convenience, a non-randomized controlled trial (i.e., a quasi-experimental study design) was chosen for the planned pilot study. A sample size of 231 students is needed per intervention arm for the main study and 10% (92, 93) of this for the pilot study (i.e., 23 students per arm) to have sufficient power to detect intervention effects (94). The pre and post data assessments of the effect evaluation planned in fall and spring considered the structure of school terms in Germany (first term: fall to spring; second term: spring to summer) and seasonal influences on cycling to school observed between fall (52%), winter (3%), and spring (51%) (95) as well as between winter (12%) and summer (22%) (96). During and at the

end of the intervention, the process evaluation should be placed. As cycling to school rates decrease in Germany in winter (43), the implementation of the five-month intervention was planned for this particular season during the first term of the school year.

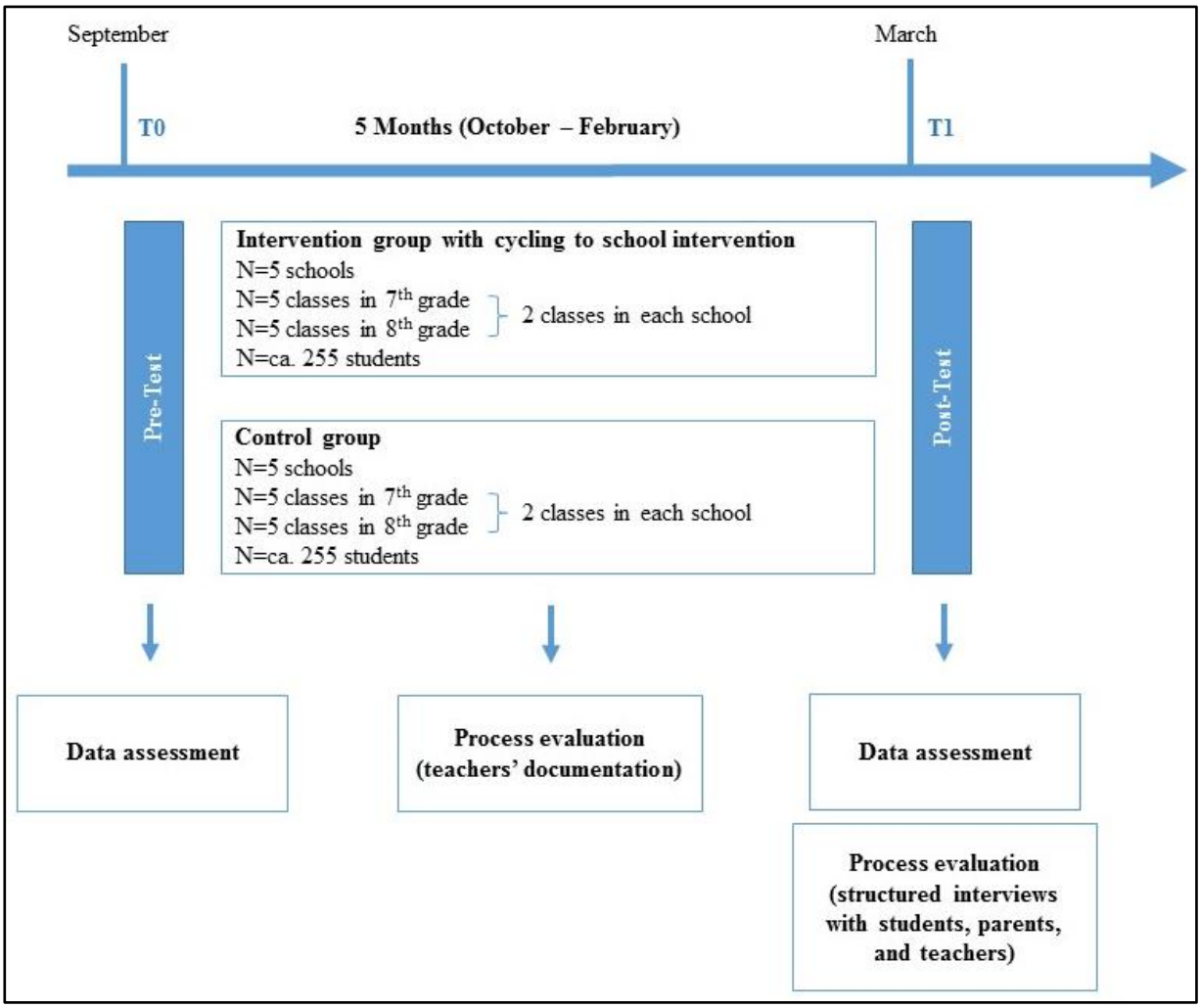

Figure 5. Study design (57) (n.p.).

2.3.4 Intervention components and implementation

For a successful promotion of cycling to school, it was hypothesized in the created logic model of change that complementary and stimulating impulses of changes in both the social (i.e., parents, teachers, peers, school and its policies, social norms) and physical environment (e.g., equipment, distance from home to school) influence the satisfaction of basis psychological needs in students. This in turn was hypothesized to lead to a more self-determined form of motivation towards cycling to school, which it promotes and therewith physical activity. Following these

assumptions, both a situational approach (i.e., changes in the social and physical environment) and behavioral approach (i.e., changes in motivation as a personal factor) were considered. The intervention was based on 27 behavior change techniques[3]. In the first instance, a preparation phase should be implemented: (a) a joint parents', teachers', and students' evening, (b) a bicycle inspection including provision and personalization of required bicycle-related equipment, (c) three cycle training sessions off-road to improve basic cycling skills, (d) theoretical knowledge about traffic rules, (e) one cycle training session on-road to practice social behavior in road traffic, and (f) a final exam with a certification of basic cycling skills. Afterwards, a practice phase should take place: (g) a voluntary bicycle train to cycle to school with peers using arranged routes and stops including three events (e.g., kick-off).

The implementation of components should be conducted one after another during five months by following a whole-of-school approach with components taking place before, during (i.e., in art and physical education lesson), and after school. For the coordination of the intervention implementation, a person of contact should be defined at each school. This person should also help exchange information by phone or e-mail between physical education and art teachers as implementers at their school and the researcher as well as manager at the Technical University of Munich. A researcher and student assistants from the Technical University of Munich and external collaborators (i.e., ADFC, ADAC, police) free of charge should also be involved in the intervention implementation. All materials and contacts of collaborators should be provided to schools in order to be able to replicate the intervention and ensure sustainability. Intervention's approval should be obtained by the Ethics Commission from the Technical University of Munich and the Bavarian State Ministry for Education and Cultural Affairs prior to the implementation. Also, the provision of signed consent forms from parents on behalf of their child should be required before participation.

2.3.5 Analyses

A structural equation modeling using *R* to conduct a multiple group analysis considering both intervention arms (i.e., intervention/control group) should analyze the

[3] As proposed in the taxonomy (v1) (58) and supplemented by findings of publication two (35).

effectiveness of the developed intervention. This analysis was found to be appropriate due to the determined variances in cycling to school rates between and within the three schools as stated in publication three. Therefore, the following four levels should be considered in the analysis: “(a) repeated measurements for each student, (b) students, in which the repeated measurements are nested, (c) the class, of which each student belongs to, and (d) the school, in which classes are nested” (57) (p. 7). In levels (b) to (d), cycling to school should be regressed onto potential mediators and potential moderators should be added to the model. Additionally, a gender analysis should be conducted.

3 DISCUSSION

The aim of this work was to generate a foundation for school-based interventions to sustainably promote cycling to secondary school in Germany. Therefore, knowledge was acquired on gender-specific needs of cycling to school in Germany, perceived by the target group and relevant stakeholders. Additionally, effective intervention strategies in the school setting were searched, which promote children’s and adolescents’ cycling to school behavior. The findings of this fundamental research were incorporated in the production of a theory- and evidence-based intervention, which should promote physical activity based on increased rates of cycling to secondary school among children and adolescents in Germany. This new routine of cycling to school is expected to lead to a potentially lifelong cycling habit to any other destination (e.g., university, work, friends) (12) and health throughout the span of life (2).

3.1 STRENGTHS

Overall, this work is of importance for the society in line with the 2030 agenda for sustainable development proposed by the United Nations (97), which highlights the role of transport and mobility as central components in climate action for improving air quality by reducing traffic and therewith air pollution as well as greenhouse gas emissions (98). Simultaneously, the reduction of traffic minimizes noise and increases safety on roads due to less congestion (98). In the physical activity strategy for the World Health Organization European region 2016-2025,

economic benefits (e.g., new jobs) are expected to be established “if the level of cycling could be increased to that of Copenhagen, Denmark” (98) (p. 3). Additionally, this work is in line with the proposed action to create active environments in the global action plan on physical activity 2018-2030 by the World Health Organization, according to which a focus is on implementing interventions that promote cycling to school (99). This work closes the research gap by focusing on cycling as uncommon mode of active commuting to school in Germany (23). Also, this work supports schools in Germany, which are responsible for teaching mobility and traffic education as defined by the Standing Conference of the Ministers of Education and Cultural Affairs (27). This is in line with the physical activity strategy for the World Health Organization European region 2016-2025, according to which schools should receive “assistance, adequate resources and the necessary training” (98) (p. 12) when promoting the participation of their students in physical activity.

To the best of knowledge, the systematic review was the first that exclusively focused on the effectiveness of strategies to promote cycling to school. In order to adequately make policy decisions in this field of study, the evidence of effectiveness is required (9). The decision on using two independent reviewers, extractors, assessors, and evaluators to objectify the structured process of study selection, data extraction, quality assessment, and behavior change techniques identification is a strength. Besides, this procedure represents the attempt to prevent incorrect decisions. Also, it is an advantage to contact authors of relevant publications in case of unavailable full texts or missing/unclear information in order to counteract an underestimation of the methodological quality. Additionally, the illustration of both global and component-based quality ratings of included publications in the systematic review give insights into weak points of individual variables summarized in components, which are the basis of the global quality rating.

The mixed-methods procedure of the concept mapping approach is favorable as the mentioned needs of participants had been expressed entirely in their own language and remained as such (76). As the amount of answers was not previously restricted, this procedure provides a rich understanding of perceived needs in students, parents, and teachers. Accordingly, their mentioned needs can help policy-makers and city planners change transport planning. Notably, this was the first study

to our knowledge conducted in Germany, examining needs of students to cycle daily to school in particular, and considering teachers' perspective. As role models, teachers need to put into practice what they demand from students (32). The analyses of variables used in the first concept mapping session, which were expected to influence habits of cycling to school, expands the current state of research. Referring to this, the influence of educational level and distance from home to school on cycling to school were only examined in one representative study conducted among children and adolescents from one city in Germany (26). Instead of using the distance of crow flies, it was decided to objectively quantify the shortest distance by using Google Maps in the first concept mapping session as this corresponds to the actual practice (88). Similarly, neither parents' socio-demographic characteristics nor population density in the school's region were previously examined in Germany.

To the best of knowledge, this work was the first that used the detailed intervention mapping approach in this field of study, possibly due to its time-consuming and complex nature (100-102), in order to obtain the best possible intervention in terms of having the highest chance of being effective (55). Based on experiences gathered in previous steps of the intervention mapping protocol, findings could be reused throughout the planning process. For example, the finding of publication two that interventions targeting students attending two levels from grade 7 upwards are lacking (35) influenced the decision to select students attending grades 7 or 8 in publications three, four, and five. Simultaneously, students in grades 7 (approximately 12 years) and 8 (approximately 13 years) in Germany are in the transitional phase from childhood to adolescence with unstable behavior patterns with lower tracking (7) that need to be stabilized. Additionally, it is a strength that modifications from one of our conducted study to another could be incorporated in the planning process. For example, socioeconomic status and roadworthiness of bicycles should be collected in the intervention. Therefore, this work establishes a basis for further research. To accurately measure the physical activity level while cycling, a combination of objective and subjective measuring instruments was chosen following a recommendation in previous research (103). There are several beneficial reasons for the chosen study design of the developed intervention: (a) randomized controlled trials provide a high evidence level (36), (b) randomized controlled trials are

lacking in this field of study (35), (c) the developed intervention will be the first randomized controlled trial in this field of study conducted in Germany (35), (d) variances in cycling to school rates were considered (21), (e) sample size calculation was conducted (35), and (f) seasonal influences were considered (43, 95, 96). Overall, four out of five influence levels of the social-ecological model were represented in developed intervention components (i.e., individual, interpersonal, community, built environment). The innovative multilevel approach involving the target group and relevant stakeholders from the beginning of the intervention development ensures the feasibility and usefulness of the implementation. A minimization of unfavorable practical implications was considered as it is not possible to implement an intervention at school, which is a time-consuming burden (29) and costly in terms of material resources, and unsafe to let students cycle to school without practicing appropriate behaviors in road traffic previously. The intervention's sustainability is ensured by providing user-friendly materials and contacts of involved collaborators to schools. A whole-of-school approach was chosen for the implementation in line with a previous recommendation (11). Finally, the planned analyses consider potential moderators and mediators as recommended in previous research (104) and a process evaluation to ensure that the intervention meets local needs at schools. Additionally, it was planned to pilot the elaborated intervention in order to provide evidence that the intervention effectively increases cycling to school rates.

The decisions to publish a systematic review protocol and a study protocol describing the detailed methodological process of how conducting a systematic review and developing an intervention are strengths as this demonstrates transparency for other researchers. Overall, it is a strength that gender analyses were considered in each of the five publications described in this work in order to obtain a gender-sensitive intervention.

3.2 LIMITATIONS

The decisions on restricting inclusion criteria in the systematic review to (randomized) controlled trials published in English are a limitation as this could have led to a selection bias (37). Due to the heterogeneity of outcome variables in the

included publications in the systematic review, a meta-analysis could not be conducted.

Overall, the recruited samples of students, parents, and teachers in the concept mapping approach could not be considered as representative. Therefore, findings should be interpreted with caution. High drop-out rates in teachers and parents were problematic who participated in an online version of the concept mapping approach at home. In parents, the sample size did not meet the recommended minimum of 50 participants for a binary logistic regression (84). Especially fathers hesitated to participate, possibly due to a different perceived parenting responsibility, and needed to be excluded from the gender analyses. Low father involvement is in line with previous research reporting that fathers are clearly underrepresented in research (105). Further limitations are that needs were not collected separately for cycling to and from school (46) and that we used stratified analyses instead of collecting data in genders separately. Using a five-point Likert scale might have caused a central tendency bias in the ratings of importance and feasibility. Technical failures of the online programs used (i.e., Survalyzer, Ariadne) might have negatively affected the analyses due to the exclusion of incomplete data sets. Data on socioeconomic status (23, 68), migration background (24, 65), residential area (24), weight status (65-67), and educational level of parents (42) was not collected. As there was no variance between educational level and school's region (i.e., urban school with high educational level, suburban schools with intermediate educational level), it remains unclear whether both or only one of these factors influenced habits of cycling to school. Additionally, the cross-sectional study design provides information about correlates of cycling to school only, which do not allow to draw conclusions on causality between analyzed variables in contrast to determinants (41).

A major limitation of this work is that the developed intervention was not implemented and evaluated in order to prove its effectiveness and process quality. Despite a lack of long-term interventions, interventions targeting adolescents only, and interventions proving sustainability (35), the planned treatment is a moderate-term intervention targeting children and adolescents without planning to examine its sustainability in a follow-up measurement. The promising intervention strategy identified in the systematic review and used in the study protocol was based on a

study, whose quality was rated as weak. However, this strategy identified as promising, a bicycle train, has also been suggested in the physical activity strategy for the World Health Organization European region 2016-2025 (98). One need concerning storage and changing room was not considered in the planning process of the intervention.

Finally, publications three, four, and five are characterized by a selective sample from Southern Germany as we did not consider a low educational level, rural school's region, and diverse gender as a third category. However, this work was concerned with fundamental research and was not aimed at the consideration of every possibly relevant characteristic of the target group.

3.3 RECOMMENDATIONS

When comparing the rate of cycling to school in students aged 11 to 15 from Azerbaijan, Czech Republic, Denmark, Germany, Ireland, Norway, Poland, Scotland, and Wales, Germany was ranked with the second highest rate after Denmark ranked first and before Norway ranked third (106). The total average mean of cycling to school across these nine countries (7.3%) suggests that the promotion of cycling to school should be a priority across all of them, not just in Germany.

When using the concept mapping approach for a needs assessment, face-to-face sessions at schools using online versions should be conducted. Additionally, an even-point scale in ratings should be used to avoid a central tendency bias. Generally, more attention should be directed to the identification of determinants related to cycling to school by using longitudinal and/or experimental studies.

Overall, it is highly recommended to implementing the developed intervention and to evaluating its effectiveness and process quality. Because generally, the development, implementation, and evaluation of effective intervention strategies in this field of study is warranted to understand the mechanisms of promoting cycling to as well as from school and to provide evidence for effectiveness. In particular, gender-sensitive interventions meeting the needs of both girls and boys are required. For a structured planning process, researchers should follow a theory- and evidence-based methodological procedure. Future studies involving diverse gender as a third category, rural school's region, and low educational level are necessary. When

deciding on an age group, interventions aimed at adolescents are needed. More research is warranted in parents‘ socio-demographic characteristics (e.g., educational level). Studies are missing that effectively involve parents, especially fathers, as well as teachers in research. Concerning father involvement, innovative strategies need to be applied to increase the recruitment rate of fathers (107). Associations between cycling to school behavior of students and teachers should be examined as there was an indication of similar gender-specific patterns of behavior in both samples[4], possibly due to the influence of teachers as role models. Researchers should measure moderate-to-vigorous physical activity by combining objective with subjective instruments. To be able to conduct a meta-analysis, the heterogeneity of outcome variables should be reduced. The quality of publications reporting interventions needs to be improved by using (randomized) controlled trials. Sample size determination should be common. When developing an intervention, the variance of cycling to school rates and seasonal influences should be considered. Also, further research should be aimed at establishing nationwide, long-term interventions. Sustainability of interventions should be more clearly demonstrated using follow-up measurement. A whole-of-school approach is recommended. More research examining characteristics of the social environment (e.g., social norms) (85, 108) and considering the policy level is essential. Analyses should consider moderators, mediators, gender as well as a process evaluation.

From a more global perspective, cycling to school is only one possibility to promote physical activity related to the school setting. It is highly recommended to considering the whole school environment (e.g., activities in physical education, recess, and the classroom) in a multicomponent intervention for a more comprehensive treatment (109).

In summary, the full potential in this field of study should be tapped through further research, for which this work provides a firm foundation.

[4] 44.4% of girls sometimes cycled to school on 1.6±2.0 days per week and 46.2% of female teachers on 1.6±2.1 days per week (21). 72.9% of boys sometimes cycled to school on 2.7±2.0 days per week and 76.9% of male teachers on 2.8±2.2 days per week.

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APPENDIX

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LIST OF PUBLICATIONS

Schönbach DMI, Chillón P, Marques A, Peralta M, Demetriou Y. A school-based randomized controlled trial to promote cycling to school among students in Germany using the intervention mapping protocol: the ACTS study. Front Public Health. Submitted 30 Jan 2021.

Schönbach DMI, Brindley C, Reimers AK, Marques A, Demetriou Y. Socio-demographic correlates of cycling to school among 12- to 15-year olds in Southern Germany. Int J Environ Res Public Health. 2020; doi:10.3390/ijerph17249269.

Schönbach DMI, Altenburg TM, Marques A, Chinapaw MJM, Demetriou Y. Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents: a systematic review. Int J Behav Nutr Phys Act. 2020; doi:10.1186/s12966-020-01035-1.

Schönbach DMI, Vondung C, Hidding LM, Altenburg TM, Chinapaw MJM, Demetriou Y. Gender influence on students, parents, and teachers' perceptions of what children and adolescents in Germany need to cycle to school: a concept mapping study. Int J Environ Res Public Health. 2020; doi:10.3390/ijerph17186872.

Marques A, Henriques-Neto D, Peralta M, Martins J, Demetriou Y, **Schönbach** DMI, et al. Prevalence of physical activity among adolescents from 105 low, middle, and high-income countries. Int J Environ Res Public Health. 2020; doi:10.3390/ijerph17093145.

Schönbach DMI, Altenburg TM, Chinapaw MJM, Marques A, Demetriou Y. Strategies and effects of promising school-based interventions to promote active school transportation by bicycle among children and adolescents: protocol for a systematic review. Syst Rev. 2019; doi:10.1186/s13643-019-1216-0.

SUMMARY OF PUBLICATIONS

PUBLICATION ONE

Title: Strategies and effects of promising school-based interventions to promote active school transportation by bicycle among children and adolescents: protocol for a systematic review

Authors: Dorothea M I Schönbach, Teatske M Altenburg, Mai J M Chinapaw, Adilson Marques, Yolanda Demetriou

Publication date: 29 Nov 2019

Summary:
Cycling is a less common mode of active commuting to school even though it can contribute to promoting physical activity, expanding the mobility in leisure time, and establishing a lifelong active travel routine. To counteract the observed declining trend of cycling to school in some European countries, effective school-based intervention strategies aimed at the promotion of cycling to school need to be identified. In the eight electronic databases ERIC, PsycINFO, PSYNDEX, PubMed, Scopus, SPORTDiscus, SURF, and Web of Science, a literature search using a detailed search strategy based on PICo should be conducted. Outcomes should not be restricted to a predefined topic. Only (randomized) controlled trials published in English between 2000 and 2019 should be included in the planned systematic review. The study selection process, data extraction, assessment of study quality using the Effective Public Health Practice Project, and evaluation of behavior change techniques using the taxonomy (v1) should be conducted by two independent researchers. A meta-analysis quantifying intervention effects should be conducted if data permits. The planned systematic review should give insights into how cycling to school can be promoted in school-based interventions and provide evidence for the effectiveness of intervention strategies. Based on the findings of the planned systematic review, researchers could use promising strategies to develop a school-based intervention that promotes cycling to school. The planned systematic review has been registered in PROSPERO.

Individual contribution: DMIS conceptualized the methodological procedure of the planned systematic review described in the protocol including the development and pretest of the search strategy as well as the definition of the inclusion criteria. She conducted the literature search and was the first reviewer in the study selection process. The manuscript including visualizations was drafted by her. She was the corresponding author and responsible for the progress through the review process by suggesting revisions.

PUBLICATION TWO

Title: Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents: a systematic review

Authors: Dorothea M I Schönbach, Teatske M Altenburg, Adilson Marques, Mai J M Chinapaw, Yolanda Demetriou

Publication date: 12 Nov 2020

Summary:
Cycling to school can contribute to establishing a lifelong routine of physical activity. In this systematic review, strategies of school-based interventions aimed at the promotion of cycling to school and its effects were summarized. A search strategy based on PICo was used to conduct a literature search in eight electronic databases. Only (randomized) controlled trials with pre-post-measurements in primary/secondary school students and published in English between 2000 and 2019 were included. Study selection, data extraction, quality assessment using the Effective Public Health Practice Project, and evaluation of behavior change techniques using the taxonomy (v1) were conducted by two independent researchers. Seven unique interventions, described in nine publications of weak quality from 2012 to 2018, were included in the narrative synthesis. Eleven main groups including 19 behavior change techniques were identified. Seven main groups including 35 different outcome variables were built. Significant intervention effects in the treatment group were found in nine different outcomes reported in four publications. A voluntary, adult-guided bicycle train to/from school in children was promising to promote cycling to school. Findings help develop a school-based intervention aimed at the promotion of cycling to school.

Individual contribution: DMIS conceptualized the methodological procedure of the systematic review including the development and pretest of the search strategy as well as the definition of the inclusion criteria and design of the data extraction sheet. The literature search was conducted and updated by her. She was the first reviewer in the study selection process, extracted data of each included study, assessed methodological quality, and evaluated behavior change techniques. Data analyses were conducted by her. She drafted the manuscript including visualizations and was responsible for the progress through the review process by suggesting revisions as the corresponding author.

PUBLICATION THREE

Title: Gender influence on students, parents, and teachers' perceptions of what children and adolescents in Germany need to cycle to school: a concept mapping study

Authors: Dorothea M I Schönbach, Catherina Vondung, Lisan M Hidding, Teatske M Altenburg, Mai J M Chinapaw, Yolanda Demetriou

Publication date: 20 Sept 2020

Summary:
For several reasons, active commuting to school is highly recommended. A child interacts with its parents and teachers in the decision-making process of active commuting to school. So far, gender-specific perspectives of students, parents, and teachers on the needs of children and adolescents for cycling to school remained unclear. Therefore, 136 students, 58 parents, and 29 teachers participated in a concept mapping study conducted between November 2019 and February 2020 asking what children and adolescents aged 12 to 15 in Germany need to cycle daily to and from school. Their answers were analyzed stratified by gender. Findings showed that almost all girls (87.8%) and all boys owned a bicycle. However, the cycling to school rates were 44.4% in girls and 72.9% in boys, whereby girls cycled to school on 1.6±2.0 days per week and boys on 2.7±2.0 days per week. Similar needs identified in concept maps of mothers and in students and teachers independent of gender were bicycle and related equipment, the way to school, and personal factors. Unique, gender-independent needs were identified in concept maps of students (cycle training) and teachers (storage and changing room, financial aspects, information and services). Unique, gender-specific needs were identified in concept maps of girls (social behavior in road traffic), mothers (role of the school), mothers and female teachers (role of parents), and female teachers (sense of safety). No final conclusion could be drawn from the ratings of importance and feasibility in identified needs due to a central tendency bias. Based on these findings, the development of a school-based intervention aimed at the promotion of cycling to school could be inspired.

Individual contribution: DMIS prepared and conducted data collection of all sessions in the concept mapping study. Additionally, she analyzed and interpreted data. She drafted the manuscript including visualizations and was responsible for the progress through the review process by suggesting revisions as the corresponding author.

PUBLICATION FOUR

Title: Socio-demographic correlates of cycling to school among 12- to 15-year olds in Southern Germany

Authors: Dorothea M I Schönbach, Catherina Brindley, Anne K Reimers, Adilson Marques, Yolanda Demetriou

Publication date: 11 Dec 2020

Summary:
The rate of cycling to school varies largely in Germany depending on the region and level of urbanization. So far, the influence of children's socio-demographic characteristics, such as distance from home to school, educational level and the region of the school, as well as parents' socio-demographic characteristics, such as age, on cycling to school in Germany remained unclear. Therefore, data from 121 students (girls: 40.5%; boys: 59.5%) aged 12 to 15 (13.1±0.9 years), who attended different (sub)urban secondary schools in Southern Germany, and 42 parents (mothers: 81%; fathers: 19%) aged 47.8±5.5 who participated in the first session of a concept mapping study conducted in 2019 were analyzed. Analyses of correlates used binary logistic regressions and were conducted (in)dependent of gender. A paper/pencil or online version of a self-report questionnaire was completed by students, whereas parents completed online versions of a self-report questionnaire for themselves and a proxy-report questionnaire for their child. Approximately two-thirds of students (self-report: 61.7%; proxy-report: 67.5%) sometimes cycled to school in (sub)urban regions in Southern Germany. Findings showed that girls, older students (mainly in girls), a combination of attending an intermediate educational level and a school located in suburban regions of a small (mainly in girls) or medium-sized town, living further away from school, and children of parents who did not cycle to work were less likely to cycle to school. Based on these findings, the identified correlates of students' and parents' socio-demographic characteristics with cycling to school should be considered when developing a school-based intervention aimed at the promotion of cycling to school.

Individual contribution: DMIS prepared and conducted data collection of the first session in the concept mapping study. Additionally, she analyzed and interpreted data. She drafted the manuscript including visualizations and was responsible for the progress through the review process by suggesting revisions as the corresponding author.

PUBLICATION FIVE

Title: A school-based randomized controlled trial to promote cycling to school among students in Germany using the intervention mapping protocol: the ACTS study

Authors: Dorothea M I Schönbach, Palma Chillón, Adilson Marques, Miguel Peralta, Yolanda Demetriou

Submission date: 30 Jan 2021

Summary:
Even though almost every child and adolescent in Germany owns a bicycle, the rate of cycling to school remains low. More children and adolescents would meet the physical activity recommendation if cycling to school. This publication followed the intervention mapping approach to systematically develop a school-based intervention in (sub)urban regions in Southern Germany, which should sustainably increase the frequency of cycling to secondary school and physical activity levels in 12- to 15-year-olds. A needs assessment using the concept mapping approach was conducted to examine what needs students have in order to cycle to school, perceived by students, parents, and teachers. For the logic model of change, the self-determination theory and social-ecological model were combined. The intervention was structured in two phases and includes 27 behavior change techniques. In the first eight weeks, weekly components for the targeted behavior are planned in the preparation phase involving parents, teachers, and peers. The twelve-week practical phase involves peers only and includes a daily repeated component of the targeted behavior, which was promising according to a previously conducted systematic review. For the implementation, it was decided to use a whole-of-school approach with components taking place before, during, and after school and several implementers (researcher, student assistants, teachers, other collaborators). The study design is a two-arm three-level cluster randomized controlled trial including an effect and process evaluation. In the first instance, a pilot study is planned with approximately 250 of seventh or eighth graders attending an intermediate or high educational level. With this intervention, it is expected to gain insights into the underlying mechanisms of behavior change in cycling to school and its influence on levels of physical activity.

Individual contribution: DMIS designed the intervention concept using the findings of her preliminary work. She drafted the manuscript including visualizations and was responsible for the progress through the review process by suggesting revisions as the corresponding author.

ORIGINAL PUBLICATIONS

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Systematic Reviews

PROTOCOL Open Access

Strategies and effects of promising school-based interventions to promote active school transportation by bicycle among children and adolescents: protocol for a systematic review

Dorothea M. I. Schönbach[1*], Teatske M. Altenburg[2], Mai J. M. Chinapaw[2], Adilson Marques[3] and Yolanda Demetriou[1]

Abstract

Background: Active school travel by bike may provide appropriate means to promote physical activity through commuting to and from school, expanding the mobility during leisure time, and integrating a lifelong positive behavior routine. However, bicycling seems to be a less common form of active school transport and declining cycling to school trends in some European countries have been observed. Therefore, effective interventions aiming at promoting biking to school are warranted. To gain a better understanding of effective programs, the systematic review will summarize strategies and effects of school-based interventions targeted on positively influencing active school travel by bicycle.

Methods: The databases ERIC, PsycINFO, PSYNDEX, PubMed, Scopus, SPORTDiscus, SURF, and Web of Science will be searched utilizing a detailed search strategy according to "PICo". Consequently, there will be no restriction regarding the outcomes measured in studies. For inclusion in the review, the identified primary studies (i.e. randomized and non-randomized controlled trials) should be published between 2000 and 2019 due to their current relevance, and written in English. The screening, data extraction, and appraisal of study quality as well as behavior change techniques will be undertaken by two independent researchers. To assess the methodological quality of every included study, the quality assessment tool "Effective Public Health Practice Project" for quantitative studies will be used. Behavior change techniques will be identified by utilizing the "BCT Taxonomy v1". If data permits, meta-analyses for intervention effects will be conducted where appropriate.

Discussion: The planned systematic review can provide information about how bicycling is considered in school-based interventions as an effective strategy to promote active commuting to school among students. In this regard, the conclusions drawn from the review will establish a basis for researchers to plan and implement a comprehensive cycling intervention in the school setting.

Systematic review registration: PROSPEROCRD42019125192

Keywords: PRISMA-P, Program, Educational facilities, Pupil, Active school travel, Biking, (Randomized) controlled trial

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Background

Despite the well-proven health benefits of physical activity (PA) in childhood and adolescence [1], most young people in Europe still do not meet the PA recommendation of the World Health Organization [2], which includes 60 min of moderate-to-vigorous intensity PA accumulated every day [3]. The low compliance with the PA recommendation is alarming as all health benefits of PA appear to have their origin in early life [4] just as various health problems in adulthood, like overweight or obesity [5]. Given that the development of active habits in this period of life is expected to remain stable [6–10], the effort of PA promotion has to occur as early and continuously as possible.

Schools are an ideal setting for promoting PA [11–14]: Firstly, school attendance is compulsory in many countries [15]. As a result, all children and adolescents can be reached regardless of their social background and they have to commute to and from school each day [16]. Secondly, students spend about half of their day at school since the implementation of full-time schools in most countries [12] and therewith, they may have less time to engage in leisure time PA according to the displacement hypothesis [17]. Due to the educational mandate at schools, the Institute of Medicine published an international PA recommendation for schools according to which traveling to and from school is highly recommended for pupils as an additional opportunity for being physically active [18].

Active school travel (AST) could be a meaningful long-term possibility to promote PA [18]. Current research has indicated that AST is positively associated with PA levels per day [19–22], per school day [20, 23], and immediately before and after school [20, 21, 23]. Especially female adolescents seem to benefit from engaging in AST [20]. Additionally, a potentially lifelong habit of active transport in general may be established as a result of a daily AST routine in early years [16]. Furthermore, AST provides favorable health benefits, such as a positive effect on body composition [21, 24]. Simultaneously, AST may also have a positive impact on reducing traffic [25, 26], which consequently protects the environment concerning air pollution [16, 26] and increases road safety [25]. But since the development of intervention studies in this area of research is still in an early stage [27], the promotion of AST has been described as the least implemented measure up to now, especially in secondary schools [28]. This circumstance may explain the current lack of knowledge about the effectiveness of intervention studies in the long term [27] despite cross-sectional findings of increased AST rates when schools supported AST behavior [29].

One option of AST besides walking is cycling. Lately, it was reported that bicycling makes a positive contribution to improving cardiovascular fitness in children and adolescents aged 5 to 17.9 years due to its higher intensity compared with walking [16] as well as to meeting the international PA recommendation [22]. Thirty-six percent of AST cyclists aged 5 to 15 years achieved the guideline per week with a mean weekly cycling-related AST time of 1.4 h, which contributes 20% to the recommended weekly minutes [22]. Thus, cycling-related AST may be promising for decreasing future risk of cardiovascular diseases. Regarding bicycle ownership in this context, between 57 and 98% of children and adolescents aged 0 to 17 years already own a bicycle in Germany for instance [30]. Accordingly, bicycling seems to be a cost-effective form for students to get to and from school [16]. By contrast, the percentage of German students who actually use their bikes to cycle to school varies from 8 [31] to 22.2% [32] depending on the region with observed gender differences of 23.8% in boys versus 20.6% in girls [32]. Compared with cycling to school trends between 2006, 2010, and 2014 among Czech schoolboys (5.7%, 3.2%, 2.2%) and schoolgirls (2.3%, 0.5%, 2%) aged 11 to 15 years [33], biking tradition seems to vary enormously between individual European countries. In accordance with the current state of research, the need for action with respect to cycling as a less common form of AST is warranted [33] and the negative development has also to be reversed.

Against this background, evidence-based interventions aiming at promoting biking to school are needed. To the authors' knowledge, none of the previously published systematic reviews dealt exclusively with cycling as a mode of AST, whereas there is already one that focused on walking in particular [25]. Hence, this review will summarize strategies and effects of school-based interventions to promote AST by bicycle among children and adolescents, which follow a pretest-posttest comparison group design.

Methods

This systematic review protocol has been registered in the international prospective register of systematic reviews called PROSPERO (registration number: CRD42019125192). For the preparation of the protocol, the checklist "Preferred Reporting Items for Systematic review and Meta-Analysis for Protocols" [34] was utilized (PRISMA-P: see Additional file 1). Any discrepancies in the announced procedure of this protocol will be documented and published within the final review and PROSPERO.

Search strategy

The search strategy will be designed in collaboration with two specialists employed at the information services in the University Library (Technical University of Munich) and will be based on "PICo" [35]. According to the three factors of "PICo", three groups of search terms will be defined that have to be integrated in title or

abstract. The combinations of keywords related to population, interest, and context are illustrated in Additional file 2. To identify potentially relevant primary studies, the systematic literature search will be conducted in the following eight electronic databases: ERIC, PsycINFO, PSYNDEX, PubMed, Scopus, SPORTDiscus, SURF, and Web of Science. All search results given by the utilized electronic information sources will be restricted to English language and will be limited to studies published between 2000 and 2019 due to their current relevance.

Eligibility criteria

Only studies will be included whose school-based intervention components pursue the goal to increase the use of bicycles during the school travel as appropriate means of promoting AST, such as an adult-guided cycling route to and from school. In this context, the term "school-based" is defined as everything that happens in or on the way to and from school but school staff (e.g. teachers) do not necessarily have to be involved. Intervention outcomes can be quantified by any type of common measures (e.g. questionnaires, accelerometers, interviews, tests, cycle computer) and will not be restricted to a predefined issue. In addition, only samples targeted on primary and/or secondary schools will be taken into consideration. Moreover, randomized controlled trials (RCTs), in terms of parallel-group or cluster-randomized, and controlled trials (CTs) that represent children and adolescents without specific health issues will be included in the systematic review. The comparators should be either an active control group, for example receiving an intervention to promote young people's creativity or cognitive performance without components promoting AST, PA or reducing sedentary behavior, or a control group with no intervention. Finally, all of the included studies must have provided intervention effects analysis by comparing pretest and posttest values between intervention and control group.

Study selection

All identified records will be imported into EndNote, and duplicates will be removed. Then, the identified references will be screened by two independent reviewers (DS and TA) in consideration of the described eligibility criteria for inclusion following three steps based on title, abstract, and full text. If necessary, any potential discrepancies during these three steps of the selection process will be resolved by discussions between DS and TA after re-examination of studies, or in case of continued disagreement by a third independent reviewer (YD). Authors will be contacted a maximum (max.) of two times via e-mail when articles are not available, or relevant details are missing in the article.

Data extraction

Specific study details for each included full text pertaining the two research questions will be listed in a spreadsheet (excel) by DS and TA/AM. Prior to this, the spreadsheet will be piloted on the basis of three randomly selected full texts to ensure consistency among the two independent data extractors as well as to ensure a systematic process during data extraction. Information will be entered into the table, such as general study details (i.e. author, country, year, design, study aim), theoretical background, characteristics of participants (i.e. total/subgroup sample size/s, sample size determination, class level/age, stage of life, participants' recruitment/retention rate), intervention description (i.e. name, components, approach, behavior change technique (BCT), tasks of control group, duration, frequency, points of data collection), statistical analysis (incl. confounder), and measuring instruments as well as effects of individual intervention outcomes. With reference to BCT, two independent evaluators (DS and TA) will code intervention strategies applied in all included studies utilizing the "BCT Taxonomy v1" [36], which consists of 93 hierarchically clustered techniques. Any discrepancies between both evaluators will be resolved by discussions, or if needed, by consulting a third independent evaluator (YD). While extracting the data, the data extractors will not be blinded to authors and journals.

Quality assessment

The component-based quality assessment tool "Effective Public Health Practice Project" [37] for quantitative studies will be used for assessing methodological quality of all included primary studies.

Critical judgements will be made separately for all items within the eight sections/components shown in Additional file 3. DS and TA/AM will rate the methodological quality for each item as strong, moderate or weak according to standardized instructions published in the associated tool dictionary. Any discrepancies between the evaluators (DS and TA/AM) regarding the individual rating of items will be resolved through discussion. As the final review will only include RCTs or CTs, the item "study design" will be rated as strong for all included studies and will only be used to separate RCTs from CTs. With reference to the eight selected confounders based on the "Model of Children's Active Travel" [38] mentioned in Additional file 3, this item will be assessed as strong when at least five relevant confounders are considered in the study, moderate when between three and four relevant confounders are taken into account, and weak when less than two relevant confounders are reported. Based on the current evidence of controlled confounders, the quality of this item will be rated as strong for gender [33] and migration background [32]

whereas age [33, 39] and previous AST experiences at baseline level [40, 41] will be rated as moderate, and all other variations will be rated as weak.

After rating all individual items, each of the eight quality components will be assessed as strong (more strong than moderate ratings and no weak ratings), moderate (not more than one weak rating), or weak (two weak ratings or more). The global quality of a study will be rated as strong when at least five components are assessed as strong and no components are assessed as weak [42]. When less than five components are assessed as strong and one component is assessed as weak, the global quality of a study will be rated as moderate [42]. The methodological quality of a study will be rated as weak when two or more components are assessed as weak [42]. Even though the studies will be assessed according to their quality, they will not be weighted [43]. As a result, findings from studies with weak quality will not be given less importance than findings from studies with strong quality [43].

Data synthesis

The included articles in the systematic review will focus on various intervention characteristics and outcome variables collected by utilizing diverse measuring instruments. This is why conducting a narrative synthesis to describe and summarize the findings of these studies is expected to be the most appropriate method. The following two criteria will be used to decide whether or not a meta-analysis will be integrated: (a) Sufficient content-related homogeneity regarding similar research questions is necessary among studies. (b) To reach a good approximation in terms of statistical distributions, the minimum (min.) number of studies is set at five. In case of performing a meta-analysis, the software "R" with its packages "meta(for)" will be used. Study details, methodological quality assessments (separated into sectional and global rating), and intervention approaches (behavior change strategies) of the relevant studies will be illustrated in tables. Furthermore, it is planned to group the various outcome variables (e.g. AST behavior, overall PA levels, physical fitness, accident rates, knowledge about bike-specific traffic rules, bike-specific motor skills). A separate analysis for children and adolescents will also be performed. According to the study by Van Hecke et al. (2016), children will be defined up to 12 years of age and adolescents from 13 years of age [2]. Due to different school ages in different countries, we will not restrict the age group to a range with a min. or max. value. If reported in studies, we will consider gender and regional differences as well. This procedure is aimed at gaining insights into potential age, gender, or cultural dynamics in intervention strategies that have already been implemented and were successful in increasing AST.

Discussion

The planned systematic review will critically evaluate the literature on school-based bicycle intervention strategies and their effects on a variety of outcomes, such as AST behavior, overall PA levels, physical fitness, accident rates, knowledge about bike-specific traffic rules, or bike-specific motor skills. An extensive overview of existing studies on promising school-based bicycle intervention strategies and their effects is required for increasing the prevalence of bicycling as an important form of AST among children and adolescents.

We anticipate that the planned systematic review will have some limitations at study as well as review level. At study level, potential limitations could include intervention strategies that are not based on a theoretical framework or described in detail, heterogeneity in applied strategies or outcomes, small number of long-term studies, small sample sizes that limit representativeness, and low study quality. We further expect potential limitations at review level, like small total number of studies, inappropriateness of meta-analyses due to a variety of statistical units and analyses, or weak evidence for effectiveness. Nevertheless, the systematic review can make a contribution to closing an existing research gap.

The findings of the review will be disseminated through the publication in an international peer-reviewed journal, formal presentations at conferences, and informal meetings. In addition, the findings of the review will be used to make recommendations that will immediately be transferred into an evidence-based best practice example of a school-related AST intervention in our European project.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s13643-019-1216-0.

Additional file 1. Preferred Reporting Items for Systematic review and Meta-Analysis for Protocols (PRISMA-P) 2015 checklist: recommended items to address in a systematic review protocol.

Additional file 2. Draft of the search strategy utilized in each selected database.

Additional file 3. Sections, components and items of the quality assessment tool.

Abbreviations

AST: Active school travel; BCT: Behavior change technique; CTs: Controlled trials; e.g.: Exempli gratia (for example); i.e.: Id est (that is); incl.: Inclusive; max.: Maximum; min.: Minimum; min: minutes; PA: Physical activity; PICo: Population, interest, context; PRISMA-P: Preferred Reporting Items for Systematic review and Meta-Analysis for Protocols; RCTs: Randomized controlled trials

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Authors' contributions
DS pretested and conducted the search strategy, was the first reviewer, and drafted the manuscript. YD and DS contributed equally to developing the search strategy of the systematic review and the concept of the review protocol. In addition, both worked on designing the inclusion checklist. Moreover, YD was the third reviewer. YD, TA, MCAP, and AM provided comments as well as edits to the manuscript. Furthermore, TA was the second reviewer. The final manuscript was approved by all authors.

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Availability of data and materials
Not applicable

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Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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REVIEW

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Strategies and effects of school-based interventions to promote active school transportation by bicycle among children and adolescents: a systematic review

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Abstract

Background: Promoting cycling to school may benefit establishing a lifelong physical activity routine. This systematic review aimed to summarize the evidence on strategies and effects of school-based interventions focusing on increasing active school transport by bicycle.

Methods: A literature search based on "PICo" was conducted in eight electronic databases. Randomized and non-randomized controlled trials with primary/secondary school students of all ages were included that conducted pre-post measurements of a school-based intervention aimed at promoting active school travel by bicycle and were published in English between 2000 and 2019. The methodological quality was assessed using the "Effective Public Health Practice Project" tool for quantitative studies. Applied behavior change techniques were identified using the "BCT Taxonomy v1". Two independent researchers undertook the screening, data extraction, appraisal of study quality, and behavior change techniques.

Results: Nine studies investigating seven unique interventions performed between 2012 and 2018 were included. All studies were rated as weak quality. The narrative synthesis identified 19 applied behavior change techniques clustered in eleven main groups according to their similarities and a variety of 35 different outcome variables classified into seven main groups. Most outcomes were related to active school travel and psychosocial factors, followed by physical fitness, physical activity levels, weight status, active travel and cycling skills. Four studies, examining in total nine different outcomes, found a significant effect in favor of the intervention group on bicycle trips to school (boys only), percentage of daily cycling trips to school, parental/child self-efficacy, parental outcome expectations, moderate-to-vigorous intensity physical activity (total, from cycling, before/after school), and total basic cycling skills. Seven of these outcomes were only examined in two studies conducting the same intervention in children, a voluntary bicycle train to/from school accompanied by adults, including the following clustered main groups of behavior change techniques: shaping knowledge, comparison of behavior, repetition and substitution as well as antecedents.

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Conclusions: The applied strategies in a bicycle train intervention among children indicated great potential to increase cycling to school. Our findings provide relevant insights for the design and implementation of future school-based interventions targeting active school transport by bicycle.

Trial registration: This systematic review has been registered in the international prospective register of systematic reviews "PROSPERO" at (registration number: CRD42019125192).

Keywords: PRISMA, Program, Educational facilities, Pupil, Active school travel, Biking, (Randomized) controlled trial

Background

There is increasing focus on identifying effective strategies to improve physical activity (PA) among children and adolescents [1]. Most young people in Europe do not achieve the recommended daily accumulation of 60 min (min) in moderate-to-vigorous intensity physical activity (MVPA) [2] of the World Health Organization (WHO) [3], in spite of the well-known health benefits [4]. Both PA-related health benefits, which can persist into adult life, and a variety of health problems in adulthood, including overweight or obesity [5], appear to have their origin in early life [5, 6]. Therefore, the low compliance with PA recommendations is alarming. Since PA habits are established early in life, promoting PA from an early age is required [7–11]. Active school travel (AST) is a source of habitual PA for students and therefore highly recommended [12]. AST is positively related to total daily PA [13–16], school day PA [14, 17] as well as PA before and after school [14, 15, 17]. Cycling is an important option for AST. In England, those who cycled for AST accumulated on average 1.4 h of cycling per week, which contributed 20% of recommended weekly PA [16]. As a result, a higher percentage of cyclists (36%) aged 5 to 15 years meet the weekly WHO recommendation of PA compared to walkers (25%) and those who did not walk or cycle to/from school (22%) [16]. In particular, adolescent girls, who have lower levels of PA [18] and perceive more barriers to PA (e.g., lack of energy) [19], may benefit more from participating in AST than adolescent boys [14]. Previous research showed that adolescent girls from New Zealand who participated in AST were more likely to meet the PA recommendations compared to passive travelers [14]. This was not the case for boys [14].

In addition, AST has been positively associated with body composition [15, 20], positive emotions [21], and cognitive performance (only in adolescent girls) [22]. Compared to walking, cycling is generally of higher intensity [23]. Thereby, AST by bicycle contributes to cardiovascular fitness [23] and may reduce the future risk of cardiovascular diseases. In addition, AST has been positively associated with environmental factors, such as reduction of traffic [24, 25] which contributes to a minimization of air pollution [23, 25] and enhancement of road safety [24]. Furthermore, adopting a daily AST routine including journeys to and from school [26] as early as possible may lead to a potentially lifelong habit of active transport (AT) [16] including journeys to any other destination. Moreover, a study in Ireland showed that AST by bicycle increases the mobility of adolescents living further away from school [27]. Bicycles are also the fastest means of transportation for distances less than 5 km in cities, especially when car traffic is congested [28].

Studies in Germany showed that most children and adolescents aged up to 17 years own a bicycle (57 to 98%) [29]. However, only 8% [30] to 22.2% [31] cycle to/from school daily or usually. Additionally, more boys (23.8%) than girls (20.6%) cycle to school in Germany [31]. In the Czech Republic, the percentages of boys (5.7, 3.2, 2.2%) and girls (2.3, 0.5, 2%) aged 11 to 15 years who cycled to/from school between 2006, 2010 and 2014 decreased over time [32]. According to these data from Germany and the Czech Republic, cycling is a less common form of AST, cycling habits differ by gender in favor of boys, and there might be a declining trend in some European countries.

Following this, researchers have increased interest in developing AST interventions in the last years [33]. A previous systematic review focused on the effects of AST interventions aiming to promote walking [24]. No previous systematic review dealt exclusively with the effectiveness of intervention strategies targeting cycling as means of AST, which is required for adequate policy decisions in this field [1]. Thus, the aims of this systematic review were to summarize the evidence on strategies and effects of (randomized) controlled interventions that promote cycling to school as a mode of AST among primary and/or secondary school students.

Methods

The methodological procedure of this systematic review is described in detail elsewhere [34]. For drafting this systematic review, the checklist "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement" [35] (see Additional file 1) was utilized.

Inclusion criteria

In this systematic review, (parallel-group or cluster-randomized) controlled trials (RCTs; CTs) were considered that described a school-based bicycle intervention fostering the use of bicycles in AST. Only samples that represented primary and/or secondary school students were included. The control group (CG) could be either active in terms of getting an alternative intervention program without strategies promoting AST or not receiving any kind of intervention. Only studies published in English and, due to current relevance, between 2000 and 2019 were included.

Search strategy

A comprehensive search formula with a combination of keywords in three different categories according to "PICo" (population, intervention, context) [36] was generated in collaboration with two specialists (see Additional file 2). The first literature search based on title and abstract was conducted on November 28th, 2018 and was updated on November 25th, 2019 in eight electronic databases (ERIC: EBSCO, PsycINFO: EBSCO, PSYNDEX: EBSCO, PubMed: NCBI, Scopus: ELSEVIER, SPORTDiscus: EBSCO, SURF: BISp, and Web of Science: Clarivate Analytics).

Study selection

Records were imported into and further managed with EndNote X7.4. The identified articles were screened independently by DS and TA/AM based on title, abstract, and full text in terms of their relevance and depicted in a flow chart (see Fig. 1). Any disagreements between the reviewers during these three steps of the selection process were resolved by discussion.

Data extraction

Data regarding general study details, characteristics of participants, theoretical background, intervention description, outcome variables, measuring instruments, statistical analysis, and results were extracted using a previously piloted data extraction spreadsheet. Due to relevance, only intervention components that directly targeted AST were extracted. The authors of the included studies were contacted via e-mail with a maximum of two reminders if relevant data was missing or a clarification of descriptions was required. Therefore, the data extractors (DS and TA/AM) were not blinded to authors and journals while extracting study information. Two evaluators (DS and TA) independently coded the behavior change techniques (BCTs) applied to intervention components using the "BCT Taxonomy v1" [37]. Intervention components which could not be assigned to the 93 BCTs originally clustered in 16 main groups were classified into two newly added strategies/groups (i.e., knowledge transfer and parental involvement) by the authors according to a previously-used procedure [38]. Therefore, strategies were classified within a taxonomy of 95 BCTs clustered in 18 main groups. Any discrepancies were resolved by discussion.

Quality assessment

For the assessment of the methodological quality of included studies, the quality assessment tool for quantitative studies "Effective Public Health Practice Project" (EPHPP) [39] was used. Where an explicit reference to a joint, more detailed article (e.g., study protocol) was mentioned, this article was additionally used to complete the assessment of the study's methodological quality. Otherwise, articles in which the same intervention was analyzed with regard to different outcomes were assessed independently. A critical judgment was made for all items within the following eight quality sections/components (see Additional file 3): (A) Selection bias (two items), (B) Study design (four items), (C) Confounders (three items), (D) Blinding (two items), (E) Data collection methods (depending on the number of collected variables), (F) Withdrawals/Drop-outs (two items), (G) Intervention integrity (three items), and (H) Analyses (four items). Each item within the eight sections was assessed as strong, moderate or weak. The methodological quality of each item was rated independently by DS and TA/AM. Discrepancies between the evaluators despite discussions were resolved by consulting another independent evaluator (YD).

The following modifications to the EPHPP dictionary were made: Regarding the section (C) "confounders", eight potentially relevant variables were chosen (i.e., age, sex/gender, previous AST experiences at baseline level, weight status, migration background, bicycle ownership, socio-economic status, distance from home to school) based on the "Model of Children's Active Travel" (M-CAT) [40]. When studies included five to eight of these potentially relevant variables as confounders, this item was rated as strong. It was rated as moderate when only three to four of potentially relevant variables were included and it was rated as weak when less than two of potentially relevant variables were included. In a further item of this section C, the quality of confounders was rated. If relevant to the study, the consideration of "sex/gender" [32] and "migration background" [31] led to a strong rating, whereas including "age" [32, 41] and "previous AST experience at baseline level" [42, 43] in the analysis were rated as moderate (weak: the rest). In the section (G) "intervention integrity", the (unclear) presence of any kind of co-intervention or contamination led to a weak rating (strong: no co-intervention/contamination). Within the section (H) "analyses", the item "unit of allocation" was rated as strong for "school", as

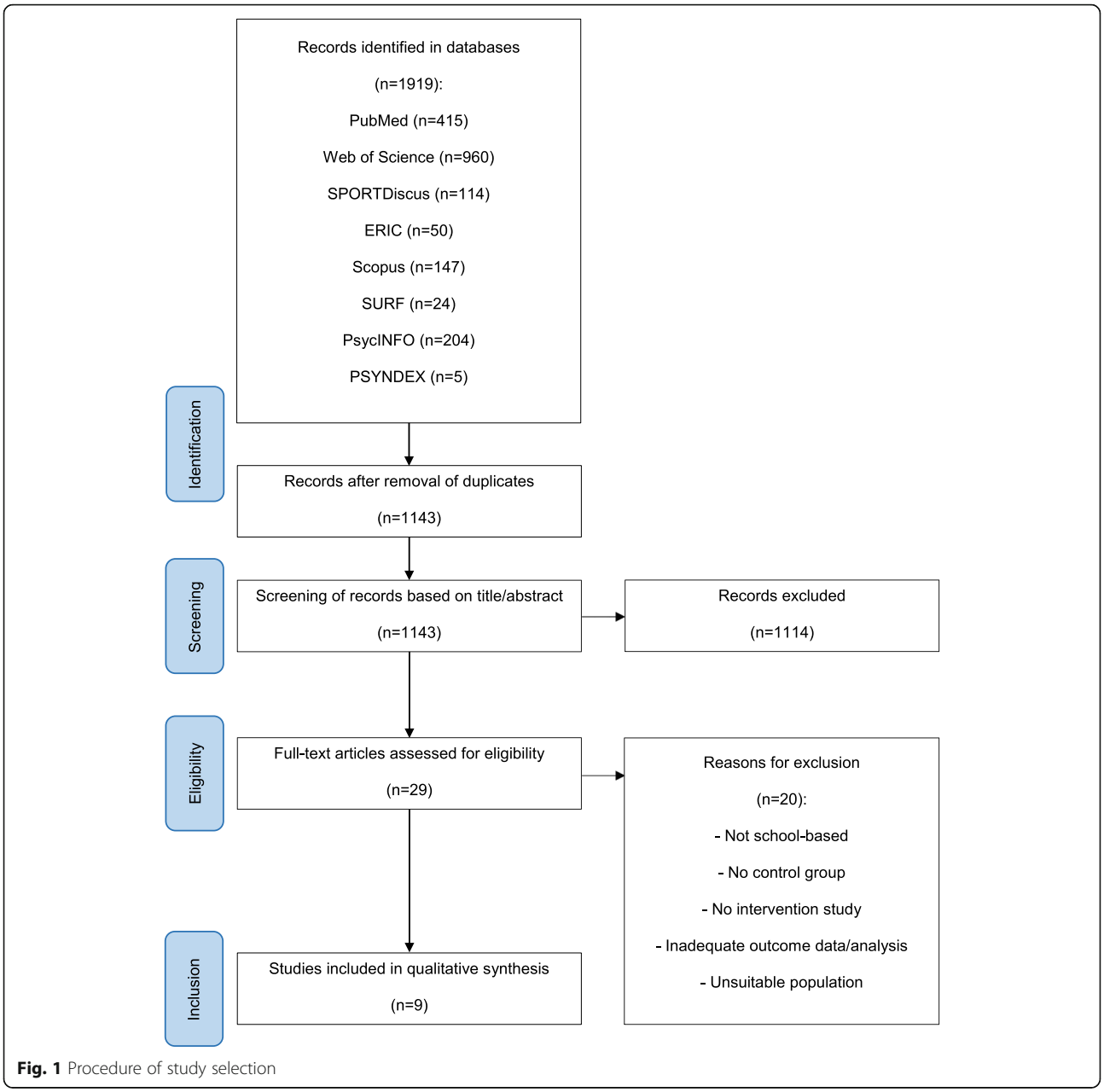

Fig. 1 Procedure of study selection

moderate for "class", and as weak for "individual" based on the randomization level. The "unit of analysis" was appropriate and determined as strong when analyses were adjusted according to the "unit of allocation". This means, for example, that analyses of a study cluster-randomized at school level had to be adjusted for schools. Otherwise, the "unit of analysis" was not appropriate and rated as weak.

After rating the individual items, each of the eight EPHPP quality components were assessed as a) strong (no weak ratings and more strong than moderate ratings), b) moderate (one weak rating), and c) weak (at least two weak ratings). Finally, a global quality rating based on the eight EPHPP components in each study was performed according to a common procedure [38]. When five or more components were assessed as strong and no components were assessed as weak, the global quality of a study was rated as strong [38]. The global quality of a study was rated as moderate when at least four components were assessed as strong and no more than one component was assessed as weak [38]. A weak methodological quality was rated when two or more components were assessed as weak [38].

Data synthesis

All findings were summarized narratively by reporting effect sizes (ES), like Cohen's d, Odds Ratio, partial Eta-squared (η_p^2), and effect estimates, like confidence intervals (CI), or *p*-values (significant: $p \leq 0.05$). The various outcome variables were grouped and studies were marked according to their effectiveness in terms of changing the related outcome(s). Results were sorted by age group (children up to the age of 12 years; adolescents from 13 years of age) [2]. If data allowed, gender effects were reported. Against our previous intention described in the published protocol [34], it was not possible to describe cultural dynamics based on regional differences. Given that only one outcome, i.e., body-mass-index (BMI), was considered in more than one intervention and measured/classified identically [44, 45], heterogeneity of variables across reviewed studies did not permit to carry out meta-analyses for intervention effects.

Results

In total, 1711 publications were found in the first search and another 208 publications in the updated search. After removal of 776 duplicates, 1143 articles were screened. Nine relevant studies evaluating seven unique interventions were included in this review [44–52].

Intervention characteristics and BCTs

The characteristics of the seven included interventions, evaluated in nine studies between 2012 and 2018, were heterogeneous (see Table 1). Interventions were carried out either in Europe ($n = 5$) or the USA ($n = 2$). Four interventions were designed as RCT. Only in three interventions, a sample size calculation was performed. Six out of seven interventions reported a sample size at baseline and indicated a range from 53 to 2401 participants. The number of recruited schools ranged from 1 to 25 (1 to 5 schools: $n = 4$; 14 schools: $n = 1$; 25 schools: $n = 1$). Primary schools and two grade levels were the most frequently chosen settings. The age of participants was up to 17 years (children: $n = 4$, children and adolescents: $n = 3$). Only five interventions reported the gender ratio of girls and boys. Interventions lasted between 4 weeks and 1 year and were classified into short-term (≤3 months: $n = 3$) or moderate-term (4 to 12 months: $n = 2$). Only one intervention included two different intervention arms (with/without parental involvement). Five interventions clearly stated that they did not deliver any kind of intervention to the CG. Three of these interventions, however, described either a provision of information ($n = 1$) or some kind of contamination in terms of minor interventions or similar conditions between the intervention group (IG) and CG ($n = 2$). Two interventions did not clearly report the conditions of the CG but mentioned contaminations, such as minor interventions, or delivery of informational letters. Three interventions reported that components were based on established theoretical frameworks, including the "Conceptual framework of AT in children", the "Active Living by Design: 5P model" and the "Social Cognitive Theory". One intervention was inspired by several correlates of cycling to school. In three interventions, no theoretical model was mentioned as a basis. The interventions included different components, such as a cycle training course or a bicycle train (i.e., adult-guided group of cycling children). Six interventions used a multicomponent approach with a combination of environmental, informational and behavioral ($n = 2$), environmental and informational ($n = 1$) or informational and behavioral ($n = 3$) components. One intervention was based on a behavioral approach only. Each intervention component was at least linked to one BCT. In total, 19 different applied BCTs were identified across the seven interventions.

These 19 different applied BCTs were clustered in a total of 11 out of 18 main groups (see Table 2), which varied in their popularity: (1) Shaping knowledge ($n = 6$), (2) Comparison of behavior ($n = 5$), (3) Repetition and substitution ($n = 5$), (4) Antecedents ($n = 4$), (5) Social support ($n = 3$), (6) Parental involvement ($n = 3$), (7) Natural consequences ($n = 2$), (8) Knowledge transfer ($n = 2$), (9) Feedback and monitoring ($n = 1$), (10) Reward and threat ($n = 1$), (11) Goals and planning ($n = 1$). The seven interventions used in average 4.7 main groups.

Study quality

All included studies were assessed as weak in the global rating but none of the nine studies had a weak rating in all eight sections (see Table 3).

Figure 2 gives an overview of the study quality for individual sections across all reviewed studies. Due to the inclusion of RCTs and CTs only, the section with the strongest methodological quality was "study design" rated as strong in all nine studies. Additional strong ratings were found in the sections "confounders", "data collection methods", "withdrawals/drop-outs", and "analyses". In the section "confounders", only one study [48] did not report adjustments. The other eight studies [44–47, 49–52] reported adjustments for at least two up to eight out of ten different covariates (i.e., age, distance from home to school, sex/gender, AST, BMI, race, bike score, neighbourhood disorder, attendance, accelerometer wear time). However, group differences at baseline were only absent in two studies [44, 51]. In the section "data collection methods", three studies were rated as weak [45, 46, 51], three as moderate [47, 48, 52], and

Table 1 Intervention characteristics and strategies sorted by age group

Author, Year, Country, Design, Name of the Intervention	Participants	Theoretical Background	Intervention Description	Approach, Behavior Change Techniques [37]
Ducheyne et al., 2014 [47] Belgium Randomized controlled trial Not reported	Sample size determination: not reported *N* = 124 (cycling test)/114 (questionnaires) 4th grade students (3 primary schools); nIG(I) = 1; nIG(I + P) = 1; nCG = 1 Children aged 9 to 10 yrs	Not reported	IG(I): Master students provided a training course for basic cycling skills by using cycle games, practical cycling exercises et cetera on the school playground in a traffic-free environment during physical education for 4 wks (one 45 min session/wk). IG(I + P): After each session, wkly parental assisted homework tasks were provided (identify: 1. legal bike requirements, 2. the safest school cycling route, the most dangerous traffic spots close to the school, 3. if own bicycle considers legal requirements, 4. the correct meaning of different road signs). CG: No intervention.	Multicomponent (informational, behavioral): Social support (practical social support), shaping knowledge (instruction on how to perform the behavior, information about antecedents), comparison of behavior (demonstration of the behavior), repetition and substitution (behavioral practice/rehearsal)
Huang et al., 2018 [49] & Mendoza et al., 2017 [50] USA Randomized controlled trial Not reported	Sample size determination: GPower *N* = 54 4/5th grade students (4 primary schools); nIG = 24 (2); nCG = 30 (2) Nf = 64.8%, Nm = 35.2%; nIGf = 54.2%, nIGm = 45.8%; nCGf = 73.3%, nCGm = 26.7% Children aged 9 to 12 yrs. (9.9 ± 0.7 yrs); IG = 9.8 ± 0.8 yrs.; CG = 10.0 ± 0.7 yrs	Not reported	IG: For ca. 2 months (4 to 6 wks), daily provision of a voluntary bicycle train to/from school accompanied by study staff (duration: 10 to 45 min, school arrival: 25 to 30 min before start, school departure: 5 to 10 min after end time). Stops along the route were based on children's addresses to pick/drop them up/off. CG: No intervention but provision of usual "school transportation" information.	Behavioral: Shaping knowledge (instruction on how to perform the behavior), comparison of behavior (demonstration of the behavior), repetition and substitution (behavioral practice/rehearsal, behavior substitution, habit formation, habit reversal), antecedents (adding objects to the environment)
Østergaard et al., 2015 [45] Denmark Controlled trial "Tryg og Sikker Skolecykling" (Safe and secure cycling to school)	Sample size determination: not reported *N* = 2401 4/5th grade students (25 schools); nIG = 1296 (13); nCG = 1105 (12) nIGf = 48.9%, nIGm = 51.1%; nCGf = 51.2%, nCGm = 48.8% Children aged 9 to 11 yrs. (mean = 11 yrs); IG = 11.0 ± 0.64 yrs.; CG = 10.9 ± 0.63 yrs	Inspired by correlates of cycling to school (Hume et al., 2009; Timperio et al., 2006)	IG: The duration of the intervention was 1 yr. 1. Hard interventions implemented by local authorities at the school level (structural changes near the school, e.g., road surface, traffic regulation, signposting). 2. Soft interventions implemented by cycling federation at class level (cycling motivation, e.g., competitions and monitoring, and cycling safety, e.g., school traffic policy, cycle training and bicycle maintenance). Cycling incentives, e.g., school campaigns/events for parents/children, free helmets/gimmicks, were also provided. CG: No intervention but some minor interventions were still conducted in some schools.	Multicomponent (environmental, informational, behavioral): Feedback and monitoring (feedback on behavior), shaping knowledge (instruction on how to perform the behavior, information about antecedents), comparison of behavior (demonstration of the behavior, social comparison), repetition and substitution (behavioral practice/rehearsal), reward and threat (material incentive for behavior), antecedents (restructuring the physical environment, adding objects to the environment), knowledge transfer, parental involvement
Villa-González et al., 2015 [51], 2017 [52] Spain Controlled trial Not reported	Sample size determination: not reported *N* = 469 3rd to 5th grade students (5 primary schools); nIG = 295 (3); nCG = 174 (2) Nf = 46.5%, Nm = 53.5%; IGf = 47.8%, IGm = 52.2%; CGf = 44.3%, CGm = 55.7% Children aged 8 to 11 yrs	Conceptual framework of active travel in children (Panter et al., 2008)	IG: Teachers/researchers implemented monthly activities (each 60 to 120 min) in the classroom during regular school hours for 6 months (1. introduction with parental inclusion, e.g., mode of commuting survey and barriers, 2. story reading/performance of scenes related to AST) and school neighborhood (3. knowledge about environmental school characteristics, 4. road safety, 5. street behaviors, 6. AST and road safety education related traditional games). CG: No intervention.	Multicomponent (informational, behavioral): Shaping knowledge (instruction on how to perform the behavior, information about antecedents), comparison of behavior (demonstration of the behavior, social comparison, information about others' approval), repetition and substitution (behavioral practice/rehearsal), parental involvement

Table 1 Intervention characteristics and strategies sorted by age group *(Continued)*

Author, Year, Country, Design, Name of the Intervention	Participants	Theoretical Background	Intervention Description	Approach, Behavior Change Techniques [37]
Børrestad et al., 2012 [44] Norway Randomized controlled trial Active transportation to school and work in Norway	Sample size determination: yes *N* = 53 5th to 7th grade students (1 school); nIG = 26; nCG = 27 Nf = 47%, Nm = 53%; IGf = 46.1%, IGm = 53.9%; CGf = 48.1%, CGm = 51.9% Children/adolescents aged 10 to 13 yrs. (mean = 10.9 yrs); IG = 10.8 ± 0.7 yrs.; CG = 10.9 ± 0.7 yrs	Not reported	IG: For 12 wks, encouragement to cycle to/from school on a daily basis by providing six 30 min group sessions every second wk. during school hours (motivation by raising awareness, counteracting passive transport, parents support, health benefits from physical activity/cycling, road safety issues, cooperation with specialist in cycling safety). Provision of information and encouragement of cycling to school in parental sessions. Delivery of four parental informational letters (study aims/ implications). Implementation by researchers/teachers. CG: Not reported but delivery of four parental informational letters (study aims/implications).	Multicomponent (informational, behavioral): Social support (unspecified social support), natural consequences (information about health consequences), knowledge transfer
Christiansen et al., 2014 [46] Denmark Randomized controlled trial SPACE–for physical activity	Sample size determination: not reported *N* = 1279 5/6th grade students (14 schools); nIG = 598 (7); nCG = 681 (7) IGf = 49%, IGm = 51%; CGf = 48.2%, CGm = 51.8% Children/adolescents aged 11.0 to 14.4 yrs.; IG/CG = 12.6 ± 0.63 yrs	Active Living by Design: 5P model (Bors et al., 2009)	IG: Eleven packages (four focused on AST). 1. Policy initiatives comprised a physical activity policy (reduction of school transport by car through parental encouragement to practice AST and be role models, acceptance of school traffic education initiatives and AST usage in educational settings, goal setting for AST and cooperation with municipalities/other stakeholders targeting environmental safety for AST). 2. Program initiatives consisted of a safe cycling education/ training and a school traffic patrol (older students). 3. Physical initiatives included changes to enhance AST safety (e.g., cycle path, speed humps, new parking area, bike pool). 4. Preparation included a cross-disciplinary network (teachers, school leaders, municipality consultants, re-searchers). Awareness of AST benefits in students/parents. CG: Not reported but some minor interventions were already conducted in some schools.	Multicomponent (environmental, informational, behavioral): Goals and planning (action planning), social support (practical social support), shaping knowledge (instruction on how to perform the behavior), natural consequences (information about health consequences), comparison of behavior (demonstration of the behavior), repetition and substitution (behavioral practice/rehearsal, behavior substitution, habit formation, habit reversal), antecedents (restructuring the physical environment, adding objects to the environment)
Gutierrez et al., 2014 [48] USA Controlled trial Not reported	Sample size determination: GPower *N* = 58 intersections; nIG = 34 at 14 primary schools; nCG = 24 Children/adolescents aged 0 to 17 yrs	Social Cognitive Theory (Bandura, 1998)	IG: 1. Placement of 24 newly hired trained and equipped crossing guards. 2. Awareness campaigns done twice (presence/location via automated phone message for faculty/staff/parents, school specific location maps/safety information via handouts, school administration announcement for faculty/students/ parents). CG: No intervention but identical crossing guard conditions.	Multicomponent (environmental, informational): Shaping knowledge (information about antecedents), antecedents (adding objects to the environment), parental involvement

AST active school travel, *ca.* circa, *CG* control group, *e.g.* for example, *f* female, *I(G)* intervention (group), *m* male, *min* minute(s), *N* total sample size, *n* subgroup sample size, *P* parents, *wk./ly/s* week/ly/s, *yr(s)* year(s)

Table 2 Applied behavior change techniques in reviewed interventions sorted by age group

		Behavior Change Techniques [37]																Others		Total
Author, Year	Age Group	Goals and Planning	Feedback and Monitoring	Social Support	Shaping Knowledge	Natural Consequences	Comparison of Behavior	Associations	Repetition and Substitution	Comparison of Outcomes	Reward and Threat	Regulation	Antecedents	Identity	Scheduled Consequences	Self-Belief	Covert Learning	Knowledge Transfer	Parental Involvement	
Ducheyne et al., 2014 [47]	Children			√	√		√		√											4/18
Huang et al., 2018 [49] & Mendoza et al., 2017 [50]					√		√		√				√							4/18
Østergaard et al., 2015 [45]			√		√		√		√		√		√					√	√	8/18
Villa-González et al., 2015 [51], 2017 [52]					√		√		√										√	4/18
Børrestad et al., 2012 [44]	Children/Adolescents			√		√												√		3/18
Christiansen et al., 2014 [46]		√		√	√	√	√		√				√							7/18
Gutierrez et al., 2014 [48]					√								√						√	3/18
		1/7	1/7	3/7	6/7	2/7	5/7	0/7	5/7	0/7	1/7	0/7	4/7	0/7	0/7	0/7	0/7	2/7	3/7	Total

three as strong [44, 49, 50]. Referring to the section "withdrawals/drop-outs", six studies declared drop-outs [44, 46, 47, 50–52] and five studies had low retention rates [45, 48, 49, 51, 52]. The sections "selection bias" and "blinding" were never rated as strong. Apart from two studies [46, 48], seven studies did not report the representativeness of the sample. Six studies [45–47, 50–52] reached a high recruitment rate. All but one study [44] either did not report blinding at all or reported unblinded conditions. In the section "analyses" ratings were either strong [46, 49, 50, 52] or weak [44, 45, 47, 48, 51] with strengths in the unit of allocation [45–47, 49–52] as well as statistical methods (including ES) [44–46, 48–50, 52] and deficits in the unit of analyses [45, 47, 48, 51] as well as usage of intention-to-treat analysis [44, 45, 47, 48, 51].

The weakest section was "intervention integrity" rated as weak in all nine studies. Only one study [45] indicated the percentage of intervention delivery and measurement of consistency. Moreover, six out of nine studies [44–46, 48–50] described a potential contamination in the CG.

Intervention effects

Altogether, six studies reported proportionally more non-significant than significant intervention effects [44–48, 51]. One study found more adverse intervention effects in boys with larger improvements in the CG [52]. Only two studies – describing the same intervention in children: a "bicycle train" to actively travel to school – showed significant beneficial intervention effects in all their seven outcomes [49, 50] (see Tables 4 and 5).

In total, 35 different outcome variables were reported across the nine included studies. These 35 outcome variables were clustered in seven main outcome groups: (1) AST ($n = 9$), (2) Psychosocial factors targeting both parents or students ($n = 9$), (3) Physical fitness divided into cardiorespiratory/muscular fitness and speed agility ($n = 8$), (4) PA levels ($n = 4$), (5) Weight status ($n = 3$), (6) AT ($n = 1$), and (7) Cycling skills ($n = 1$).

A significant intervention effect was found on 13 different outcomes analyzed across five studies [45, 47, 49, 50, 52], whereas seven studies reported non-significant effects on 25 outcomes in total [44–48, 51, 52]. Within the outcome group "AST", one study found a significant beneficial intervention effect on bicycle trips to school by boys [52] and another study on percentage of daily cycling trips to school (β = 44.9 [CI95: 26.8, 63.0]) [50]. One study, investigating psychosocial factors only, showed significant beneficial intervention effects on parental (β = 0.46 [CI95: 0.05, 0.86]) and child self-efficacy (β = 0.84 [CI95: 0.37, 1.31]) as well as parental outcome expectations (β = 0.47 [CI95: 0.17, 0.76]) [49]. Within the outcome group "physical fitness", one study found a significant adverse intervention effect on aerobic capacity with an unfavorable development in the IG (β = − 1.45 [CI95: − 1.92, − 1.00]) [45]. Another study found significantly higher values in the CG for boys only on VO_{2max} (group main effect: $\eta_p^2 = 0.01$), 20-m shuttle run test (group main effect: $\eta_p^2 = 0.04$), and handgrip strength [52]. Within the outcome group "PA levels", one study reported positive intervention effects on total MVPA (β = 21.6 [CI95: 8.7, 34.6]), MVPA from cycling (β = 23.0 [CI95: 10.7, 35.4]) and MVPA before/after

Table 3 Sectional and global quality rating of reviewed studies sorted by age group

Author, Year	Age Group	Sectional Rating								Global Rating
		Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	Withdrawals/ Drop-Outs	Intervention Integrity	Analyses	
Ducheyne et al., 2014 [47]	Children	Moderate	Strong	Weak	Weak	Moderate	Moderate	Weak	Weak	Weak
Huang et al., 2018 [49]		Weak		Moderate	Weak	Strong	Moderate		Strong	Weak
Mendoza et al., 2017 [50]		Moderate		Moderate	Weak	Strong	Strong		Strong	Weak
Østergaard et al., 2015 [45]		Moderate		Strong	Weak	Weak	Moderate		Weak	Weak
Villa-González et al., 2015 [51]		Moderate		Strong	Weak	Weak	Moderate		Weak	Weak
Villa-González et al., 2017 [52]		Moderate		Moderate	Weak	Moderate	Moderate		Strong	Weak
Børrestad et al., 2012 [44]	Children/ Adolescents	Weak		Strong	Moderate	Strong	Strong		Weak	Weak
Christiansen et al., 2014 [46]		Moderate		Moderate	Weak	Weak	Moderate		Strong	Weak
Gutierrez et al., 2014 [48]		Moderate		Weak	Weak	Moderate	Weak		Weak	Weak

school (β = 12.8 [CI95: 8.5, 17.2]) [50]. One study found a significant intervention effect on total basic cycling skills in both intervention arms (with/without parental involvement), which were taken together in this analysis [47].

The sustainability of intervention effects were examined in only two studies at 5- [47] or 6-month follow-up [51]. After participating in a 4-week cycle training course, a significant intervention effect from pre to post to follow-up for both intervention arms (with/without parental involvement) was found on total basic cycling skills but neither on cycling to school (in min) nor on parental attitudes towards cycling [47]. Significant effects at 6-month follow-up were found on "mode of trips to school" in walking only and "frequency of active trips to school" (walking/cycling) even though non-significant intervention effects from pre to post after 6 months were shown on these variables [51].

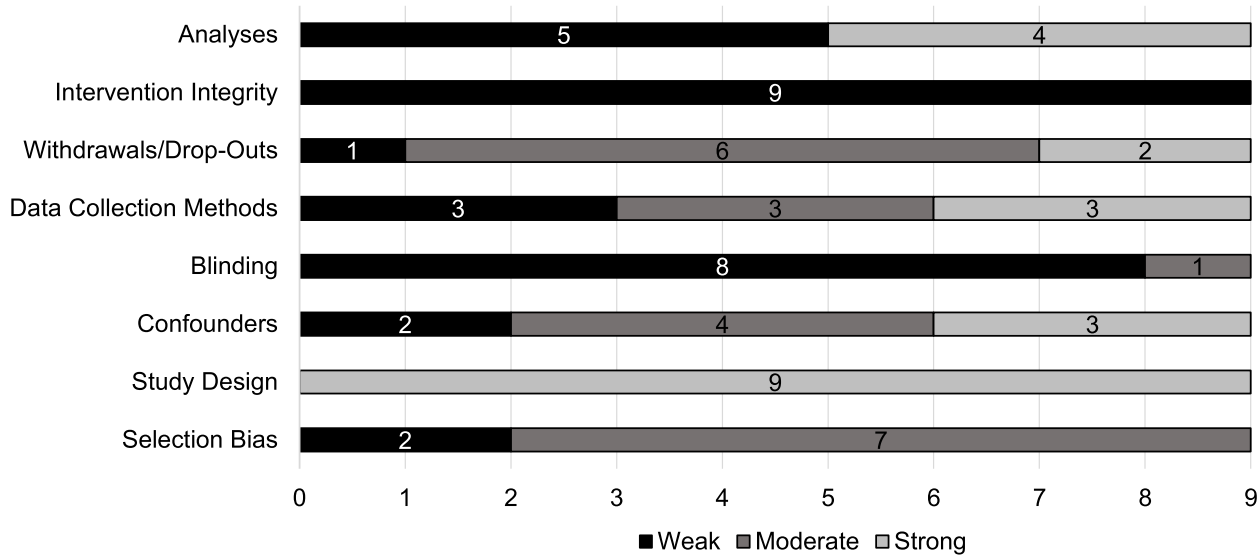

Fig. 2 Quality rating of sections across reviewed studies

Table 4 Outcome variables, measuring instruments, covariates and intervention effects in reviewed studies sorted by age group

Author, Year	Age Group	Outcomes (Measuring Instruments)	Adj. for Covariates	Intervention Effects
Ducheyne et al., 2014 [47]	Children	Cycling skills (objective: practical cycling test); AST: min of cycling to school (subjective: questionnaire); Psychosocial factors: attitudes towards cycling (subjective: questionnaire)	Baseline values of age, distance from home to school	Total basic cycling skills (adj.): group difference from pre to post, pre to follow-up and pre to post to follow-up with greater increase in IG(I/I + P) ($p <$ 0.001, respectively), n.s. group difference from post to follow-up with greater increase in CG Min of cycling to school last wk. (adj.): n.s. group difference from pre to post, pre to follow-up and pre to post to follow-up, group difference from post to follow-up with decrease in IG(I/I + P) and increase in CG ($p < 0.05$) Parental attitudes towards cycling (adj.): n.s. group difference at any time point in importance/encouragement of cycling to school, importance of cycling skills/cycle training, encouragement of cycling skills improvement, impact of cycling training course on safer cycling behaviors in real traffic situations, and feeling of safety when cycling in traffic
Huang et al., 2018 [49]		Psychosocial factors: self-efficacy, outcome expectations (subjective: questionnaire)	Race/ethnicity, age, BMI z-score, bike score, sex/ gender, neighborhood disorder, distance from home to school	Child self-efficacy (adj.): group difference from pre to post ($p < 0.05$; $\beta = 0.84$ [CI95: 0.37, 1.31]) with increase in IG ($\beta = 0.40$ [CI95: 0.05, 0.75]) and decrease in CG ($p < 0.05$; $\beta = -0.43$ [CI95: − 0.76, −0.11]) Parental self-efficacy (adj.): group difference from pre to post ($p < 0.05$; $\beta =$ 0.46 [CI95: 0.05, 0.86]) with increase in IG ($\beta = 0.21$ [CI95: − 0.09, 0.51]) and decrease in CG (n.s.; $\beta = -0.25$ [CI95: − 0.52, 0.03]) Parental outcome expectations (adj.): group difference from pre to post ($p <$ 0.05; $\beta = 0.47$ [CI95: 0.17, 0.76]) with increase in IG ($\beta = 0.14$ [CI95: − 0.07, 0.36]) and decrease in CG ($p < 0.05$; $\beta =$ − 0.32 [CI95: − 0.52, − 0.12])
Mendoza et al., 2017 [50]		AST: % of daily cycling trips to school (subjective: questionnaire); PA levels: MVPA (total, cycling, before/after school) in av. min/day (objective: accelerometer, GPS units)	Race/ethnicity, age, bike score, BMI z-score, sex/gender, neighborhood disorder, distance from home to school, accelerometer wear time	% of daily cycling trips to school (adj.): group difference from pre to post ($p <$ 0.05; $\beta = 44.9$ [CI95: 26.8, 63.0]) with greater increase in IG (n.s.; $\beta = 0.10$ [CI95: − 0.02, 0.23]) Total MVPA in av. min/day (adj.): group difference from pre to post ($p < 0.05$; $\beta = 21.6$ [CI95: 8.7, 34.6]) with increase in IG and decrease in CG (n.s.; $\beta = -4.8$ [CI95: − 13.6, 4.0]) Cycling MVPA in av. min/day (adj.): group difference from pre to post ($p <$ 0.05; $\beta = 23.0$ [CI95: 10.7, 35.4]) with decrease in CG (n.s.; $\beta = -1.6$ [CI95: − 10.0, 6.8]) Before/after school MVPA in av. min/day (adj.): group difference from pre to post ($p < 0.05$; $\beta = 12.8$ [CI95: 8.5, 17.2]) with decrease in CG (n.s.; $\beta = -0.9$ [CI95: − 3.8, 2.1])
Østergaard et al., 2015 [45]		PA levels: LTPA beyond AST (subjective: questionnaire); AST: frequency of long/ short-term school cycling (trips) (subjective: questionnaire); AT: frequency of cycling beyond school (subjective: questionnaire); Physical	Age, baseline BMI, baseline value, sex/ gender	LTPA beyond AST (adj.): n.s. group difference from pre to post with decrease in IG ($\beta = -0.09$ [CI95: − 0.21, 0.03]) Frequency of long-term school cycling (adj.): n.s. group difference from pre to

Table 4 Outcome variables, measuring instruments, covariates and intervention effects in reviewed studies sorted by age group *(Continued)*

Author, Year	Age Group	Outcomes (Measuring Instruments)	Adj. for Covariates	Intervention Effects
		fitness (CRF): aerobic capacity (objective: Andersen test); Weight status: BMI (objective: digital scale, stadiometer)		post with decrease in IG (β = − 0.02 [CI95: − 0.10, 0.05]) Frequency of short-term school cycling trips last wk. (adj.): n.s. group difference from pre to post with increase in IG (β = 0.15 [CI95: − 0.25, 0.54]) Frequency of cycling beyond school last wk. (adj.): n.s. group difference from pre to post with decrease in IG (β = − 0.04 [CI95: − 0.14, 0.05]) Aerobic capacity (adj.): group difference from pre to post with decrease in IG ($p < 0.001$; β = − 1.45 [CI95: − 1.92, − 1.00]) BMI (adj.): n.s. group difference from pre to post with increase in IG (β = 0.01 [CI95: − 0.13, 0.15]) Risk of developing overweight/obesity (adj.): n.s. group difference from pre to post with increase in IG (OR = 0.88 [CI95: 0.50, 1.57]) Dose response association between cycling to school and total intensity (adj.): n.s.
Villa-González et al., 2015 [51]		AST: mode/frequency of (active) trips to school (subjective: questionnaire)	Sex/gender, age, distance from home to school, pre/post AST variables, attendance	Mode of trips to school last wk. (adj.): n.s. group difference from pre to post in walking with greater increase in CG and biking with decrease in CG and no change in IG, group difference from post to follow-up in walking only with increase in IG and decrease in CG ($p = 0.004$) Frequency of active trips to school last wk. (adj.): n.s. group difference from pre to post in walking and cycling with greater increase in CG, group difference from post to follow-up in walking and cycling with increase in IG and decrease in CG ($p = 0.019$)
Villa-González et al., 2017 [52]		AST: mode/frequency of (active) trips to school (subjective: questionnaire); Physical fitness: CRF (VO_{2max}, 20-m shuttle run test), muscular fitness (standing long jump, handgrip strength), speed agility (4 × 10 shuttle run test) (objective: ALPHA health-related fitness test battery)	Age, distance	Mode of trips to school last wk. (adj.): n.s. group difference from pre to post in walking, group difference from pre to post in cycling with increase in IG for male only and decrease in CG for male ($p = 0.04$) Frequency of active trips to school last wk. (adj.): n.s. group difference from pre to post CRF (adj.): group difference from pre to post in VO_{2max} with increase in CG for male only and decrease in IG for male and 20-m shuttle run test with increase in CG for male only and no change in IG for male ($p < 0.05$, respectively) Muscular fitness (adj.): n.s. group difference from pre to post in standing long jump, group difference in handgrip strength with increase in CG in male only and decrease in IG for male ($p < 0.05$) Speed agility (adj.): n.s. group difference from pre to post in 4 × 10 shuttle run test

Table 4 Outcome variables, measuring instruments, covariates and intervention effects in reviewed studies sorted by age group *(Continued)*

Author, Year	Age Group	Outcomes (Measuring Instruments)	Adj. for Covariates	Intervention Effects
Børrestad et al., 2012 [44]	Children/ Adolescents	Physical fitness (CRF): VO_{2peak} (objective: cycle ergometer), HR_{peak} (objective: heart rate monitor); Weight status: BMI, overweight (objective: beam scale, stationmeter); AST: start cycling (subjective: questionnaire)	Baseline level, sex/gender, age	VO_{2peak} (adj.): n.s. group difference from pre to post (d = − 0.13) with increase in IG [CI95: 47.5, 51.8] and CG [CI95: 48.5, 52.8] HR_{peak} (adj.): n.s. group difference from pre to post (d = 0.03) with increase in IG [CI95: 189.4, 197.5] and decrease in CG [CI95: 189.2, 197.2] BMI (adj.): n.s. group difference from pre to post (d = 0.01) with no change in IG [CI95: 18.5, 19.1] and increase in CG [CI95: 18.3, 13.9] Overweight (adj.): n.s. group difference from pre to post with decrease in IG [CI95: 8.0, 33.7] and increase in CG [CI95: 7.7, 34.6] Start cycling last 3 mos: n.s. group difference from pre to post with greater increase in IG [CI95: 50.1, 88.2] than CG [CI95: 20.9, 60.5]
Christiansen et al., 2014 [46]		AST: total no. of active trips to school (subjective: transport diary); Psychosocial factors: perceived route safety to school, encouragement of cycling to school, attitude towards cycling (subjective: questionnaire)	Age, baseline proportion of AST, distance to school, sex/ gender	Total no. of active trips to school for previous day over 5 days (adj.): n.s. group difference from pre to post with increase in IG and CG (OR = 1.27 [CI95: 0.81, 1.99]), n.s. gender effect with increase in male in IG and CG Perceived route safety to school of student (adj.): n.s. group difference from pre to post with decrease in IG and increase in CG (OR = 0.87 [CI95: 0.50, 1.51]) Parental encouragement of cycling to school (adj.): n.s. group difference from pre to post with increase in IG and CG (OR = 1.26 [CI95: 0.92, 1.73]) Student attitude towards cycling (adj.): n.s. group difference from pre to post with decrease in IG and CG (OR = 1.50, [CI95: 0.90, 2.50])
Gutierrez et al., 2014 [48]		AST: counts of intersection crossings (objective: observation); Psychosocial factors: perception of safety, attitudes/ beliefs towards AST (subjective: questionnaire)	NR	Counts of intersection crossings: n.s. group difference from pre to post in AST trends with increase in IG and CG, n.s. between-intersection effects from pre to post in no. of crossing guards (η_p^2 = 0.00), experimental intersections (η_p^2 = 0.00) or interaction of experimental and supervised intersections (η_p^2 = 0.01), increase in usage of supervised intersections in IG and CG (p = 0.041; η_p^2 = 0.08) Parental perception of safety: no change (n.s.) Parental attitudes/beliefs towards AST**:** no change (n.s.)

adj. adjustment/adjusted, *AST* active school travel, *AT* active travel, *av.* average, *β* beta coefficient, *BMI* body-mass-index, *CG* control group, *CI* confidence interval, *CRF* cardiorespiratory fitness, *d* effect size (Cohen), *GPS* Global Positioning System, HR_{peak} peak heart rate, *I(G)* intervention (group), *LTPA* leisure-time physical activity, *m* meter, *min* minute(s), *mos* months, *MVPA* moderate-to-vigorous physical activity, *no.* number, *NR* not reported, *n.s.* not significant, *OR* Odds Ratio, *P* parent, *p* probability value, *PA* physical activity, VO_{2max} maximal oxygen uptake, VO_{2peak} peak oxygen uptake, *wk.* week, η_p^2 partial Eta-squared

Table 5 Overview of outcome variables and intervention effects across reviewed studies sorted by age group

Outcome variables				Intervention effects (Pre/Post)	
				Children	Children/Adolescents
AST	**Subjective**	Mode of trips to school		$0^{51}{}_{a}$, $+m^{52}{}_{a}$	
		Total no. of active trips to school			0^{46}
		Frequency of active trips to school		$0^{51}{}_{a}$, $0^{52}{}_{a}$	
		Frequency of long/short-term school cycling (trips)		0^{45}, 0^{45}	
		% of daily cycling trips to school		$+^{50}{}_{b}$	
		Min of cycling to school		0^{47}	
		Start cycling			0^{44}
	Objective	Counts of intersection crossings			0^{48}
Psychosocial Factors	**Subjective**	Parental attitude/beliefs towards AST			0^{48}
		Parental attitudes towards cycling		0^{47}	
		Student attitude towards cycling			0^{46}
		Parental perception of safety			0^{48}
		Perceived route safety to school of student			0^{46}
		Parental encouragement of cycling to school			0^{46}
		Parental/Child self-efficacy		$+^{49}{}_{b}/+^{49}{}_{b}$	
		Parental outcome expectations		$+^{49}{}_{b}$	
Physical Fitness	**Objective**	**CRF**	Aerobic capacity	$-^{45}$	
			VO_{2peak}		0^{44}
			HR_{peak}		0^{44}
			VO_{2max}	$+CGm^{52}{}_{a}$	
			20-m shuttle run test	$+CGm^{52}{}_{a}$	
		Muscular Fitness	Standing long jump	$0^{52}{}_{a}$	
			Handgrip strength	$+CGm^{52}{}_{a}$	
		Speed Agility	4x10 shuttle run test	$0^{52}{}_{a}$	
PA Levels	**Subjective**	LTPA beyond AST		0^{45}	
	Objective	MVPA (total, from cycling, before/after school) in av. min/d		$+^{50}{}_{b}/+^{50}{}_{b}/+^{50}{}_{b}$	
Weight Status	**Objective**	BMI		0^{45}	0^{44}
		Overweight			0^{44}
		Risk of developing overweight/obesity		0^{45}	
AT	**Subjective**	Frequency of cycling beyond school		0^{45}	
Cycling Skills	**Objective**	Total basic cycling skills		$+^{47}$	

Note: The symbol + indicates an intervention effect, - marks unfavorable intervention effects in the intervention condition, and 0 means no intervention effect. The letters CG declare intervention effects in favor of the control condition. The letter m depicts intervention effects in favor of males. The letters $_{a}/_{b}$ indicate studies with the same intervention, respectively

AST active school travel, *AT* active travel, *av.* average, *BMI* body-mass-index, *CRF* cardiorespiratory fitness, *d* day, HR_{peak} peak heart rate, *LTPA* leisure-time physical activity, *m* meter, *min* minute(s), *MVPA* moderate-to-vigorous physical activity, *no.* number, *PA* physical activity, VO_{2max} maximal oxygen uptake, VO_{2peak} peak oxygen uptake

Discussion

The aims of this systematic review were to provide an overview of existing school-based interventions focusing on the promotion of AST by bicycle in children and adolescents and their evidence on strategies and effects. Following our inclusion criterion for study designs, we only found a small number of (R)CTs in our literature search. This is consistent with the reported gap of strong study designs in this research field [53]. The included trials were predominantly not conducted in cycle-centric countries within Europe (exception: Belgium ($n = 1$) and Denmark ($n = 2$)) [54], showed a large variety of components and outcome measures, and were of weak quality. Three of the included trials did not differentiate between walking and cycling as two different types of AST in their analyses [46, 48, 51, 52]. Therefore, a final conclusion on cycling to school

could not be drawn from these studies. Additionally, the reported interventions were designed for children only or both children and adolescents, implemented in primary schools. The lack of interventions for adolescents, implemented in secondary schools, is also in line with the current state of research [55]. In conclusion, the findings of our systematic review need to be interpreted with caution.

Promising intervention strategies

Overall, only one intervention using a single-component approach showed consistent positive effects on all measured outcome variables [49, 50] and provides first insights into an effective intervention strategy. For approximately 2 months, a voluntary and adult-guided bicycle train to/from school with pick up/drop off stops was provided for children on schooldays [49, 50] including the following main groups of BCTs: shaping knowledge, comparison of behavior, repetition and substitution as well as antecedents. The counterpart of a bicycle train, the "walking school bus" (WSB), is based on a similar approach for walking. In a previous review, the WSB was found to increase walking to school as well as general PA levels in children [24]. However, the bicycle train intervention effect on MVPA from cycling (23.0 min/day) was higher than the intervention effect on total MVPA (21.6 min/day) [50]. This accelerometer data might suggest a compensation in total MVPA due to the additional MVPA from AST by bicycle.

The only study that performed a sex/gender analysis reported increased bicycle trips to school in boys but not in girls [52]. As boys had higher levels of health-related fitness than girls despite comparable low cycling to school rates at baseline [52], poor fitness could be a barrier to uptake AST by bicycle in girls. More research on the existence and explanation of gender differences in intervention effects is warranted in future studies to draw final conclusions.

Strengths/limitations

The major strengths of this systematic review are the specific focus on school-based interventions that promote cycling to school and including only (R)CTs, which provide a higher evidence level than other study designs [56]. Two researchers independently conducted the process of selecting studies, extracting data, evaluating methodological quality and BCTs. Furthermore, authors of included studies were contacted in case of missing data to avoid an underestimation of the methodological quality. Finally, findings were interpreted separately from the methodological quality rating in order to provide transparency.

A limitation is that the defined criterion of including only (R)CTs could have led to a selection bias [53]. The same applies to the restriction of studies published in English. At study level, there are several reasons for a lack of effectiveness. One reason could be the complete absence of intervention periods longer than 13 months [57]. According to the "Transtheoretical Model of Behavior Change", "individuals may need to go through a number of stages associated with the formulation and implementation of attitudes and beliefs before actually undertaking changes, and this whole process takes some time" [58] (p. 68). This is why a lack of immediate success in short- or moderate-term interventions might not necessarily indicate a failure of the intervention [59]. The adoption and integration of cycling to school into the daily routine could have happened after the observed period. Another reason for a lack of effectiveness could be that different local needs in terms of barriers to cycle to school were not sufficiently addressed in interventions [60]. In a previous study, barriers of AST in general were categorized according to the "Social-ecological model of the correlates of AT" [61]: intrapersonal/individual (i.e., child factors), interpersonal (e.g., parental factors), community (e.g., school policy), and environment (e.g., traffic) [62]. One multicomponent intervention among children was inspired by correlates of cycling to school considering such barriers (e.g., intrapersonal/individual including motivation by competitions and safety by cycle training, interpersonal including parental involvement, community including school policies, and environmental changes including traffic regulation) and used almost the same BCTs as the effective bicycle train intervention (apart from repetition and substitution including behavior substitution, habit formation, habit reversal) [45]. Despite this, this intervention was not effective on any outcome in favor of the IG [45]. Furthermore, the improvement of basic cycling skills in a cycle training program among children (examined in only one intervention) without practicing traffic-related skills in the natural environment may be insufficient to impact AST by bicycle [47]. Moreover, a cycle training program including parental assisted homework tasks (e.g., identification of the safest school cycling route and the most dangerous traffic spots close to the school) after each cycle training failed to find effective ways of involving parents as an intervention strategy [47]. The reason could be that the homework tasks insufficiently addressed or increased personal safety barriers in parents (e.g., fears, dangers, concerns about the child's behavior in road traffic) [62]. This may have blocked behavior change in their child as the influence of parents on AST is higher among children than adolescents [40]. Therefore, adolescents may need different intervention strategies than children because all five studies that effectively influenced 13 of 24

examined outcomes included children only [45, 47, 49, 50, 52] and three of the four studies that were not effective in influencing any outcome included both children as well as adolescents [44, 46, 48]. To adequately tailor interventions to a specific population, we recommend following a systematic approach when developing interventions (e.g., the "Intervention Mapping Approach" including a comprehensive needs assessment and theoretical frameworks [63]). Moreover, we recommend conducting a process evaluation that provides insights into the implementation of the intervention (e.g., feedback on program and material, (dis)satisfaction). In addition, we recommend using a checklist when reporting the study. Adherence to the planned intervention (e.g., delivered intensity) was lacking in the majority of studies although "the dose of an intervention is a key predictor of behavior change" [58] (p. 68). Furthermore, contamination was quite common and could have caused an underestimation of effects. Finally, interpretations of findings could be biased due to group differences at baseline.

Conclusions

As a result of the heterogeneity and low methodological quality of included studies, we conclude that the evidence for the effectiveness of interventions promoting AST by bicycle is insufficient. Therewith, our findings confirm that this research field is still in an early development stage [57]. Nevertheless, there is an indication that a bicycle train to/from school among children in primary school, including four clustered main groups of BCTs (shaping knowledge, comparison of behavior, repetition and substitution as well as antecedents), is a promising intervention. More research is needed to better understand strategies and effects of school-based interventions promoting AST by bicycle, especially among adolescents in secondary school.

Based on the findings of this systematic review, there is a need for high-quality intervention studies in this research field. This is why future studies are recommended to evaluate theory-based interventions in longer-term (R)CTs using relevant, valid and reliable outcome measures. Additionally, more research is warranted to examine the moderating effect of gender in AST interventions by bicycle and to prove long-term maintenance of behavior change.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12966-020-01035-1.

Additional file 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement.

Additional file 2. Search formula used in the eight electronic databases.

Additional file 3. Sections, components and items of the quality assessment tool.

Abbreviations

AST: Active school travel; AT: Active transport; β: Beta coefficient; BCT(s): Behavior change technique(s); BMI: Body-mass-index; CG: Control group; CI: Confidence interval; CT(s): Controlled trial(s); e.g.: For example; EPHPP: Effective Public Health Practice Project; ES: Effect size(s); h: hour(s); i.e.: That is; IG: Intervention group; m: Meter(s); M-CAT: Model of Children's Active Travel; min: Minute(s); MVPA: Moderate-to-vigorous intensity physical activity; n: Number(s); p: Probability value; PA: Physical activity; PICo: Population, interest, context; RCT(s): Randomized controlled trial(s); VO_2max: Maximal oxygen uptake; WHO: World Health Organization; WSB: Walking school bus

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Authors' contributions

DS pretested, conducted and updated the literature search, was the first reviewer, conceptualized the data extraction sheet, extracted all data, evaluated intervention strategies, rated the methodological quality of each study, analyzed data, and drafted the manuscript. YD and DS contributed equally to developing the search strategy and the concept of the systematic review. In addition, both worked on designing the inclusion checklist. Moreover, YD was the third evaluator of the methodological quality assessment. TA was the second reviewer in 2018, involved in data extraction, evaluation of intervention strategies, and rating of the studies' methodological quality as evaluator. AM helped to update the literature search as the second reviewer in 2019, performed data extraction as well as the methodological quality assessment of studies as evaluator. MCAP proposed the methods of the systematic review, in particular the methodological quality assessment, advised DS on handling study data and critically revised the manuscript to obtain final decisions. YD, TA, AM and MCAP provided comments as well as edits to the manuscript. The final manuscript was approved by all authors.

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Gender Influence on Students, Parents, and Teachers' Perceptions of What Children and Adolescents in Germany Need to Cycle to School: A Concept Mapping Study

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Abstract: Active commuting to school is highly recommended for several reasons, and in the decision-making process for doing so, a child interacts with parents and teachers. Until now, these three interactors' gender-specific perspectives on children and adolescents' need for cycling to school have been unavailable. Thus, our concept mapping study analyzed the needs of 12- to 15-year-olds in Germany for cycling to and from school daily, as perceived by students, parents, and teachers stratified by gender. From November 2019 to February 2020, 136 students, 58 parents, and 29 teachers participated. Although 87.8% of girls and 100% of boys owned a bicycle, only 44.4% of girls and 72.9% of boys cycled to school. On average, girls cycled to school on 1.6 ± 2.0 days a week and boys on 2.7 ± 2.0 days a week. A "bicycle and related equipment," the "way to school," and "personal factors" were reported needs, perceived by students and teachers of both genders and by mothers. Girls reported the additional gender-specific need for "social behavior in road traffic," mothers and female teachers reported "role of parents," and female teachers reported a "sense of safety." This study's findings could inspire the development of school-based bicycle interventions.

Keywords: childhood; adolescence; sex; active commuting to school; bicycle

1. Introduction

Only 26% of children and adolescents aged 3 to 17 in Germany achieve the physical activity (PA) as described by the guidelines of the World Health Organization (WHO) [1]. Active commuting to school (ACTS) is regarded as an additional opportunity to increase PA before and after school and is highly recommended for school-aged children and adolescents [2]. Cycling is one mode of ACTS and has additional benefits compared to walking for the following reasons: (i) Compared to 25% of walkers, 36% of children and adolescents who cycle to school meet the weekly PA recommendation [3]; (ii) ACTS by bicycle has been generally associated with higher PA intensity than walking, with positive effects on cardiovascular fitness in children and adolescents [4] leading to a risk reduction of developing cardiovascular diseases; (iii) cycling increases the mobility of students who need to manage a longer

home-to-school distance when engaging in ACTS [5,6]; (iv) in cities, a bicycle is considered the fastest means of transportation for distances less than 5 km [7], which is more time-efficient (especially when car traffic is congested); and v) ACTS by bicycle is more positively associated with cycling than walking to other destinations [3], possibly establishing a potentially lifelong active travel (AT) routine by bicycle. Over time, this maintained behavior routine is useful because it predicts PA in adults [8]. Despite these well-known benefits of ACTS by bicycle and the fact that 57% to 98% of children and adolescents aged up to 17 years in Germany own a bicycle [9], why only 8% [10] to 22.2% [11] of them cycle to and from school remains as yet an unknown. Furthermore, the reasons why more boys (23.8%) than girls (20.6%) in Germany cycle to school are still unclear [11]. In a recent systematic review of school-based ACTS interventions focusing on cycling, we found that only one in seven strategies was promising and that two grade levels between 3rd and 7th grade were chosen [12]. Moreover, analysis of gender differences has been performed for only one intervention, which indicated an unexplained beneficial effect on boys but not on girls [13].

According to the Model of Children's Active Travel (M-CAT) [14], the main factors influencing children's travel behavior include "objective characteristics" of the child (e.g., age, gender, school attended), parent (e.g., social status) or family (e.g., size), and further objective elements in physical (e.g., population density), economic (e.g., costs), or political-socio-cultural environments (e.g., school). Some previous research indicates that parents' gender predicts positive associations between parental characteristics and a child's ACTS (e.g., employed mothers [15], mothers actively commuting to work [16]). Moreover, M-CAT considers parent and child's "perception elements" including attitudes (e.g., benefits or risks), the environment (e.g., favorable or unfavorable), and the child (e.g., sense of responsibility, knowledge of road safety, cycling skills) [14]. Because perception is based on "objective characteristics" [14], it can be influenced by the child or parents' gender, so perception can also impact on the child's ACTS. Previous research has reported influential factors identified by both parents of children aged 9 to 12 (e.g., perceived convenience of using the car to drive the child to school), whereas other factors were gender-specific to mothers (e.g., a child's lack of interest) [17]. In conclusion, interaction among all these factors influences the outcome, i.e., parents and children's decisions on children's engagement in ACTS, as well as events occurring during children's engagement (e.g., bullying) [14]. According to M-CAT, children make the final decision on whether they engage in a certain behavior [14], making them experts on their own behavior [18]. Their autonomy, independence, and personal responsibility increase with maturation, while the parents' role and influence as supporters or decision-makers (i.e., ultimate allowance or restriction) simultaneously decrease [14]. Besides the child and its parents, M-CAT mentions schoolteachers as important interactors in the socialization process of ACTS [14]. In addition to the teaching mission, schoolteachers also follow an educational mission according to German laws and are commonly seen as role models on who should practice whatever they emphasize in school lessons [19]. Contrary to previous research on parents, we could not find a gender-specific analysis of teachers' perspectives on ACTS.

Following this, parents at home and teachers at school educate and observe the child, making them experts on the child's behavior and needs [20]. Parents and teachers can be aware of aspects influencing their decision to support the child's ACTS [14], but the child, due to strengths, deficits, and stage of maturation, might not perceive them. This circumstance has already been confirmed in previous research, in which parents and their child had different perspectives on barriers of ACTS [15] and, conversely, needs. In addition, parents identified more barriers to ACTS than children [15]. Moreover, complementary and stimulating impulses of the child, parents, and teachers' perceptions, especially in the gender context [14], might favor a successful socialization process of ACTS [21].

Therefore, our concept mapping study analyzed how perceptions of students, parents, and teachers differed by gender about what children and adolescents aged 12 to 15 in Germany need to cycle daily to and from school. Knowledge of potential similarities and discrepancies in gender-specific perspectives of students, parents, and teachers on perceived needs is necessary to develop future gender-sensitive, school-based bicycle interventions.

2. Materials and Methods

This study used the concept mapping method, a mixed method that combines quantitative and qualitative research [22,23]. It follows a participatory approach based on group processes [22,23] and generally consists of six steps [24]. First, the study is prepared by defining the participants and developing a main question. The second step includes the generation of participants' answers to the main question. Third, participants cluster all unique answers from step two into groups of similar content and rate these answers on importance and feasibility. The fourth step includes the use of a computer program for a (hierarchical) cluster analysis and multidimensional scaling (multivariate statistical analyses). These analyses result in the representation of unique answers, obtained in the second step and structured in the third step, arranged as dots on a two-dimensional concept map. Distances between dots provide information about the frequency with which participants clustered unique answers in the same groups of similar content (i.e., the closer, the more often; the wider, the rarer). In step five, researchers interpret the concept map by identifying an adequate number of relevant clusters and, subsequently, label clusters according to their content based on participants' suggestions. The sixth step includes use of the concept map to plan or evaluate further research.

2.1. Recruitment of Participants

To address ACTS needs in both urban and suburban living areas [6,11,25] and to address the age group (older than 12 years) in which cycling-to-school rates are low [26], in October 2019, an invitation letter was sent to four secondary schools in urban or suburban areas in Germany. Three schools (one urban; two suburban), each including two classes of 7th and/or 8th graders aged 12 to 15, agreed to participate in the study. Parents and teachers were also invited to participate. Prior to the study's beginning, parents and teachers received an information letter, but only children whose parents, parents and teachers who provided signed consent forms participated. To ensure anonymity and to connect each individual's data throughout all concept mapping sessions, participants were instructed to create a five-digit ID code themselves. In all, 136 students, 58 parents, and 29 teachers participated in at least one of the sessions (drop-out rates: 26.5% for students; 79.3% for parents; 62.1% for teachers).

2.2. Concept Mapping Sessions

2.2.1. Students

All concept mapping sessions for students were conducted face-to-face at schools and were supervised by at least one trained researcher (D.M.I.S./C.V.). In each class, the sessions occurred during two regular lessons, i.e., 90 min. Based on schools' availability of sufficient computers and/or stable internet connections, sessions were conducted using either a printed or an online version. Independent of both media, sessions followed exactly the same procedure.

The first concept mapping sessions with students took place in November and December 2019. At three schools, 123 students (49 females, 72 males, 2 diverse), aged 13.1 ± 0.9 years, from six classes (22 to 32 students per class) participated. During the first session, students completed a printed or an online questionnaire via the program Survalyzer [27]. This questionnaire was structured in three sections (see Table A1): (1) personal characteristics, e.g., age and gender (see Table A2), (2) a warm-up question (why do or don't you cycle to school?), and (3) the main question (what do you need to cycle to and from school on a daily basis?). The warm-up question served as an icebreaker to introduce "cycling to school" to the students. To answer the main question, students had an individual and a group brainstorming phase. During individual brainstorming, students were stimulated to list as many answers to the main question as they could. During group brainstorming, individual students shared their written answers and checked their clarity, resulting in a list of unique answers for each class. After all classes had completed the first session, D.M.I.S. created a single list that included all unique answers from all six classes. The working process of D.M.I.S. was checked by the second

researcher S.M., and any discrepancies were resolved through discussion. As a result, D.M.I.S. entered a list of 98 unique answers into the rating and clustering program Ariadne [28].

The second concept mapping sessions took place in January and February 2020; they were completed by 100 students (35 females, 64 males, 1 diverse). Here, students were asked to rate all 98 listed answers (paper/pencil with answers printed in a table or online via the program Ariadne) for both (a) importance and (b) feasibility on a five-point Likert scale (1 = very unimportant/unfeasible, 2 = unimportant/unfeasible, 3 = neutral, 4 = important/feasible, 5 = very important/feasible). Ninety-three (34 females, 59 males) and 83 students (32 females, 50 males, 1 diverse) completed the importance and feasibility ratings, respectively. Furthermore, students were asked to cluster all 98 answers (paper/pencil with answers printed on cards or online via the program Ariadne) in two to ten self-titled topic groups based on similarities between answers, with at least two answers in each; a "miscellaneous" pile was not allowed. Based on their individual ID code, each student used a personal link to access the tasks in Ariadne. Eighty-four students (30 females, 53 males, 1 diverse) completed the clustering task. Results from students who worked on the paper/pencil version were entered into Ariadne by D.M.I.S.

2.2.2. Parents and Teachers

All concept mapping sessions for parents and teachers were conducted online at home, without researchers' supervision. Prior to each session, parents and teachers received an information letter. During each working period per session, parents and teachers received a reminder asking them to participate in the study, in case they had not done so already.

The first concept mapping session with parents and teachers took place in November and December 2019. Participants included 42 parents (34 females, 8 males) aged 47.8 ± 5.5 years and 27 teachers (14 females, 13 males) aged 39.4 ± 10.9 years. During the first concept mapping session, parents and teachers completed separate online questionnaires via the program Survalyzer. Each questionnaire was structured in three sections (see Tables A3 and A4): (1) personal characteristics, e.g., age and gender (see Tables A5 and A6), (2) a warm-up question (parents: why does or doesn't your child cycle to school?; teachers: why do or don't your students cycle to school?), and (3) the main question (parents: what does your child need to cycle to and from school daily?; teachers: what do your students need to cycle to and from school daily?). The warm-up question served as an icebreaker to introduce "cycling to school" to parents and teachers. For the main question, parents and teachers listed as many answers as they could. After the first session, D.M.I.S. created lists that included all unique answers provided by parents and teachers, respectively. The working process of D.M.I.S. was checked by a second researcher (parents: P.W.; teachers: L.D.), and any discrepancies were resolved through discussion. As a result, P.W./L.D. (checked by D.M.I.S. and C.V.) entered parents' 90 and teachers' 94 unique answers into Survalyzer.

Because they completed the online questionnaire at home, parents and teachers could not participate in group brainstorming on the main question. Thus, in January 2020, an additional session was conducted in which 29 parents (10 females, 4 males, 15 unknown) and 7 teachers (1 female, 4 males, 2 unknown) checked the clarity of answers to the main question. Furthermore, parents and teachers could add new answers if inspired by other participants' answers. After the second session, D.M.I.S. revised and combined their answers where necessary, based on parents/teachers' comments, and created final lists that included all unique answers provided by parents and teachers, respectively. The working process of D.M.I.S. was checked by a second researcher (parents: P.W.; teachers: L.D.), and any discrepancies were resolved through discussion. As a result, D.M.I.S. entered revised lists of 90 parents' answers and 94 teachers' answers into Ariadne.

The third concept mapping session took place in February 2020, and was completed by 12 parents (9 females, 2 males, 1 unknown) and 11 teachers (6 females, 5 males). Here, parents and teachers rated all 90 and 94 answers listed online, via Ariadne, for both (a) importance and (b) feasibility on a five-point Likert scale (1 = very unimportant/unfeasible, 2 = unimportant/unfeasible, 3 = neutral,

4 = important/feasible, 5 = very important/feasible). Twelve parents (9 females, 2 males, 1 unknown) and 10 teachers (5 females, 5 males) completed the importance and feasibility rating. Furthermore, parents and teachers were asked to cluster all 90 and 94 answers listed online, via Ariadne, in two to ten self-titled topic groups based on similarities between answers with at least two answers in each; a "miscellaneous" pile was not allowed. Based on their individual ID code, each parent and teacher used a personal link to access the tasks in Ariadne. The clustering task was completed by 11 parents (9 females, 1 male, 1 unknown) and 10 teachers (5 females, 5 males).

2.3. Statistical Analyses and Interpretation of Concept Maps

Descriptive data from students, parents, and teachers as well as these groups' statistical gender differences (female vs. male) were analyzed using the program IBM SPSS Statistics 25 [29]. Additionally, this program was used to determine the within and between variance of days per week students cycled to the three participating schools by calculating an intraclass correlation coefficient (ICC) [30]. In the development of future intervention designs, the ICC is relevant for dealing with potential variance among participating schools.

Only students, parents, and teachers who reported their gender as female or male, and completed at least one of the two rating tasks (importance or feasibility) or the clustering task were included in analyses. The small number of fathers completing rating tasks ($n = 2$) and the clustering task ($n = 1$) did not allow for separate data analysis. Each subgroup rated and clustered the same answers, and only the analysis was stratified by gender using Ariadne. D.M.I.S. looked at all possible options of clusters, illustrated in a hierarchical cluster tree, to define an adequate number of relevant clusters for the concept map. A hierarchical cluster tree arranges all answers in one cluster at first and suggests how this cluster can be further split into two, three, four, or more clusters based on how students, mothers, or teachers clustered the answers. When considered necessary, items were reallocated into already existing clusters (indicated by arrows) or newly created clusters (indicated by circles) to ensure plausibility of answers in clusters. These procedures were checked by a second researcher (students: S.M.; parents: P.W.; teachers: L.D.). Any discrepancies were resolved through discussion. Lastly, all clusters were named according to suggestions by students, mothers, and teachers. For each cluster, average ratings of both importance and feasibility were calculated and descriptively described. These average ratings were based on the mean individual rating of all answers in each cluster. As Ariadne did not provide the participants' individual rating of all answers in each cluster, the appropriate statistical test for ordinal data (U-test) was not applicable to analyze differences in ratings [31].

3. Results

3.1. Cycling Behavior in Students

In total, 87.8% of girls and 100% of boys owned a bicycle (see Table A2). However, 44.4% of girls and 72.9% of boys cycled to school, but of these, 68.4% of girls and 62.7% of boys did not cycle to school daily. Girls cycled to school on 1.6 ± 2.0 days a week and boys on 2.7 ± 2.0 days a week.

Within and between the three participating schools, the variance of days per week students cycled to school, calculated with an ICC for 114 valid girls and boys, was 0.2 (high school in an urban area with 7th graders: 40 students; junior high school in a suburban area with 7th and 8th graders: 34 students; junior high school in a suburban area with 8th graders: 40 students).

3.2. Concept Maps and Ratings

3.2.1. Students

The concept map of the 30 girls who completed the clustering task included the following five clusters, illustrating their needs to cycle to school daily (see Figure A1): (1) "Bicycle and related equipment" (30 answers), e.g., lock, bicycle, pump, helmet, bell, reflectors, lights, bicycle basket,

repair kit; (2) "Way to school" (20 answers), e.g., less traffic and roadworks, crossing guards, (wide, signposted, extra) cycle paths, (direct, shorter, simple, even) route; (3) "Requirements" (41 answers), e.g., health and environmental awareness, fun, motivation and energy, breathing fresh air, good weather conditions (no rain, warm temperatures), saving time, company of friends or classmates, later start of school lessons, liking own bicycle; (4) "Cycle training" (2 answers), e.g., cycling test, ensure cycling abilities; (5) "Social behavior in road traffic" (5 answers), e.g., more mutual respect, friendly car drivers, paying attention to avoid accidents or dangerous situations.

The concept map of the 53 boys who completed the clustering task included the following four clusters, illustrating their needs to cycle to school daily (see Figure A2): (1) "Bicycle and related equipment" (33 answers), e.g., lock, bicycle, pump, helmet, bell, reflectors, lights, bicycle basket, repair kit; (2) "Way to school" (23 answers), e.g., less traffic and roadworks, crossing guards, (wide, signposted, extra) cycle paths, (direct, shorter, simple, even) route; (3) "Requirements" (38 answers), e.g., health and environmental awareness, fun, motivation and energy, breathing fresh air, good weather conditions (no rain, warm temperatures), saving time, company of friends or classmates, later start of school lessons, liking own bicycle; (4) "Cycle training" (4 answers), e.g., cycling test, ensure cycling abilities, paying attention to avoid accidents or dangerous situations.

All four and five clusters identified in boys or girls, respectively, were rated as either unimportant/neutral or unfeasible/neutral on the Likert scale (see Table 1).

Table 1. Students' clusters and ratings of importance and feasibility by gender.

Name of Cluster	Rating of Importance		Rating of Feasibility	
	Girls (n = 34)	Boys (n = 59)	Girls (n = 32)	Boys (n = 50)
Bicycle and related equipment	3.4 ± 1.2	3.1 ± 1.3	3.5 ± 1.2	3.5 ± 1.4
Way to school	3.1 ± 1.2	2.9 ± 1.2	2.9 ± 1.3	2.8 ± 1.3
Requirements	3.0 ± 1.2	3.0 ± 1.4	2.9 ± 1.3	3.0 ± 1.4
Cycle training	3.6 ± 1.2	3.4 ± 1.3	3.7 ± 1.2	3.5 ± 1.4
Social behavior in road traffic	3.3 ± 1.2	-	3.1 ± 1.3	-

Means ± standard deviation.

3.2.2. Mothers

The concept map of the nine mothers who completed the clustering task included the following six clusters, illustrating their perceptions of what children and adolescents need to cycle to school daily (see Figure A3): (1) "Bicycle and related equipment" (26 answers), e.g., lock, (cool) bicycle, (cool) helmet, reflectors, (cool) signal clothing, (strip) lights, carrier systems, bicycle basket; (2) "Way to school" (24 answers), e.g., road lighting, (wide) cycle paths, less traffic, (uncomplicated, interesting, optimal) route, no large roadworks, crossing guards, combination of active and passive parts, speed limit; (3) "Requirements" (13 answers), e.g., health (awareness), sense of safety, self-confidence, knowledge of traffic rules, orientation skills, outdoor affinity, fitness, liking to cycle, cycling experiences; (4) "Motivation and social aspects" (12 answers), e.g., company of friends, classmates, or siblings (group trips with meeting points), sense of community, breathing fresh air; (5) "Role of the school" (7 answers), e.g., storage facilities, no vandalism, cycling projects, lighter schoolbag; (6) "Role of parents" (8 answers), e.g., trust, not taking the child to school by car, role models (obligatory helmet wearing, outdoor affinity).

All six clusters identified in mothers were rated as either unimportant/neutral or unfeasible/neutral/feasible on the Likert scale (see Table 2).

Table 2. Mothers' clusters and ratings of importance and feasibility (n = 9).

Name of Cluster	Rating of Importance	Rating of Feasibility
Bicycle and related equipment	3.5 ± 1.0	4.3 ± 0.7
Way to school	3.1 ± 1.0	2.9 ± 0.9
Requirements	3.5 ± 1.0	3.8 ± 0.7
Motivation and social aspects	2.5 ± 1.0	2.9 ± 0.9
Role of the school	3.5 ± 0.9	3.6 ± 0.9
Role of parents	2.9 ± 1.0	3.7 ± 0.9

Means ± standard deviation.

3.2.3. Teachers

The concept map of the five female teachers who completed the clustering task included the following nine clusters, illustrating their perceptions of what children and adolescents need to cycle to school daily (see Figure A4): (1) "Bicycle and related equipment" (20 answers), e.g., lock, (cool) bicycle, (cool) helmet, reflectors, pump, lights; (2) "Motivation and social aspects" (15 answers), e.g., fun, incentives (scoring system, tests, class contests), rewards (certificate, price), sense of community, positive experiences in road traffic, sport interest, role models (friends, parents, teachers, siblings, classmates), good weather conditions (no rain, warm temperatures); (3) "Awareness" (5 answers), e.g., health and environmental awareness, cycling is cool (trendsetting), seeing the bicycle as sport object and means of transportation; (4) "Financial aspects" (9 answers), e.g., financial support to buy a bicycle and related equipment, appropriate clothing or a bicycle pool for cycle trainings at school; (5) "Information and services" (10 answers), e.g., information about appropriate clothing (rain jacket, pants) and carrier systems, repair service and bicycle flea market at school, information evening on advantages (environment and climate, health and fitness, saving money for fuel and public transport tickets, mobility, and independence), cycle training including traffic rules, kick-off event, school projects; (6) "Way to school" (21 answers), e.g., road lighting, cycle paths, orientation skills, less traffic around the school, cycle path guide, nice route, group trips with meeting points for friends, speed limit; (7) "Storage and changing room" (8 answers), e.g., (roofed, monitored) bicycle rack, access to changing rooms; (8) "Role of parents" (4 answers), e.g., not taking the child to school by car, support, traffic education, confidence in child; (9) "Sense of safety" (2 answers), i.e., everyone can cycle to school.

The concept map of the five male teachers who completed the clustering task included the following five clusters, illustrating their perceptions of what children and adolescents need to cycle to school daily (see Figure A5): (1) "Bicycle and related equipment" (20 answers), e.g., lock, (cool) bicycle, (cool) helmet, reflectors, pump, lights; (2) "Motivation, social aspects and awareness" (27 answers), e.g., parents not taking the child to school by car, role models (friends, parents, teachers, siblings, classmates), health and environmental awareness, cycling is cool (trendsetting), incentives (scoring system, class contests), fun, parental support, group trips with meeting points for friends, rewards (certificate, price), sense of community, positive experiences in road traffic, giving the feeling that everyone can cycle, parental confidence in child, sport interest, seeing the bicycle as sport object and means of transportation, good weather conditions (no rain, warm temperatures), saving time; (3) "Financial aspects" (10 answers), e.g., financial support to buy a bicycle and related equipment, appropriate clothing or a bicycle pool for cycle trainings at school; (4) "Information and services" (12 answers), e.g., information about appropriate clothing (rain jacket, pants) and carrier systems, repair service and bicycle flea market at school, traffic education (cycle training including traffic rules and test), information evening on advantages (environment and climate, health and fitness, saving money for fuel and public transport tickets, mobility and independence), kick-off event, school projects; (5) "Infrastructure" (25 answers) including the "way to school" and "storage and changing room," e.g., (roofed, monitored) bicycle rack, road lighting, cycle paths, speed limit, less traffic around the school, cycle path guide, access to changing rooms, nice route.

All five and nine clusters identified in male or female teachers, respectively, were rated as either neutral/important or unfeasible/neutral/feasible on the Likert scale (see Table 3).

Table 3. Teachers' clusters and ratings of importance and feasibility by gender.

Name of Cluster	Rating of Importance		Rating of Feasibility	
	Female Teachers (n = 5)	Male Teachers (n = 5)	Female Teachers (n = 5)	Male Teachers (n = 5)
Bicycle and related equipment	3.6 ± 0.8	3.7 ± 0.7	3.5 ± 0.7	3.4 ± 0.7
Motivation and social aspects	3.6 ± 1.0	3.6 ± 0.8	3.6 ± 0.9	3.5 ± 0.6
Awareness	4.0 ± 0.9		4.0 ± 0.8	
Financial aspects	3.3 ± 0.9	3.3 ± 1.0	2.8 ± 0.9	2.8 ± 1.1
Information and services	3.2 ± 1.0	3.4 ± 0.7	4.2 ± 0.8	3.7 ± 0.7
Way to school	3.6 ± 0.9	3.6 ± 0.9	3.3 ± 0.7	3.2 ± 1.0
Storage and changing room	3.3 ± 1.2		3.6 ± 1.0	
Role of parents	4.1 ± 0.7	-	3.6 ± 0.8	-
Sense of safety	4.3 ± 0.7	-	4.0 ± 0.4	-

Means ± standard deviation.

4. Discussion

Our concept mapping study analyzed factors needed by children and adolescents aged 12 to 15 in Germany to ride their bicycles to school every day based on gender perspectives of students, parents, and teachers. We found that every boy but not every girl owned a bicycle; this should be considered in future interventions (e.g., provision of bicycles) because only students who own a bicycle can actually cycle to school. Additionally, considerably more boys than girls cycled to school, in line with previous research in Germany [11]. Despite asking a similar question in this study, however, cycling rates were much higher (girls: 44.4% vs. 20.6%, boys: 72.9% vs. 23.8%) [11], suggesting that rates of cycling to school might have changed from 2003–2006 [11] and 2019. Nevertheless, cycling to school was not a daily habit in our sample, indicating room for improvement. Even though our low ICC, calculated for the within and between variance of days per week students cycled to the three participating schools, is in line with previously reported ICCs for group-randomized intervention designs (0.1 to 0.3 [32]), very low ICCs of 0.05 or 0.01 can lead to a meaningful bias in the results of significance tests [30] due to variances. Following this, researchers should keep a potential variance in mind when planning a school-based bicycle intervention (i.e., several schools per intervention condition in group-randomized designs). Contrary to our intention, we could not analyze fathers' perspectives and compare them with mothers' data due to the small number of complete data for fathers. Between girls and boys, we found one difference in clustering. Only girls clustered answers into "social behavior in road traffic." For each cluster, ratings of importance and feasibility were very similar in girls and boys. Between female and male teachers, we found differences in four clusters. Male teachers classified clusters into broader subjects, i.e., the cluster "motivation and social aspects" included "awareness" and the cluster "infrastructure" included "way to school" as well as "storage and changing room." Only female teachers clustered answers into "role of parents" and "sense of safety." For each cluster, ratings of importance and feasibility were very similar in female and male teachers.

4.1. Clusters in Concept Maps

4.1.1. Similar Clusters in Concept Maps of Mothers and Students and Teachers Independent of Gender

The need for a "bicycle and related equipment" (e.g., lock, bicycle, helmet, reflectors, lights) was stated by students, teachers, and mothers. When children and adolescents want to cycle to school, the basic necessity of bicycle ownership is indisputable. As every boy and nearly every girl in our sample owned a bicycle, providing all students in our sample with a bicycle in a future intervention does not seem necessary. Regarding bicycle-related equipment, previous research remained unclear on

whether "the equipment of a child's bicycle is a potential determinant of cycling to school" [33] (p. 290). Nevertheless, the only overall effective bicycle intervention in our recent systematic review [12] was conducted in the USA and provided every child with a bicycle and related equipment (i.e., helmet, lock, lights) prior to the beginning of the intervention [34,35]. In our study, girls rated a lock and brakes as important equipment, whereas boys rated only a lock as important equipment. According to German Road Traffic Licensing Regulations, researchers might provide specific equipment (i.e., a bell, two independent brakes, two anti-slip and screwed-on pedals with two yellow reflectors shining to the front and rear, white front and red rear light, two reflectors per wheel, white front, and a red rear reflector [36]) to ensure the roadworthiness and safety of bicycles in an intervention.

Factors related to the "way to school," such as less traffic (especially around the school), (wide, signposted, extra) cycle paths, a cycle path guide, and an even route, were identified across all concept maps of students, teachers, and mothers. Traffic density and type of cycle paths (e.g., evenness) were reported as the most important factors for a cycling-friendly environment for children in previous research [37]. In addition, a cycle path guide (e.g., parental accompaniment while cycling) was positively associated with cycling behavior in children [38]. Comprehensive changes related to the way to school in school-based interventions require the involvement of municipal stakeholders.

Personal needs were represented in the cluster of students as "requirements" (e.g., motivation, company of friends or classmates), in the clusters of teachers as "motivation and social aspects" and "awareness," and in clusters of mothers as "requirements" and "motivation and social aspects." Because previous research also underlined the role of personal factors [39], it might be relevant to address the three basic psychological needs "autonomy, competence, and relatedness" of Self-Determination Theory [40] in future interventions with children and adolescents for long-term internalization of cycling-to-school behavior.

4.1.2. Unique Clusters in Concept Maps of Students (In) Dependent of Gender

"Cycle training" (e.g., cycling test, ensure cycling abilities) was identified by both girls and boys. To overcome barriers to cycle to school, cycle training is recommended by the "NZ Transport Agency" [41]. However, results from a previous study demonstrated that providing only cycle training on the school playground during physical education lessons was not effective in children's cycling-to-school behavior [42]. Following this, cycle training content should not only be chosen carefully based on needs mentioned by students but should also be implemented in the natural environment in future interventions to promote cycling to school.

The cluster "social behavior in road traffic" (e.g., more mutual respect, friendly car drivers, paying attention to avoid accidents or dangerous situations) was mentioned only by girls. Besides theoretical knowledge of traffic rules and practical cycling skills, social competences are considered essential for responsible and anticipated participation in road traffic by the "Standing Conference of the Ministers of Education and Cultural Affairs" (KMK) in Germany [43]. To acquire these competences, the KMK assigns mobility and traffic education to schools [43]. The reason boys did not mention this cluster might be explained by the observation in Germany that boys have a higher risk of injury in road traffic (accidents) due to more risky behavior than girls [44]. Therefore, the topic "social behavior in road traffic" is an important element in mobility and traffic education (especially for boys to reflect on the impact of their gender role) [44].

4.1.3. Similar and Unique Clusters in Concept Maps of Mothers, and Teachers (In) Dependent of Gender

Mothers and female teachers mentioned the "role of parents," e.g., not taking the child to school by car. Several theoretical models, for example, the M-CAT [14] or the "Social-ecological model of the correlates of active transportation" [45], consider parents' role as supporters or decision-makers. However, this role's impact decreases as the child matures [14]. Additionally, the 12- to 15-year-olds in our sample did not acknowledge their parents' role. Therefore, future interventions for this age

group should empower parents to support children's need for autonomy, independence, and personal responsibility regarding mobility.

In line with theoretical models [14,45], mothers mentioned the cluster "role of the school" (e.g., storage facilities, no vandalism, cycling projects, lighter schoolbags). Additionally, the KMK has defined the teaching and educational role of mobility and traffic in schools [43], but neither students nor teachers acknowledged this. Therefore, the role of schools should be emphasized in future school-based bicycle interventions.

Mentioned by both female and male teachers, "storage and changing room" referred, for example, to a roofed and monitored bicycle rack or access to changing rooms. Even though students and mothers did not identify this cluster, the lack of or poor quality changing rooms and bicycle racks in schools have been previously reported to influence children and adolescents' PA behavior negatively [19]. Students and mothers might not have identified this need if they were satisfied by conditions at their school, but it might be relevant at schools with poor conditions.

Independent of gender, teachers identified the need for "financial aspects" (e.g., financial support to buy a bicycle and related equipment, appropriate clothing, or a bicycle pool for cycle trainings at school). In line with this, M-CAT states parents' income as a relevant factor for ACTS [14]. However, mothers and students did not mention this cluster, so financial aspects might not be a major issue for parents (who bear financial responsibility) or for students. Our assumption might be reflected in students' pervasive bicycle ownership because in our study sample, every boy owned a bicycle and only 12.2% of girls did not. This also makes it unnecessary to provide an entire bicycle pool for cycle training at the three participating schools.

Independent of gender, teachers identified the need for "information and services," e.g., information about appropriate clothing (rain jacket, pants) and carrier systems, repair service and a bicycle flea market at school, an information evening on advantages (environment and climate, health and fitness, saving money for fuel and public transport tickets, mobility and independence), cycle training including traffic rules, a kick-off event, and school projects (bicycle tour, project day). In grades 5 to 10 (students aged 10 to 15), the KMK explicitly mentions the provision of informational manuals and materials (e.g., about environment and climate), implementation of activities (e.g., ecological school trips), and cooperation with out-of-school partners (e.g., bicycle repair shops) to promote students' independent mobility [43]. However, provision of information and services might be feasible but not crucial in the development of future school-based bicycle interventions. Perhaps this is why students and mothers did not consider this need relevant.

Clusters between female and male teachers differed as only female teachers clustered answers into "sense of safety," i.e., giving the feeling that everyone can use a bicycle to engage in ACTS. As an important barrier to ACTS, children's personal safety fears were also identified in previous research [39], and this cluster might be reflected in students' identified needs for cycle training and social behavior in road traffic. Thus, future school-based bicycle interventions should attempt to establish feelings of safety among students.

4.2. Importance and Feasability

Across students, mothers, and teachers, Likert scale ratings of the degree of importance and feasibility of their provided answers showed not a single extreme response, i.e., very (un) important or (un) feasible. Participants noticeably tended to choose the unimportant/unfeasible or neutral rating categories so that ratings were very similar. Undecidedness [46], lack of motivation [47] due to the large number of participants' answers (students: 98; parents: 90; teachers: 94) that had to be rated, or a question not specific enough [48] might have led to this central tendency bias. Therefore, findings on ratings should be interpreted with caution.

4.3. Strengths and Limitations

Quantitative analysis of qualitative data in the concept mapping approach could be seen as a strength of this study. Additionally, stratified gender analyses provide a deeper understanding of different perspectives on what is needed for cycling to school. We found one and two unique gender-dependent cluster(s) in students and teachers, respectively. A limitation might be that group sessions were not conducted separately for females and males. Moreover, we could not include grades 7 and 8 in each session at every school since the schools decided the participating grades. Contrary to our previous intention, teachers did not allow us to divide classes of 22 to 32 into smaller groups of 8 to 10 students. This made conducting sessions challenging in terms of personnel, time, and resources (e.g., sufficient computers, stable internet connections) but led to a higher student recruitment rate (i.e., planned: 48; recruited: 136), which is a major strength. In general, participants were interested in the concept mapping sessions and liked getting involved by providing their opinions, which gave us an insight into their perceptions. This might explain why we also exceeded our recruitment goals for parents and teachers (58 and 29 instead of 25 each). Interestingly, more mothers than fathers contributed to the concept mapping sessions. This gender bias in our online survey's response rate aligns with previous research [49] and might be explained by differences in perceived parenting responsibilities. Due to small sample sizes as well as high drop-out rates of parents and teachers and to the few regions sampled in Germany, our findings cannot be generalized and might differ in comparison with other nations. Nevertheless, studies using the concept mapping approach in very small samples of five to eight participants are not unusual [50].

Throughout our sessions, we were confronted with several difficulties. Participants complained about the time-consuming involvement (e.g., too many answers), the type of survey (i.e., paper/pencil) and other participants' "absurd" answers (e.g., "I need training wheels"). Furthermore, non-native speakers (e.g., refugees) struggled especially with the amount of information in German. Generally, participants also found it difficult to separate ratings between importance and feasibility. In addition, participants struggled with rating tasks when answers were not applicable to their situations (e.g., students, whose parents were not worried, struggled how to rate "reduction of fear in parents"). Due to technical failures that occurred throughout the sessions with both online programs (Survalyzer, Ariadne), we could not ensure completeness of data (an inclusion criterion for Ariadne analyses). Some of these difficulties might have led to a lowered willingness and motivation to participate, thus possibly explaining the central tendency bias in importance and feasibility ratings and the relatively high drop-out rates, particularly in parents (79.3%) and teachers (62.1%), in contrast with students (26.5%).

4.4. Recommendations

Based on our experience from this study, we recommend modifying the concept mapping approach for such a complex subject and/or for its application in large groups due to school rules. To achieve participants' maximum commitment and to reduce their burden, we suggest conducting all sessions online (especially the clustering task), but in school groups supervised by researchers to ensure personal contact. Another advantage of online sessions is the immediate digital availability of collected data, which eliminates the risk of errors in transferring data manually. We further recommend removing the second online session in which participants check the clarity of answers. Instead, the first online session could be completed with a group brainstorming phase including a clarity check and a removal of duplicates. To make "ACTS by bicycle" less complex for participants (i.e., fewer answers), the main question in the first session could be specified according to factors in the "Social-ecological model of the correlates of active transportation" [45] (e.g., the needs in terms of environmental factors only). Still, to acquire a comprehensive picture of needs, the concept mapping approach could be conducted for each factor of this model based on more specific questions in different samples (e.g., different classes) in the same schools. Another possibility could be to restrict the number of answers to a more

manageable number (e.g., 40 to 70) [51] by checking duplicates more strictly and combining answers after session one.

To maintain participants' motivation and to address their need for time efficiency, each provided answer could be immediately rated for importance and feasibility. In the second study session, we changed this when students received the paper/pencil version and reflected positive experiences with the procedure. Future studies could optimize rating tasks to avoid central tendency bias and inconclusive findings by replacing the five-point Likert scale with an even-point scale, i.e., a scale without a midpoint, which forces participants to choose positively or negatively. Independent of language skills, the majority of students had problems answering the question about frequency of "cycling to school (days/week)" because they cycled every day in the summer but took the bus or train in the winter. These seasonal differences align with previous Norwegian findings that reported large variations in fall (52%), winter (3%), spring (51%) [52], and in summer (22%) compared to winter (12%) [53]. Therefore, we highly recommend modifying this question to consider potential seasonal variations in surveys and to take different weather conditions into account when developing an intervention. Finally, the program Ariadne appeared to be prone to error and was perceived to be user-unfriendly, so we recommend that this program be improved for future concept mapping studies.

5. Conclusions

This study provides insight into the perceptions of girls and boys, mothers, and female and male teachers on what 12- to 15-year-old children and adolescents living in Germany need to cycle daily to school. Between genders, we found more overall similarities than differences in clusters. Students and teachers, independent of gender, and mothers mentioned the need for "bicycle and related equipment," "way to school," and "personal factors." Additionally, independent of gender, students identified "cycle training" and teachers a "storage and changing room," "financial aspects," and "information and services" as children and adolescents' needs. Furthermore, girls identified the need for "social behavior in road traffic," mothers and female teachers the "role of parents," and female teachers the "sense of safety." However, boys and male teachers did not mention these three needs. Only mothers clustered the "role of the school." Furthermore, we found bias in clusters' importance and feasibility ratings and could not draw final conclusions. Nevertheless, we hope that the combined perceptions complement each other to support the uptake and long-term maintenance of ACTS by bicycle. Our findings can be used to inform students, mothers, and teachers about their mutual perceptions and can help researchers develop school-based interventions to promote daily cycling to school.

Author Contributions: D.M.I.S. was responsible for the preparation, data collection, analyses, and interpretation of concept mapping sessions. Moreover, she drafted the manuscript. C.V. assisted in preparation and data collection. L.M.H., T.M.A. and M.J.M.C. designed the study's methodological process. Furthermore, L.M.H. advised D.M.I.S. in the methodological process and in the analyses using the program Ariadne. Y.D. acquired funding for the project and was involved in the study's preparation. C.V., L.M.H., T.M.A., M.J.M.C. and Y.D. commented on the manuscript. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A1. Overview of sections, questions, and response options of the first concept mapping session with students.

Section	Questions	Response Option(s)
Personal characteristics	age (years)	open-end
	gender	(a) female (b) male (c) diverse
	school's region	(a) urban (b) suburban
	school's zip-code	open-end
	educational level	(a) high school (b) junior high school
	class level	(a) 7 (b) 8
	bicycle ownership	(a) yes (b) no
	ability to cycle	(a) yes (b) no
	cycling to school	(a) yes (b) no
	cycling to school (days/week)	0–5
	shortest cycling distance home/school (km [1])	open-end
Warm-up question	Why do or don't you cycle to school?	open-end
Main question	What do you need to cycle to and from school on a daily basis?	open-end

[1] km = kilometer.

Table A2. Personal characteristics of participating students by gender.

Personal Characteristics	Female (n = 51)	Male (n = 83)	p-Value [3]	Diverse (n = 2)	Response Rate (N = 136)
Age (years in M ± SD [1])	13.1 ± 0.9	13.1 ± 0.9	0.778	13.0 ± 0.000	123
Educational level (school's region)					
(a) high school (urban)	13 (25.5%)	31 (37.3%)	0.156	0 (0%)	136
(b) junior high school (suburban)	38 (74.5%)	52 (62.7%)		2 (100%)	
Class level					
(a) 7th grade	22 (43.1%)	44 (53.0%)	0.267	0 (0%)	136
(b) 8th grade	29 (56.9%)	39 (47.0%)		2 (100%)	
Bicycle ownership					
(a) yes	43 (87.8%)	72 (100%)	0.004 **	2 (100%)	123
(b) no	6 (12.2%)	0 (0%)		0 (0%)	
Ability to cycle					
(a) yes	49 (100%)	72 (100%)	n.a. [4]	2 (100%)	123
(b) no	0 (0%)	0 (0%)		0 (0%)	
Cycling to school					
(a) yes	20 (44.4%)	51 (72.9%)	0.002 **	1 (50.0%)	117
(b) no	25 (55.6%)	19 (27.1%)		1 (50.0%)	
Cycling to school (days/week in M ± SD [1])	1.6 ± 2.0	2.7 ± 2.0	0.003 **	1.5 ± 2.1	116
Shortest cycling distance home/school (km [2] in M ± SD [1])	3.3 ± 2.6	4.0 ± 3.1	0.307	8.0 ± 9.9	122

[1] means ± standard deviation, [2] km = kilometer, [3] p-values were calculated for gender differences (female vs. male) using U-test or Chi-squared tests, [4] n.a. = not applicable, ** = $0.01 \geq p > 0.001$.

Table A3. Overview of sections, questions, and response options of the first concept mapping session with parents.

Section	Question(s)	Response Option(s)
Personal characteristics	age (years)	open-end
	gender	(a) female (b) male (c) diverse
	age of child (years)	(a) 12 (b) 13 (c) 14 (d) other
	gender of child	(a) daughter (b) son
	child's school region	(a) urban (b) suburban
	child's school zip-code of child	open-end
	educational level of child	(a) high school (b) junior high school
	class level of child	(a) 7 (b) 8
	bicycle ownership of child	(a) yes (b) no
	child's ability to cycle	(a) yes (b) no
	cycling to school of child	(a) yes (b) no
	cycling to school of child (days/week)	0–5
	shortest cycling distance home/school of child (km [1])	open-end
	bicycle ownership	(a) yes (b) no
	ability to cycle	(a) yes (b) no
	work (days/week)	0–5
	cycling to work	(a) yes (b) no
	cycling to work (days/week)	0–5
	shortest cycling distance home/work (km [1])	open-end
Warm-up question	Why does or doesn't your child cycle to school?	open-end
Main question	What does your child need to cycle to and from school daily?	open-end

[1] km = kilometer.

Table A4. Overview of sections, questions, and response options of the first concept mapping session with teachers.

Section	Question(s)	Response Option(s)
Personal characteristics	age (years)	open-end
	gender	(a) female (b) male (c) diverse
	work experience (years)	open-end
	school's region	(a) urban (b) suburban
	school's zip-code	open-end
	educational level	(a) high school (b) junior high school
	class level of target group	open-end
	cycling to school of target group (%)	open-end
	cycling to school of target group (days/week)	0–5
	bicycle ownership	(a) yes (b) no
	ability to cycle	(a) yes (b) no
	work (days/week)	0–5
	cycling to work	(a) yes (b) no
	cycling to work (days/week)	0–5
	shortest cycling distance home/work (km [1])	open-end
Warm-up question	Why do or don't your students cycle to school?	open-end
Main question	What do your students need to cycle to and from school daily?	open-end

[1] km = kilometer.

Table A5. Personal characteristics of participating parents by gender.

Personal Characteristics	Female (n = 35)	Male (n = 8)	p-Value [3]	Response Rate (N = 43)
Age (years in M ± SD [1])	46.8 ± 5.1	52.1 ± 5.2	0.034 *	42
Age of child (years in M ± SD [1])	12.6 ± 0.7	13.0 ± 0.8	0.145	42
Gender of child				
(a) daughter	(a) 12 (34.3%)	(a) 3 (37.5%)	1	43
(b) son	(b) 23 (65.7%)	(b) 5 (62.5%)		
Educational level (school's region) of child				
(a) high school (urban)	(a) 15 (42.9%)	(a) 4 (50.0%)	1	43
(b) junior high school (suburban)	(b) 20 (57.1%)	(b) 4 (50.0%)		

Table A5. *Cont.*

Personal Characteristics	Female (n = 35)	Male (n = 8)	p-Value [3]	Response Rate (N = 43)
Class level of child				
(a) 7th grade	(a) 23 (65.7%)	(a) 6 (75.0%)	1	43
(b) 8th grade	(b) 12 (34.3%)	(b) 2 (25.0%)		
Bicycle ownership of child				
(a) yes	(a) 34 (100%)	(a) 8 (100%)	n.a. [4]	42
(b) no	(b) 0 (0%)	(b) 0 (0%)		
Child's ability to cycle				
(a) yes	(a) 34 (100%)	(a) 8 (100%)	n.a. [4]	42
(b) no	(b) 0 (0%)	(b) 0 (0%)		
Cycling to school of child				
(a) yes	(a) 22 (66.7%)	(a) 5 (71.4%)	1	40
(b) no	(b) 11 (33.3%)	(b) 2 (28.6%)		
Cycling to school of child (days/week in M ± SD [1])	2.6 ± 2.3	3.1 ± 2.2	0.985	40
Shortest cycling distance home/school of child (km [2] in M ± SD [1])	4.3 ± 3.2	5.2 ± 3.2	0.432	42
Bicycle ownership				
(a) yes	(a) 33 (97.1%)	(a) 8 (100%)	1	42
(b) no	(b) 1 (2.9%)	(b) 0 (0%)		
Ability to cycle				
(a) yes	(a) 34 (100%)	(a) 8 (100%)	n.a. [4]	42
(b) no	(b) 0 (0%)	(b) 0 (0%)		
Work (days/week in M ± SD [1])	3.7 ± 1.5	4.9 ± 0.4	0.004 **	42
Cycling to work				
(a) yes	(a) 12 (40.0%)	(a) 4 (50.0%)	0.698	38
(b) no	(b) 18 (60.0%)	(b) 4 (50.0%)		
Cycling to work (days/week in M ± SD [1])	1.3 ± 1.9	1.8 ± 2.2	0.549	38
Shortest cycling distance home/work (km [2] in M ± SD [1])	13.0 ± 14.4	7.9 ± 5.5	0.676	39

[1] means ± standard deviation, [2] km = kilometer, [3] p-values were calculated for gender differences (female vs. male) using U-test or Chi-squared tests, [4] n.a. = not applicable, * = $0.05 \geq p > 0.01$, ** = $0.01 \geq p > 0.001$.

Table A6. Personal characteristics of participating teachers by gender.

Personal Characteristics	Female (n = 14)	Male (n = 13)	p-Value [4]	Response Rate (N = 27)
Age (years in M ± SD [1])	43.3 ± 11.5	35.3 ± 8.9	0.068	27
Work experience (years in M ± SD [1])	15.2 ± 12.0	7.2 ± 5.6	0.068	27
Educational level (school's region)			0.12	27
(a) high school (urban)	(a) 3 (21.4%)	(a) 7 (53.8%)		
(b) junior high school (suburban)	(b) 11 (78.6%)	(b) 6 (46.2%)		
Class level of target group (min/max [2])	6–9	6–9	n.a. [5]	27
Cycling to school of target group (% in M ± SD [1])	40.0%	20.0% ± 15.8%	0.277	5
Cycling to school of target group (days/week in M ± SD [1])	5.0	4.0 ± 0.8	0.264	5
Bicycle ownership			1	27
(a) yes	(a) 13 (92.9%)	(a) 13 (100%)		
(b) no	(b) 1 (7.1%)	(b) 0 (0%)		
Ability to cycle			n.a. [5]	27
(a) yes	(a) 14 (100%)	(a) 13 (100%)		
(b) no	(b) 0 (0%)	(b) 0 (0%)		
Work (days/week in M ± SD [1])	4.1 ± 0.8	4.9 ± 0.4	0.008 **	27
Cycling to work			0.107	26
(a) yes	(a) 6 (46.2%)	(a) 10 (76.9%)		
(b) no	(b) 7 (53.8%)	(b) 3 (23.1%)		
Cycling to work (days/week in M ± SD [1])	1.6 ± 2.1	2.8 ± 2.2	0.127	26
Shortest cycling distance home/work (km [3] in M ± SD [1])	8.9 ± 7.8	13.0 ± 12.9	0.382	27

[1] means ± standard deviation, [2] min/max = minimum/maximum, [3] km = kilometer, [4] p-values were calculated for gender differences (female vs. male) using U-test or Chi-squared tests, [5] n.a. = not applicable, ** = $0.01 \geq p > 0.001$.

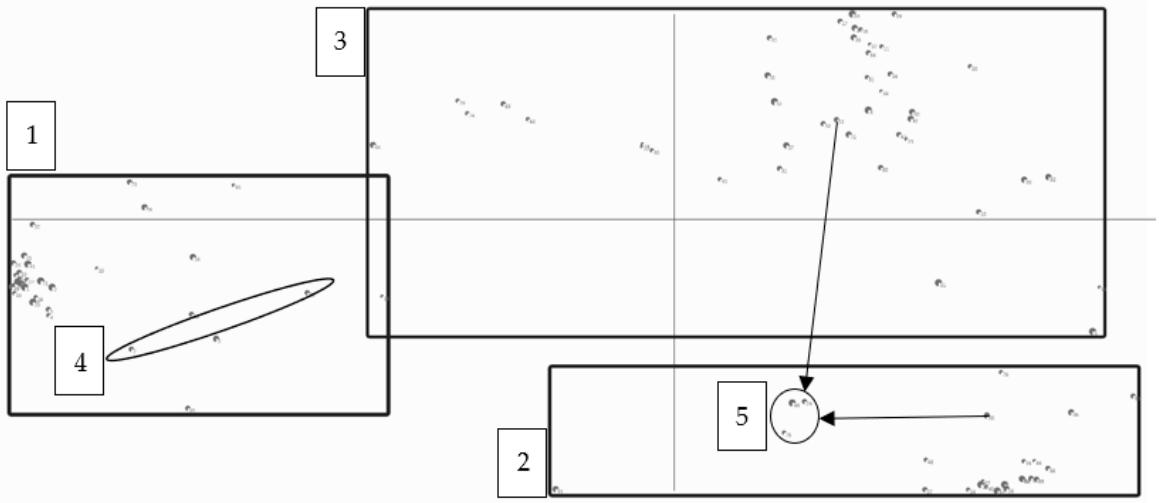

Figure A1. Concept map of girls (n = 30). Cluster 1: "bicycle and related equipment." Cluster 2: "way to school." Cluster 3: "requirements." Cluster 4: "cycle training." Cluster 5: "social behavior in road traffic." A square indicates an original cluster, and a circle indicates a newly created cluster. An arrow indicates reallocation of an answer (illustrated as a dot) into another cluster.

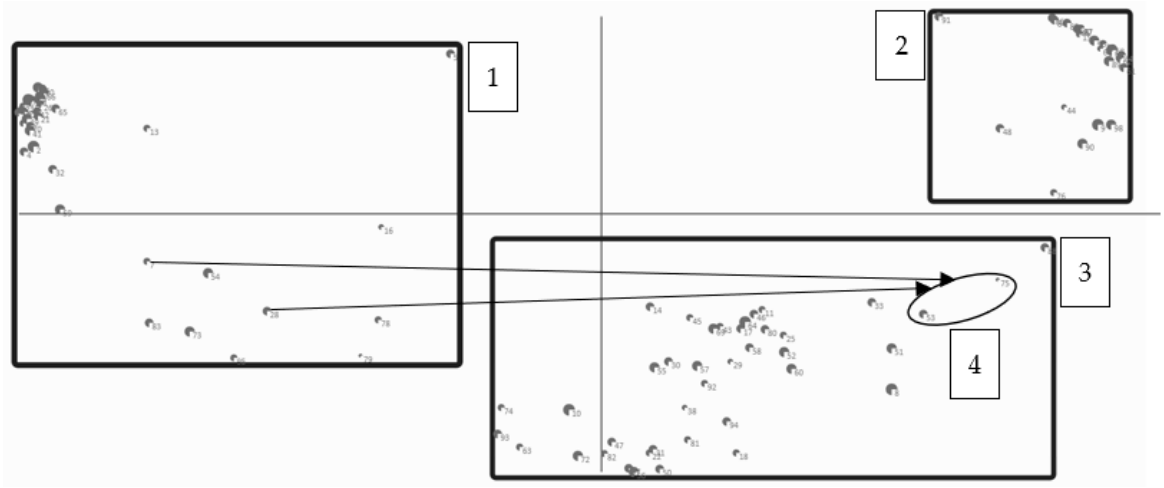

Figure A2. Concept map of boys (n = 53). Cluster 1: "bicycle and related equipment." Cluster 2: "way to school." Cluster 3: "requirements." Cluster 4: "cycle training." A square indicates an original cluster, and a circle indicates a newly created cluster. An arrow indicates reallocation of an answer (illustrated as a dot) into another cluster.

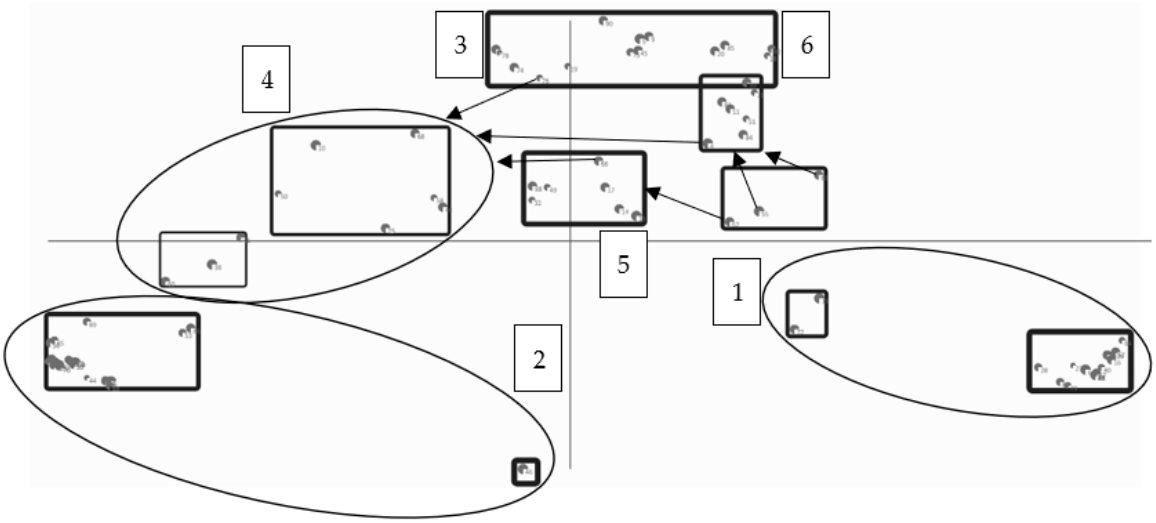

Figure A3. Concept map of mothers (n = 9). Cluster 1: "bicycle and related equipment." Cluster 2: "way to school." Cluster 3: "requirements." Cluster 4: "motivation and social aspects." Cluster 5: "role of the school." Cluster 6: "role of parents." A square indicates an original cluster, and a circle indicates a newly created cluster. An arrow indicates reallocation of an answer (illustrated as a dot) into another cluster.

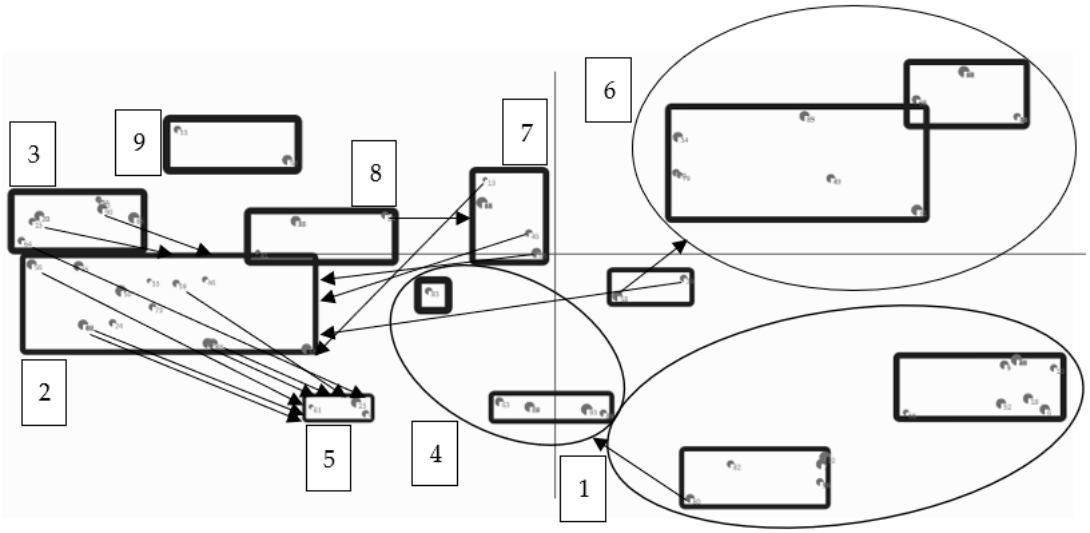

Figure A4. Concept map of female teachers (n = 5). Cluster 1: "bicycle and related equipment." Cluster 2: "motivation and social aspects." Cluster 3: "awareness." Cluster 4 "financial aspects." Cluster 5: "information and services." Cluster 6: "way to school." Cluster 7: "storage and changing room." Cluster 8: "role of parents." Cluster 9: "sense of safety." A square indicates an original cluster, and a circle indicates a newly created cluster. An arrow indicates reallocation of an answer (illustrated as a dot) into another cluster.

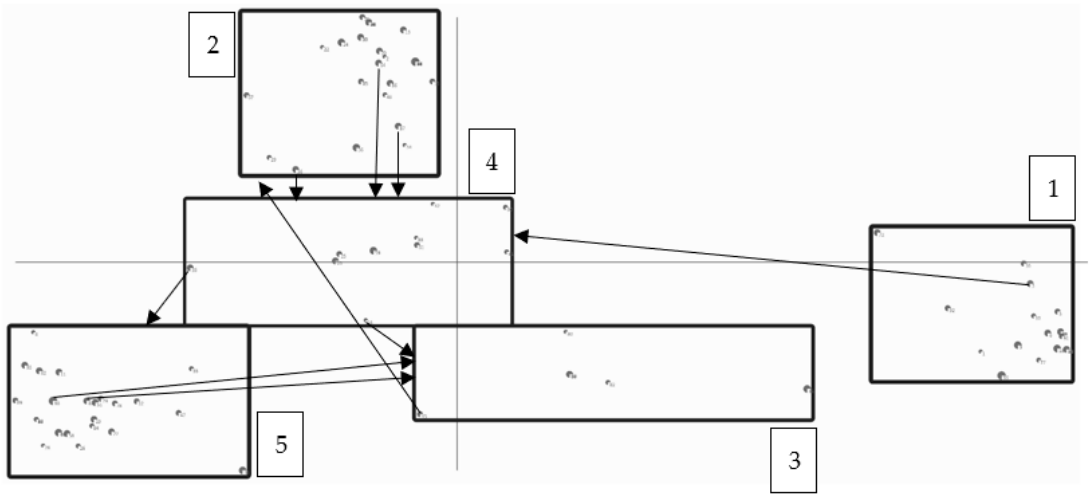

Figure A5. Concept map of male teachers (n = 5). Cluster 1: "bicycle and related equipment." Cluster 2: "motivation, social aspects and awareness." Cluster 3: "financial aspects." Cluster 4: "information and services." Cluster 5: "infrastructure." A square indicates an original cluster. An arrow indicates reallocation of an answer (illustrated as a dot) into another cluster.

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Article

Socio-Demographic Correlates of Cycling to School among 12- to 15-Year Olds in Southern Germany

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Abstract: Depending on the region and urbanization level, the rate of cycling to school in Germany varies largely. The influence of distance from home to school, educational level, the school's region, and parents' socio-demographic characteristics on cycling to secondary school in Germany is unclear. Therefore, this study analyzed students' and parents' socio-demographic correlates of cycling to school, including separate analyses by gender, among 12- to 15-year-olds attending different (sub)urban schools in Southern Germany. In 2019, 121 students (girls: 40.5%, boys: 59.5%) aged 13.1 ± 0.9 and 42 parents (mothers: 81%, fathers: 19%) aged 47.8 ± 5.5 participated. Students completed a self-report questionnaire; parents completed a self- and proxy-report questionnaire. In total, between 61.7% and 67.5% of students sometimes cycled to school. Binary logistic regressions revealed that being a girl, increasing age, attending an intermediate educational level combined with a suburban school region (small or medium-sized town), increasing distance from home to school, and having parents who did not cycle to work led to declining odds of cycling to school. Many 12- to 15-year-olds sometimes cycled to school in (sub)urban school regions in Southern Germany. As several socio-demographic characteristics correlated with cycling to school, this should be considered when developing a future school-based bicycle intervention.

Keywords: associations; girls; boys; mothers; fathers; bicycle; active commuting to school

1. Introduction

Physical activity (PA) has positive impacts on physical, psychosocial, and cognitive health in children and adolescents aged 5 to 17 [1]. Nevertheless, only 26% of children and adolescents (girls: 22.4%; boys: 29.4%) aged 3 to 17 in Germany achieve the PA guidelines of the World Health Organization [2]. Children and adolescents aged 5 to 15 who cycle to school have the highest chance to achieve these guidelines weekly (cyclists: 36%; walkers: 25%, neither cyclists nor walkers: 22%) [3]. Additionally, cardiorespiratory [4–6] as well as cardiovascular fitness [7] are positively associated with cycling to school in children and adolescents, possibly due to a higher intensity of PA [7]. A higher PA intensity is associated with more solid health benefits in children and adolescents [1]. Therefore, cycling to school might have better health-related outcomes than other means of transportation.

Previous studies conducted in Germany between 2003 and 2019 reported different rates of cycling to school, especially among adolescents. In nationwide representative samples of 11- to 17-year olds,

the rate of cycling to school was consistently low but slightly increased [8,9]. Between 2003 and 2006, 22.2% within this age group (girls: 20.6%, boys: 23.8%) usually cycled to school [8], while 21.5% of girls and 25.2% of boys usually cycled to school between 2014 and 2017 [9]. In a regionally representative study conducted in a city located in Northern Germany, 50% of adolescents aged 14 typically cycled to school between 2004 and 2005 [10]. Another regionally representative study conducted in a city located in Southern Germany in 2005 showed that 8% of students from grades 3 to 13 cycled to school daily [11]. In our recent non-representative study from 2019, conducted in a small town, a medium-sized town and a city located in Southern Germany, 44.4% of girls and 72.9% of boys aged 12 to 15 sometimes cycled to school [12]. Following this, the rate of cycling to school among children and adolescents in Germany varies largely depending on the context, i.e., sampled region(s) and the level of urbanization. According to the Global Matrix 3.0, Germany was graded with C– based on reports that ca. 40% of children and adolescents use active modes to commute to school [13].

We chose the age range 12 to 15 as a study conducted in Finland between 1980 and 2007 found that the rate of active commuting to school (ACTS), including both walking and cycling, decreased sharply between the ages of 12 and 15 [14], suggesting that this age range might be a high-risk population. Similar findings were reported for cycling to school in a study conducted in Colombia where more children up to 12 years cycled to school compared with adolescents aged 13 and older [15]. However, we reported very high rates of cycling to school among 12- to 15-year olds in our recent study [12], suggesting that the contexts in which cycling to school occurs also vary by countries.

In the model of children's active travel (M-CAT), characteristics of the child (e.g., gender, age, or school attended) and its parents (e.g., employment or socioeconomic status (SES)) impact the decision-making process to actively travel to school [16]. Furthermore, M-CAT highlights the influence of those characteristics (e.g., gender) on the perceptions of the child and its parents, which affects the ultimate decision of the child to actively travel to school while taking into account how parents had decided on allowance or restriction [16]. With increasing age of the child, the influence of its parents' decision decreases [16]. In particular for cycling to school, previous studies have identified age [3,9,15,17], gender [3,8,11,15,17,18], migration background [8,19], weight status [19–21], distance from home to school [11,22,23], residential area [8], SES [9,24], and child's [11]/parents' educational level [15] as socio-demographic correlates. However, the contributing role of distance from home to school among secondary school students has only been examined for one city in Germany [11]. Moreover, the influence of the child's educational level on cycling to school among secondary school students has only been examined for one city in Germany [11] and never in other countries. The role of parents' socio-demographic characteristics is generally unclear, not only in Germany. Additionally, the school's region has never been studied in previous research up to now, neither in Germany nor in other countries.

Thus, this study aimed to determine the correlations of students' and parents' socio-demographic characteristics with habits of cycling to school among 12- to 15-year olds attending different educational levels of schools located in different (sub)urban regions in Southern Germany and to analyze correlates concerning the gender of students as well as parents. When identifying those correlates of cycling to school, researchers can address them in future school-based bicycle interventions.

2. Methods

2.1. Study Design

We analyzed data from 121 out of 154 students (49 girls, 72 boys) aged 13.1 ± 0.9 (see Table A1) and 42 parents (34 mothers, 8 fathers) aged 47.8 ± 5.5 (see Table A3) from a study conducted in Germany in 2019 aiming to understand what is needed to cycle to school daily according to students, parents, and teachers [12]. Data was collected at three secondary schools, each including two classes of seventh and/or eighth graders aged 12 to 15, with two different educational levels (intermediate = two schools, high = one school) located in urban (one school in a city with 1.5 m inhabitants) and

suburban (one school in a small town with 13,000 inhabitants and one school in a medium-sized town with 21,000 inhabitants) regions in Southern Germany. The medium-sized town and city were rated as (in)sufficient in a ranking for the satisfaction of cyclists in Germany [25], whereas no scientific evaluation on bikeability is available for the small town. However, the bicycle-friendliness for students in the small town appears to be rather low as there are no bicycle lanes.

2.2. Data Collection

The study comprised a sample of students and a sample of their parents. Both questionnaires were delivered independently of each other. Parents received an information letter and provided signed consent forms for themselves and on behalf of their child before the beginning of data collection. Prior to data collection, students and parents were instructed to produce a five-digit ID-code themselves, respectively, which ensured anonymity. Students completed a printed or online version of the questionnaire via the program Survalyzer (Survalyzer AG, Zurich, Switzerland) [26] at school, supervised by at least one trained researcher (D.M.I.S./C.B.). Parents completed an online version of the questionnaire via Survalyzer at home.

2.3. Measures

2.3.1. Socio-Demographic Characteristics and Cycling to School in the Sample of Students

Based on self- and proxy-reported correlates of cycling to school in children and adolescents found in previous studies [3,8,9,11,15,17,18,22,23] as well as in a child and parental questionnaire on specific determinants of cycling to school [27], students were asked to provide the following socio-demographic characteristics in a self-report questionnaire: (a) age; (b) gender; (c) educational level; (d) region of the school (urban/suburban, number of inhabitants); (e) bicycle ownership; (f) ability to cycle; and (g) habit, frequency, and distance of cycling to school.

2.3.2. Socio-Demographic Characteristics and Cycling to School in the Sample of Parents

Due to separate data collections in students and their parents, students could not have been matched to their parents (i.e., data could not have been merged). This is why parents were asked similar questions to provide their child's socio-demographic characteristics (proxy-report) and their own socio-demographic characteristics (self-report), based on previous studies [28–31], in a questionnaire: (a) parents'/child's age; (b) parents'/child's gender; (c) child's educational level; (d) region of child's school (urban/suburban, number of inhabitants); (e) parents'/child's bicycle ownership; (f) parents'/child's ability to cycle; (g) parents'/child's habit, frequency, and distance of cycling to school/work; (h) employment status; and (i) number of working days a week.

2.3.3. Distance from Home to School

Previous research has shown that the actual cycling route is not longer than the shortest route [32]. Furthermore, the shortest route is easier to estimate with Google Maps (Google LLC, Mountain View, USA), which objectively quantifies the distance from home to school. Following this, distance from home to school was estimated by participants for the shortest rather than the actual route by foot using Google Maps.

2.4. Statistical Analysis

All analyses were performed using the program IBM SPSS Statistics 25 (IBM Corporation, Armonk, USA) [33]. Only female and male participants who completed data collection on socio-demographic characteristics were included in this analysis. Binary logistic regressions were conducted, for which a minimum sample size of 50 is recommended [34]. Separate analyses were performed to determine associations between the habits of cycling to school among 12- to 15-year-olds (as a dependent variable) and each of the independent variables collected in the sample of students (self-reported

socio-demographic characteristics: age, gender, educational level/school's region, number of inhabitants, and distance from home to school) as well as parents (proxy-reported socio-demographic characteristics for their own child: age, gender, educational level/school's region, number of inhabitants, and distance from home to school; self-reported socio-demographic characteristics: age, gender, employment status, number of working days a week, and habit/frequency/distance of cycling to work). Additionally, separate gender analyses were performed for the sample of students (i.e., girls and boys) and parents (i.e., mothers). No separate gender analysis for fathers was performed as the number of participants was too small ($n = 8$). Predicted probability in all analyses is of giving a negative answer to the question: "Do you cycle to school sometimes?". The reference group was set based on the favored population according to the current state of the literature.

3. Results

3.1. Students' Socio-Demographic Characteristics as Correlates of their Cycling to School Habits

In total, 95% of students owned a bicycle and 61.7% of students sometimes cycled to school, of which 35.7% cycled to school daily (see Table A1). On average, students generally cycled to school on 2.3 ± 2.0 days a week.

The results of the binary logistic regressions for students' habits of cycling to school showed that students (girls and boys) attending an intermediate educational level combined with a suburban school region ($p = 0.035$; OR = 2.5 [CI 95 for OR: 1.1, 5.8]) and girls ($p = 0.003$; OR = 3.4 [CI 95 for OR: 1.5, 7.4]) were less likely to cycle to school (see Table A2). Moreover, cycling to school among students (girls and boys) became less likely with increasing age ($p = 0.002$; OR = 2.1 [CI 95 for OR: 1.3, 3.3]) and when attending a school located in a small town ($p = 0.010$; OR = 3.5 [CI 95 for OR: 1.4, 8.9]). Both associations were mainly due to girls according to the results of the separate gender analysis as no correlates were found in the separate gender analysis of boys.

3.2. Parents' and their Child's Socio-Demographic Characteristics as Correlates of their Child's Cycling to School Habit

All parents reported that their child owned a bicycle and 67.5% of parents indicated that their child sometimes cycled to school, of which 63% cycled to school daily according to parents (see Table A3). On average, parents stated that children generally cycled to school on 2.7 ± 2.3 days a week.

The results of the binary logistic regressions for the child's habit of cycling to school reported by parents (mothers and fathers) showed that cycling to school became less likely when the child's parent did not cycle to work ($p = 0.043$; OR = 5.9 [CI 95 for OR: 1.1, 32.9]) (see Table A4). Moreover, proxy-reports of parents (mothers and fathers) revealed that children were less likely to cycle to school when attending an intermediate educational level combined with a suburban school region ($p = 0.010$; OR = 9.4 [CI 95 for OR: 1.7, 51.0]), attending a school located in a medium-sized town ($p = 0.008$; OR = 10.6 [CI 95 for OR: 1.9, 60.2]), and living further away from school ($p = 0.006$; OR = 1.4 [CI 95 for OR: 1.1, 1.8]). These three associations were also found in the separate gender analysis of mothers' proxy reports.

4. Discussion

The purposes of this study were to determine the correlations of students' and parents' socio-demographic characteristics with 12- to 15-year-olds' habits of cycling to school, who attended different educational levels of schools located in different (sub)urban regions in Southern Germany, and to consider gender in the analyses.

More than half of the students sometimes cycled and one-third to two-thirds cycled daily to school in this study, which are the highest rates compared to all other studies reporting cycling to school rates in Germany [8–11]. As correlates of cycling to school, attending an intermediate educational level in combination with a suburban region of the school led to a lower likelihood to be engaged in cycling

to school. Girls were less likely to cycle to school than boys. Mainly due to girls, attending a school located in a small town and increasing age were also identified as inhibitive factors. Living further away from school as well as attending a school located in a medium-sized town and having parents not using a bicycle to commute to work were negatively associated with 12- to 15-year-olds cycling to school habits.

4.1. Rate and Correlates of Cycling to School

The high rate of cycling to school in our samples might be explained by the sizes and characteristics of the included municipalities (suburban = small town and medium-sized town, urban = city) and the gender ratio in favor of boys (59.5% boys participated and parents referred to 64.3% sons). A rural region, which was not included in our study, was identified as the strongest barrier of cycling to school in previous research [8], whereas being a boy was an advantage [3,8,11,15,17,18]. Although previous research reported that a lower urbanization level (i.e., a medium-sized town compared to a city) was positively associated with cycling to school [8], we found the opposite relationship in parents' proxy-reports. This contrary finding confirmed the dependency of the context, i.e., sampled municipalities. Concerning gender differences, girls mentioned an additional gender-specific need (i.e., social behavior in road traffic) in order to cycle to school daily compared with boys, who did not mention this need, in our recent study including the same sample [12]. This could explain the high rates of boys cycling to school if the specific girls' need is not sufficiently addressed. Additionally, we found a first indication in our previous systematic review that poorer health-related fitness among girls, possibly due to engaging less in PA overall, could be a barrier to uptake cycling with its moderate-to-vigorous intensity [35].

It remained unclear which of the two factors, i.e., the educational level of students or the school's region, or a combination of both were associated with a lower probability of cycling to school. The reason for this is that there was no variance between the combination of both factors in the present study (i.e., only one school with a high educational level located in the urban region and two schools with intermediate education levels located in suburban regions). In previous research, it has been suggested that regions with a lower urbanization level are characterized by a lower school density, which can lead to a longer distance from home to school [8] and this lowers the chance of cycling to school [11,23]. Concerning the influence of educational levels in students, a previous assumption that bicycle ownership could be a limiting factor [9] is not reasonable in our study as almost all students owned a bicycle in line with the official report of a German Federal Ministry [36]. However, it remains unclear whether these bicycles are roadworthy, usable, and suitable. We rather support the idea mentioned in a previous study [24] that factors not considered in our analyses (e.g., the social norm among peers [37]) might explain this finding.

Increasing age, especially in girls, was associated with a declining habit of cycling to school, which is in line with the current state of research [15] reporting that the stability of PA in transitional phases (e.g., from childhood to adolescence) was found to be lower due to growth and life-changing events [38].

Finally, parents' habits of cycling to work appeared to serve as supportive role modeling [28–30], which could be an explanation for the association with children's cycling to school odds. However, mothers but not students acknowledged the role of parents in our recent study [12], suggesting that social norms play an unconscious role [37]. In contrast to previous research targeting ACTS [28,30], we did not find a relationship between mothers' habits of cycling to work and children's cycling to school habits. As no gender analysis could be made for fathers, it remains unclear if the fathers' gender matters in this finding [28,30].

4.2. Strengths and Limitations

The major strengths of this study are to focus on the high-risk group of 12- to 15-year-olds in terms of cycling to school and to identify inhibitive or supportive socio-demographic characteristics of

students as well as parents, including separate analyses for gender. Moreover, our study is the first in Germany that considered distance from home to school and educational levels in secondary school students who cycle to school in more than one city and state. In general, the influence of the school's region was studied for the first time. Compared to the high response rate of students at schools, the number of participating parents at home was relatively low. The conclusions drawn from our findings are limited due to the small, non-representative sample size, the restriction to (sub)urban regions in Southern Germany, and selective educational levels (i.e., intermediate and high). Additionally, it must be acknowledged that the reliability of estimated effect sizes is uncertain in some findings. Also, this study did not provide insights into correlates associated with fathers' socio-demographic characteristics. Furthermore, information about SES and residential area was not directly assessed. Migration background, weight status, and parents' educational level were not considered.

5. Conclusions

Although conclusions can only be drawn with caution, our findings give new insights into habits of cycling to school and its influencing factors in Germany. This study indicated that approximately every second student aged 12 to 15 sometimes cycled to school in Southern Germany. We observed that several socio-demographic characteristics of students and parents, i.e., gender, age, educational level/school's region (urban/suburban, number of inhabitants), distance from home to school, and parents' habits of cycling to work, were correlated with habits of cycling to school. These findings suggest that it is essential to address the gender-specific need of girls, stabilize habits of cycling to school in the transition from childhood to adolescence, establish supportive social norms, and involve parents as role models in future school-based bicycle interventions. Concerning the barrier "distance from home to school", the active part on the way to school could be shortened by splitting the way into active and passive parts (if necessary) as all three schools are closely located to public transport facilities. Furthermore, we suggest inviting parents to school for data collection to ensure a high response rate [12]. Finally, more research regarding the (gender) influence of parents' socio-demographic characteristics on children's cycling to school habits is warranted as there are many other possible socio-demographic characteristics in parents that have not been analyzed up to now, e.g., marital status [16], number of children [16], or car availability [39].

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Abbreviations

ACTS = active commuting to school; ca. = circa; CI = confidence interval; e.g. = for example; i.e. = that is; m = million; M-CAT = model of children's active travel; *n* = sample size; OR = odds ratio; *p* = probability value; PA = physical activity, SES = socioeconomic status.

Appendix A

Table A1. Socio-Demographic Characteristics based on the Sample of Students.

Socio-Demographic Characteristics	Girls (n = 49)	Boys (n = 72)	Total (N = 121)
Age (years in M ± SD)	13.1 ± 0.9	13.1 ± 0.9	13.1 ± 0.9
Educational level/school's region			
(a) high/urban	13 (26.5%)	29 (40.3%)	42 (34.7%)
(b) intermediate/suburban	36 (73.5%)	43 (59.7%)	79 (65.3%)
Number of inhabitants			
(a) city	13 (26.5%)	29 (40.3%)	42 (34.7%)
(b) medium-sized town	15 (30.6%)	22 (30.6%)	37 (30.6%)
(c) small town	21 (42.9%)	21 (29.2%)	42 (34.7%)
Bicycle ownership			
(a) yes	43 (87.8%)	72 (100%)	115 (95.0%)
(b) no	6 (12.2%)	0 (0%)	6 (5.0%)
Ability to cycle			
(a) yes	49 (100%)	72 (100%)	121 (100%)
(b) no	0 (0%)	0 (0%)	0 (0%)
Cycling to school (habit)			
(a) yes	20 (44.4%)	51 (72.9%)	71 (61.7%)
(b) no	25 (55.6%)	19 (27.1%)	44 (38.3%)
Cycling to school (days/week in M ± SD)	1.6 ± 2.0	2.7 ± 2.0	2.3 ± 2.0
Cycling distance home/school (km in M ± SD)	3.3 ± 2.6	4.0 ± 3.1	3.7 ± 2.9

km = kilometer; M = means; SD = standard deviation.

Table A2. Binary Logistic Regressions of Socio-Demographic Characteristics and Habits of Cycling to School based on the Sample of Students.

Socio-Demographic Characteristics	Girls				Boys				Girls and Boys			
	p	OR	95% CI for OR		p	OR	95% CI for OR		p	OR	95% CI for OR	
			Lower	Upper			Lower	Upper			Lower	Upper
Gender												
(a) girls									**0.003**	3.4	1.5	7.4
(b) boys (ref.)												
Age (in years)	**0.002**	4.9	1.8	13.6	0.329	1.4	0.7	2.5	**0.002**	2.1	1.3	3.3
Educational level/school's region												
(a) high/urban (ref.)												
(b) intermediate/suburban	0.078	3.5	0.9	14.1	0.382	1.6	0.5	5	**0.035**	2.5	1.1	5.8
Number of inhabitants												
(a) city (ref.)												
(b) medium-sized town	0.790	1.3	0.2	6.4	0.353	1.8	0.5	6.6	0.336	1.6	0.6	4.5
(c) small town	**0.012**	8	1.6	40.6	0.566	1.5	0.4	5.4	**0.01**	3.5	1.4	8.9
Cycling distance home/school (in km)	0.098	1.3	1	1.7	0.469	1.1	0.9	1.3	0.226	1.1	1	1.2

CI = confidence interval; km = kilometer; OR = odds ratio; p = probability value; ref. = reference value.

Table A3. Parents' and their Child's Socio-Demographic Characteristics based on the Sample of Parents.

Socio-Demographic Characteristics	Mothers (n = 34)	Fathers (n = 8)	Total (N = 42)
Age (years in M ± SD)	46.8 ± 5.1	52.1 ± 5.2	47.8 ± 5.5
Age of child (years in M ± SD)	12.6 ± 0.7	13.0 ± 0.8	12.7 ± 0.7
Gender of child			
(a) daughter	12 (35.3%)	3 (37.5%)	15 (35.7%)
(b) son	22 (64.7%)	5 (62.5%)	27 (64.3%)

Table A3. *Cont.*

Socio-Demographic Characteristics	Mothers (n = 34)	Fathers (n = 8)	Total (N = 42)
Educational level/school's region of child			
(a) high/urban	15 (44.1%)	4 (50.0%)	19 (45.2%)
(b) intermediate/suburban	19 (55.9%)	4 (50.0%)	23 (54.8%)
Number of inhabitants			
(a) city	15 (44.1%)	4 (50.0%)	19 (45.2%)
(b) medium-sized town	16 (47.1%)	4 (50.0%)	20 (47.6%)
(c) small town	3 (8.8%)	0 (0%)	3 (7.1%)
Bicycle ownership of child			
(a) yes	34 (100%)	8 (100%)	42 (100%)
(b) no	0 (0%)	0 (0%)	0 (0%)
Child's ability to cycle			
(a) yes	34 (100%)	8 (100%)	42 (100%)
(b) no	0 (0%)	0 (0%)	0 (0%)
Cycling to school of child (habit)			
(a) yes	22 (66.7%)	5 (71.4%)	27 (67.5%)
(b) no	11 (33.3%)	2 (28.6%)	13 (32.5%)
Cycling to school of child (days/week in M ± SD)	2.6 ± 2.3	3.1 ± 2.2	2.7 ± 2.3
Cycling distance home/school of child (km in M ± SD)	4.3 ± 3.2	5.2 ± 3.2	4.5 ± 3.2
Bicycle ownership			
(a) yes	33 (97.1%)	8 (100%)	41 (97.6%)
(b) no	1 (2.9%)	0 (0%)	1 (2.4%)
Ability to cycle			
(a) yes	34 (100%)	8 (100%)	42 (100%)
(b) no	0 (0%)	0 (0%)	0 (0%)
Employment status			
(a) yes	31 (91.2%)	8 (100%)	39 (92.9%)
(b) no	3 (8.8%)	0 (0%)	3 (7.1%)
Work (days/week in M ± SD)	3.7 ± 1.5	4.9 ± 0.4	3.9 ± 1.4
Cycling to work (habit)			
(a) yes	12 (40.0%)	4 (50.0%)	16 (42.1%)
(b) no	18 (60.0%)	4 (50.0%)	22 (57.9%)
Cycling to work (days/week in M ± SD)	1.3 ± 1.9	1.8 ± 2.2	1.4 ± 1.9
Cycling distance home/work (km in M ± SD)	13.0 ± 14.4	7.9 ± 5.5	11.9 ± 13.2

km = kilometer; M = means; SD = standard deviation.

Table A4. Binary Logistic Regressions of Socio-Demographic Characteristics and Child's Habit of Cycling to School based on the Sample of Parents.

Socio-Demographic Characteristics	Mothers				Mothers and Fathers			
	p	OR	95% CI for OR		p	OR	95% CI for OR	
			Lower	Upper			Lower	Upper
Gender								
(a) mothers (ref.)								
(b) fathers					0.807	0.8	0.1	4.8
Age (in years)	0.349	1.1	0.9	1.2	0.265	1.1	0.9	1.2
Age of child (in years)	0.103	2.7	0.8	8.8	0.228	1.8	0.7	4.8

Table A4. *Cont.*

Socio-Demographic Characteristics	Mothers				Mothers and Fathers			
	p	OR	95% CI for OR		*p*	OR	95% CI for OR	
			Lower	Upper			Lower	Upper
Gender of child (a) daughter (b) son (ref.)	0.445	1.8	0.4	7.9	0.308	2	0.5	8
Educational level/school's region of child (a) high/urban (ref.) (b) intermediate/suburban	**0.036**	6.5	1.1	37.5	**0.01**	9.4	1.7	51
Number of inhabitants (a) city (ref.) (b) medium-sized town (c) small town	**0.029** 0.413	7.4 3.3	1.2 0.2	45 54.8	**0.008** 0.313	10.6 4.3	1.9 0.3	60.2 70.8
Cycling distance home/school of child (in km)	**0.02**	1.4	1.1	1.8	**0.006**	1.4	1.1	1.8
Employment status (a) yes (ref.) (b) no	1	1	0.1	12.4	0.974	1	0.1	12.7
Work (in days/week)	0.739	1.1	0.7	1.8	0.764	1.1	0.7	1.7
Cycling to work (habit) (a) yes (ref.) (b) no	0.103	4.4	0.7	26.7	**0.043**	5.9	1.1	32.9
Cycling to work (in days/week)	0.130	0.7	0.4	1.1	0.063	0.6	0.4	1
Cycling distance home/work (in km)	0.586	1	1	1.1	0.779	1	1	1.1

CI = confidence interval; km = kilometer; OR = odds ratio; *p* = probability value; ref. = reference value.

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STUDY PROTOCOL
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Study Protocol of a School-Based Randomized Controlled Trial to Promote Cycling to School Among Students in Germany Using Intervention Mapping: The ACTS Project

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Background: Despite a high rate of bicycle ownership, the prevalence of cycling to school among children and adolescents in Germany has been constantly low. Cycling to school can contribute to meeting the physical activity recommendations, which the majority of children and adolescents in Germany do not meet.

Methods: By using intervention mapping, this study protocol describes the systematic planning process of a school-based intervention in Germany aimed to increase the number of days on which students cycle to school and to increase their physical activity levels. To make sure that the intervention will match the needs of students, we conducted a concept mapping study investigating what students need to cycle to school, as perceived by students, parents, and teachers. The logic model of change was based on an integration of the self–determination theory and the social–ecological model. We structured our intervention as two phases, a preparatory phase with weekly components for and a practical phase with a daily repeated component of the targeted behavior. In the 8-week preparatory phase, teachers, parents, and peers will be involved. The content of the 12-week practical phase will involve peers only and was considered promising based on the findings from a systematic review that we conducted to identify the effective strategies of school-based interventions to promote cycling to school among children and adolescents. Overall, our intervention includes 27 behavior change techniques. A researcher, student assistants, teachers, and other collaborators will implement the intervention; a whole-of-school approach with components performed before, during, and after school was chosen. As a study design, we decided to draft a two-arm three-level cluster randomized controlled trial. Both the effect and process evaluation were prepared. In the first instance, approximately 250 students of 12–15 years of age from grade 7 or 8, who attend a secondary school of intermediate or high educational level located in (sub)urban regions in Southern Germany, will pilot the intervention.

Discussion: We expect to provide an effective and sustainable intervention for students, which gives insights into the mechanisms of change concerning the behavior of cycling to school and its influence on physical activity levels.

Keywords: bicycle, active travel to school, program, children, adolescents, intervention mapping

INTRODUCTION

In Germany, up to 98% of children and adolescents until 17 years own a bicycle (1). However, cycling is the rarest mode used by girls and boys overall for commuting to school (2). Additionally, the prevalence of cycling to school in the years from 2003 to 2017 was constantly lower in girls (20.6 vs. 21.5%) compared with boys (23.8 vs. 25.2%) aged 11–17 years (2, 3). Living in a small town (5,000–19,999 inhabitants) and a city (>100,000 inhabitants) or attending an intermediate educational level providing a general education school leaving certificate lowered the chance of cycling to school among children and adolescents in Germany compared with those living in a medium-sized town (20,000–99,999 inhabitants) or attending a high educational level providing a general higher education entrance qualification (3, 4). These associations may vary based on the context (i.e., sampled regions of residential or school area) (5).

In Germany, only 26% of the children and adolescents (girls: 22.4%, boys: 29.4%) aged up to 17 years achieve the physical activity (PA) recommendations proposed by the World Health Organization (6). As the stability of PA patterns among girls and boys is lower in transitional phases (e.g., from childhood to adolescence) (7), the PA prevalence declines with age in Germany (6), which makes it important to counteract this negative trend in this phase of life. According to previous research from England, it is noteworthy that 36% of children and adolescents aged 5–15 years who cycle to school meet the weekly PA recommendations (8). In comparison, only 25% of walkers to school and 22% of neither cyclists nor walkers to school meet these recommendations. Following this, the promotion of cycling to school could be a promising strategy to increase PA levels among children and adolescents.

However, interventions in this research field are not well established (9) and especially interventions implemented in secondary schools (10) involving two grade levels from grade 7 upward (11) are lacking. Previous research recommended the stepwise structured intervention mapping protocol (IM) when planning interventions to change behavior (12). According to this conceptual review, the IM protocol uses theories and evidence, follows a social–ecological approach to intervene at multiple levels, and is characterized by involving the target group and all relevant stakeholders using a participatory approach. The authors concluded that the best possible intervention with the best chance of effectiveness can be expected when following this detailed and systematic protocol.

Therefore, this study protocol used IM to document the systematic planning process of a school-based intervention based on a combination of the social–ecological model and the self–determination theory. It is designed as a two-arm three-level cluster randomized controlled trial (RCT) with a pre- and post-measurement for the effect evaluation before and after the 5-month period of implementation. As the primary aim, the planned intervention should increase the number of cycling days to school and as a secondary aim, should increase the total moderate-to-vigorous physical activity (MVPA) among children and adolescents aged 12–15 years from grade 7 or 8 attending secondary schools of intermediate or high educational levels located in (sub)urban regions (small town, medium-sized town, city) in Southern Germany.

METHODS AND ANALYSIS

In this study protocol, IM was used. IM describes an iterative process, which consists of six steps (i.e., logic model of the problem, logic model of change, program design, program production, program implementation plan, and evaluation plan) divided into several tasks described in **Figure 1** (13).

This study protocol includes the following terms, which explain the most crucial tasks allocated to steps one to three of the IM protocol. In step one, we defined the needs assessment as "the collection and analysis of information that relates to the needs" (14) (p. 314) of our identified high-risk population of cyclists to school, which help determine the facilitators and barriers of their behavior. For the construction of the matrix in step two, we used the following definitions of "performance objectives" and "change objectives." Performance objectives are observable and specific behaviors, which are judged necessary to meet the desired aims of our intervention (i.e., who needs to do what) (13) and were allocated to modules (A, B, C, etc.) in the study matrix. The combination of determinants for behavioral outcomes and performance objectives lead to change objectives (13). In step three, intervention components were defined as different packages of contents (15), which were allocated to the different modules in order to address the changes needed according to the identified performance objectives. The composition of components will define the success of our intervention due to their direct relatedness to change methods (16). A change method (also technique) "provides evidence for how change may occur" (13) (p. 17).

Logic Model of the Problem

In 2019, the ACTS project was initiated. It was aimed at promoting active commuting to school (ACTS) with a

Abbreviations: ACTS, active commuting to school; ADAC, German Automobile Club; BPNs, basic psychological needs; CG, control group; e.g., for example; etc., et cetera; ICC, intraclass correlation coefficient; i.e., that is; IG, intervention group; IM, intervention mapping; min, minutes; MVPA, moderate-to-vigorous physical activity; *n*, sample size; PA, physical activity; PE, physical education; RCT, randomized controlled trial; TUM, Technical University of Munich; vs., versus.

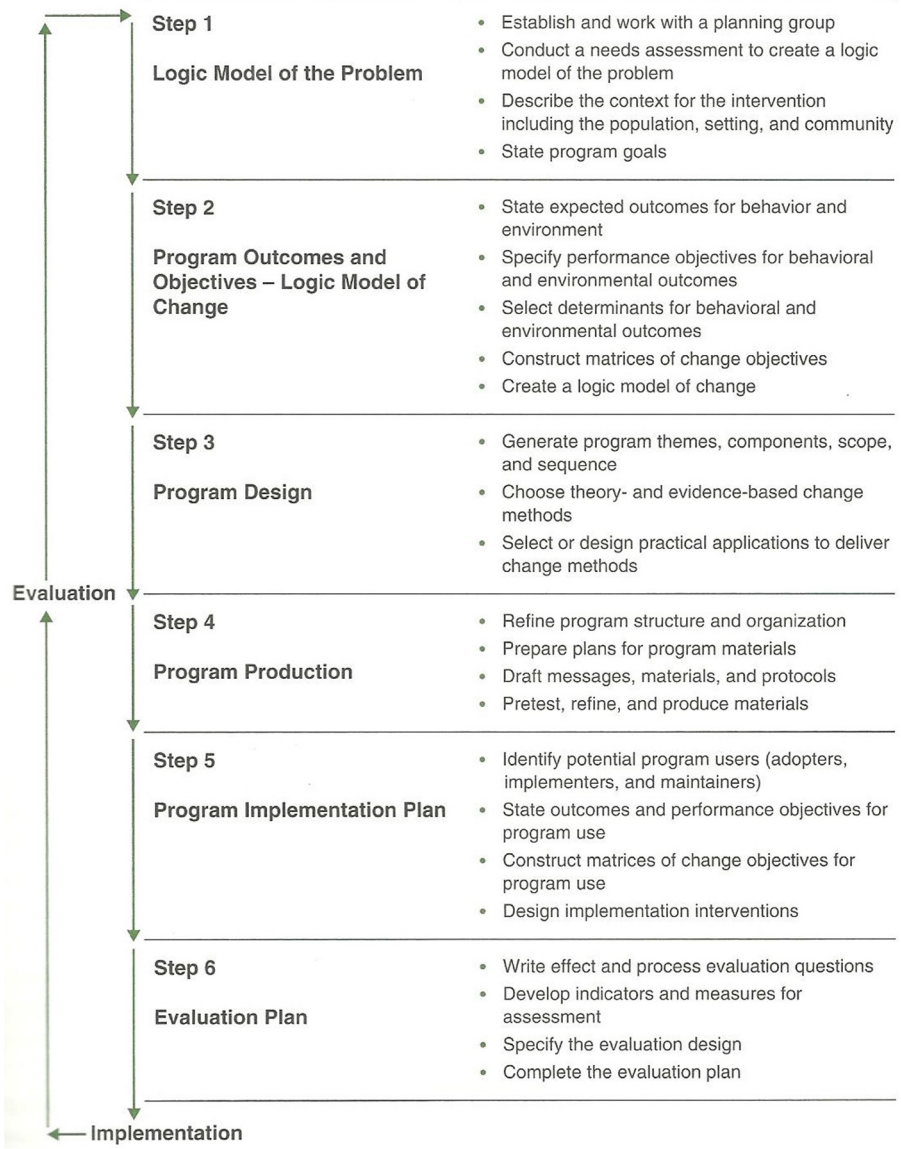

FIGURE 1 | Steps and tasks of the intervention mapping protocol (13) (p. 13).

particular focus on cycling to school in Europe. To plan interventions is part of this project. This project involves six research institutes from Poland, Czech Republic, Portugal, the Netherlands, and Germany, which were set as the planning group. For each country, an intervention adapted to the needs of the local context is planned. The intervention described here aims to address students aged 12–15 years attending grade 7 or 8 at secondary schools of intermediate or high educational levels located in sub(urban) regions (small town, medium-sized town, city) in Southern Germany. We involved teachers in the planning process of the intervention to ensure that the implementation will be feasible in their community, at their school, and with their students. Therefore, we sent teachers the draft of our planned intervention and asked for their feedback, which we considered in this study protocol.

In step one of the IM protocol, the logic model of the problem was created (see **Figure 2**). Here, the needs of students to cycle to school daily were assessed using a concept mapping study (17). In total, 136 students aged 12–15 years attending grade 7 or 8 at three different secondary schools of different educational levels located in different sub(urban) regions in Southern Germany participated in the study. For a more comprehensive understanding of the behavior of the students, concept mapping

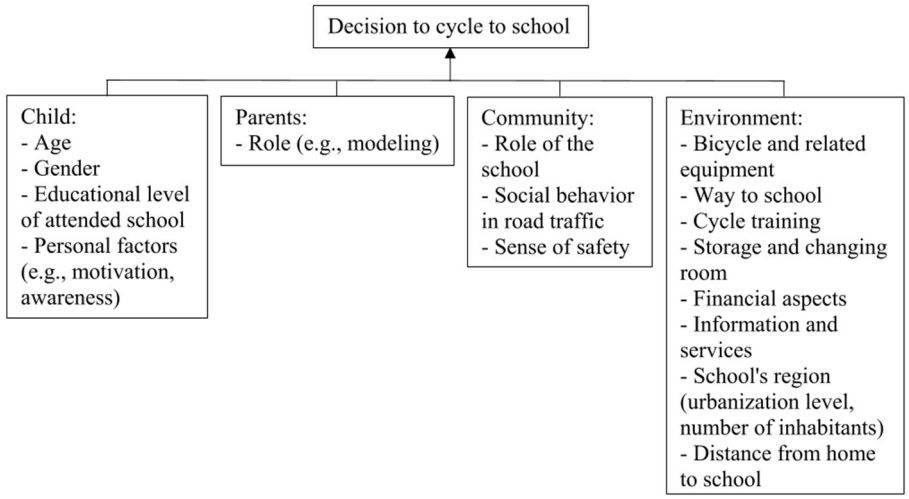

FIGURE 2 | Logic model of the problem: Factors that influence cycling to school based on concept mapping (5, 17).

was also performed among students' parents ($n = 58$) and teachers ($n = 29$) of both genders female and male, whereby the low retention rate of fathers did not permit a separate gender analysis. As needs to cycle to school daily, a "bicycle and related equipment," the "way to school," and "personal factors" were mentioned by all three analyzed samples of students, mothers, and teachers. Additionally, students mentioned "cycle training," mothers mentioned the "role of the school," and the teachers mentioned "storage and changing room," "financial aspects," as well as "information and services." Furthermore, "social behavior in road traffic" was mentioned by girls only, "role of parents" by mothers and female teachers, and "sense of safety" by female teachers. As none of these mentioned needs stood out as particularly (un)important and/or (un)feasible, we treated all of them as equally relevant. In this study, almost all students owned a bicycle (girls: 87.8%, boys: 100%) and all were able to cycle (5). When examining the habits of the students in cycling to school, we found that approximately two-thirds of students stated to sometimes cycle to school (girls: 44.4%, boys: 72.9%), of whom approximately one-third cycled to school daily (girls: 31.6%, boys: 37.3%). On average, students generally cycled to school on 2.3 ± 2.0 days per week (girls: 1.6 ± 2.0, boys: 2.7 ± 2.0). Moreover, the following correlates were identified to be negatively associated with cycling to school habits of students: (a) being a girl, (b) increasing age (mainly in girls), (c) attending an intermediate educational level in combination with a suburban region of the school, (d) attending a school located in a small town (mainly in girls) or a medium-sized town, (e) living further away from school, and (f) having parents not using a bicycle to commute to work.

The primary aim of the planned intervention is to increase the number of days on which students cycle to school. As a secondary aim, the planned intervention should increase the total MVPA in students due to positive changes in their cycling to school behavior.

Logic Model of Change

According to the previous IM step, complementary and stimulating impulses of behavioral (including personal factors) and situational (including social and physical environment) approaches are relevant for the successful promotion of cycling to school. All circumstances of the external reality of the students embody the environment (18). We defined the term "social environment" as all political–social–cultural factors (including parents, teachers, peers, school and its policies, and social norms), in which the student lives in, is educated, and interacts (19, 20). The term "physical environment" includes all factors related to the structural conditions, such as the (functional) quality of equipment, financial aspects, transportation system, design of the infrastructure, services, and the distance from home to school (20–22).

In step two of the IM protocol, a theoretical model has to be chosen to create the logic model of change. Therefore, two theoretical models were integrated as already described in a previous study protocol (23). This integration illustrates why the situational approach influences the behavior of the students and how the behavioral and situational approaches interrelate and interact (21) (see **Figure 3**): (a) The social–ecological model of the correlates of active transportation shows "the complex interaction of multiple levels of factors [i.e., individual, interpersonal, community, built environment, policy (19)] affecting decisions to be active" (21) (p. 57). This theoretical model was chosen as we identified multiple levels in our concept mapping study at which we need to intervene (i.e., individual, interpersonal, community, environment) (see **Figure 2**). (b) A sub-theory of the self–determination theory, the basic psychological needs (BPNs), emphasizes that the support and satisfaction of autonomy, competence, and relatedness lead to a more self-determined form of motivation toward a specific behavior (21, 24). This theoretical model was chosen as motivation (personal factors) of students was identified in our

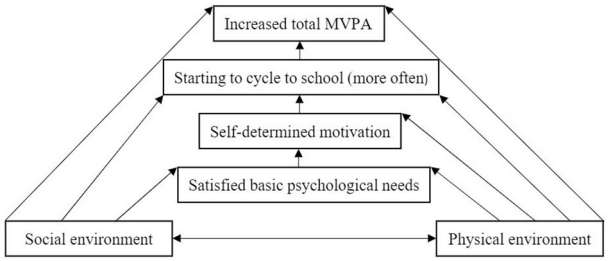

FIGURE 3 | Logic model of change [modified according to (21) (p. 67)]. MVPA, moderate-to-vigorous physical activity.

concept mapping study to play a role in their decision to cycle to school (see **Figure 2**).

Based on the social and physical environment, BPNs can be either satisfied or frustrated leading to a certain degree of motivation, which is crucial for the decision process of the students to cycle to school and the influence on total MVPA. Following this logic model of change, **Table 1** illustrates the matrix of performance objectives and determinants targeting the promotion of cycling to school.

Program Design and Production

As illustrated in **Table 2**, the intervention will be structured in two phases: (a) preparation for and (b) practice of the targeted behavior. All chosen components and some of their descriptions were based on the findings and conclusions from our concept mapping study (5, 17) and our systematic review (11), which was conducted to identify effective strategies of school-based interventions to promote ACTS by bicycle among children and adolescents. We also used the following documents to design the mobility and traffic education components in the preparatory phase: (a) The content of the three-cycle training sessions off-road was based on a German research report on road safety education concepts for children and adolescents in secondary schools (25). (b) For the session in which theoretical knowledge about traffic rules will be transferred, two guidebooks published by the German Automobile Club (ADAC) (26, 27) were the basis. (c) The content of the cycle training session on-road to practice social behavior in road traffic was also based on these two guidebooks (26, 27). (d) To finally certify the basic cycling skills of students in a final exam, another guidebook of the ADAC was the basis (28). All students will obtain a certificate regardless of their scoring to allow for self-monitoring of their basic cycling skills.

Each component could be linked to at least one behavior change technique as proposed in the taxonomy v1 (29) and supplemented by our systematic review (11). Overall, 27 different techniques were applied to the components of our intervention.

Program Implementation Plan

For convenience, the three secondary schools included in our concept mapping study were asked to pilot the intervention. Two more secondary schools, each characterized by similar features as the already recruited ones, that is, in terms of regions, educational levels, and grades, will be searched by sending random invitation letters. Similar random invitation letters will also be sent to recruit secondary schools in the main study.

The school year in Germany starts in fall and ends in summer, whereby the first term ends in spring. In previous research from Norway, seasonal differences in cycling to school were observed between fall (52%), winter (3%), and spring (51%) (30) as well as between winter (12%) and summer (22%) (31). Also in Germany, cycling to school decreases in winter (32). Therefore, the implementation of the intervention should start in fall and end in spring (i.e., during the first term of the school year). According to the preparatory and practical phases, individual components will be implemented one after another at the participating secondary schools over a period of 5 months (see **Table 3**). As implemented components will prepare students for the possibly more difficult (weather) conditions in winter, we do not expect a negative seasonal influence on the effectiveness of the intervention. For example, information about appropriate clothes will be provided during the joint parents', teachers', and students' evening. Furthermore, parents and teachers will be reminded of serving as role models so that the 12- to 15-year-olds learn how to establish a cycling routine regardless of (weather) conditions in winter. Students will feel safer and more confident in dealing with difficult road conditions after participating in the cycle training, which will improve their basic cycling skills and practice them on-road (e.g., handling obstacles and appropriate driving style). The bicycle train will increase the motivation and safety of students through positive experiences when accompanied by and interacting socially with peers instead of cycling to school alone in the darkness. Furthermore, the bicycle train will establish a new social norm (i.e., cycling to school as an activity throughout the whole year, including winter and not only in summer). The intervention will follow a whole-of-school approach as we designed components that will take place before, during (i.e., in art and physical education (PE) lesson), and after school. At each participating secondary school, a person of contact will be defined who will act as a coordinator for implementing the intervention. Furthermore, the person of contact will interact with the responsible implementers at their school (i.e., PE and art teacher) and a researcher as well as the project manager at the Technical University of Munich (TUM) who can be called or e-mailed any time in case of occurring questions or problems. The researcher from TUM will be in touch with the person of contact to organize data collections and the implementation of components, which will be led by the researcher and student assistants from TUM. As our aim was to draft a sustainable intervention, we will provide secondary schools with all materials needed for the replication of the intervention and initiate several collaborations with government facilities (i.e., police) and nongovernmental organizations (e.g., ADAC) free of charge that can be continued after we will have left schools.

Evaluation Plan

To report the findings of our planned evaluation, the "CONSORT 2010 statement: extension to cluster randomized trials" (33) will be followed.

TABLE 1 | Matrix of performance objectives and determinants targeting the promotion of cycling to school.

Modules	Performance objectives	Psychological determinants		
		Autonomy	**Competence**	**Relatedness**
A	Researcher communicates to parents and students the purpose and benefits of cycling to school, useful bicycle-related equipment, and feasible mixed methods when living too far away from school.	Students can choose between different options.	Students are aware of the purpose/benefits and solutions to tolerate adverse conditions (e.g., bad weather, heavy schoolbags) when cycling to school.	Students perceive social support.
B	Researcher seeks help from parents and teachers (e.g., parents do not drive their child to school by car, parents/teachers motivate their child/students to cycle to school, parents/teachers are role models for their child/students by cycling to work regardless of the weather condition and wearing a helmet, teachers develop a cycling-to-school-mission-statement).	Students are personally responsible and extensively independent in planning how to get to school.	Students feel empowered to cycle to school when encouraged.	Students perceive a new social norm, social support from parents and teachers, and social cohesion. Students learn how to establish a cycling routine regardless of the weather condition and wear a helmet through the role modeling of parents and teachers.
C	Researcher shows helmet-compatible hairstyle to students and parents.	Students make their own decisions, which helmet-compatible hairstyle they want to do.	Students know, which hairstyles are helmet-compatible, and can do them.	Students establish the new social norm to wear a helmet and receive social support from parents who can help them to do their helmet-compatible hairstyle. Peers serve as role models.
D	Students and parents plan routes and stops so that students can cycle to school together.	Students are free in choosing the best route to cycle to school.	Students feel proud to cycle to school on their own chosen routes.	Students feel involved in the planning process, interact socially with peers and parents, establish a new social norm at school, and perceive social support from peers and parents. Peers serve as role models.
E	Students, parents, and teachers plan cycling-to-school-events.	Students have the freedom to choose what kind of events they want to plan.	Students are proud of the successful realization of their planned events.	Students feel involved in the planning process of the intervention, perceive social support from peers, parents, and teachers, and interact with peers, parents, and teachers. Peers serve as role models.
F	Students set goals on how often they want to try to cycle to school per week.	Students decide on their own how often they want to try to cycle to school per week.	Students successfully reach their set goals.	Students establish a social norm and perceive social support from peers. Peers serve as role models.
G	Researcher ensures that bicycles of students are roadworthy and provides required bicycle-related equipment if necessary.	Students have the chance to engage in cycling to school if they want to.	Students trust in the safety of their bicycles.	Students perceive the principle of equal opportunities and social support.
H	Students personalize bicycle-related equipment.	Students decide on their own how to make their bicycle-related equipment more attractive to themselves.	Students receive positive feedback for their art from the teacher and peers, which encourage them to present it on-road.	Students identify with the intervention and their bicycle-related equipment. Students develop group cohesion through personalized bicycle-related equipment as a common identifying feature of participating in the intervention.
I	Students can cycle to school in road traffic (e.g., improve basic cycling skills, know traffic rules, practice social behavior, take part in a final exam).	Students make their own decisions on how to appropriately behave in road traffic.	Students feel safe in applying traffic rules, have confidence in and do not overestimate their cycling skills, and make positive experiences when cycling to school.	Students interact socially with other traffic participants.

Study Design

The main study is planned as a two-arm (i.e., intervention and control group (IG; CG)) three-level cluster (i.e., students in classrooms in schools) RCT (see **Figure 4**), whereby a simple randomization technique (i.e., flipping a coin) on school-level was chosen. For convenience, the pilot study will follow a quasi-experimental study design as a non-RCT. Directly before and after the implementation of the intervention, a pre- and post-measurement will take place as part of the effect evaluation. Furthermore, the process evaluation will take place during and after the implementation of the intervention. Based on the intraclass correlation coefficient (ICC) of 0.2 calculated for the

TABLE 2 | Program design.

Phases	Modules	Components	Descriptions	Materials	Behavior change techniques (11, 29)
Preparation	A-F	Joint parents', teachers', and students' evening	- General information for students, parents, and teachers: ➔ Purpose and benefits of cycling to school (e.g., health, emotion, environment) ➔ Options when living too far away from school (e.g., splitting the way to school into active and passive parts) ➔ The role of parents and teachers (e.g., role modeling, motivators) ➔ Useful bicycle-related equipment (e.g., clothes, carrier systems) ➔ Helmet-compatible hairstyles - Parents help students to develop a cycling-to-school-plan by letting students tell peers where they live and forming small groups when living close together to determine a joint route and stops - Teachers develop a cycling-to-school-mission-statement as part of a new school policy - Students, parents, and teachers determine three cycling-to-school-events - Students set goals in written form	To perform: Computer, projector, paper, pencils, roadmaps To provide students, parents, and teachers with: Online video and booklet of the live meeting	Involving parents and teachers, pros and cons, information about health, emotional, social, and environmental consequences, avoidance/reducing exposure to cues for the behavior, restructuring the physical and social environment, social support (unspecified, practical, emotional), demonstration of the behavior, knowledge transfer, adding objects to the environment, information about antecedents, goal setting (behavior), action planning
	G-H	Bicycle inspection in the presence of parents and provision of required bicycle-related equipment; personalization of bicycle-related equipment		To perform: Tool kits, paper and pencils to document required bicycle-related equipment, paint, paintbrush	Information about antecedents, restructuring the physical environment, social support (practical), adding objects to the environment, involving parents
	I	Three cycle training sessions off-road (improvement of basic cycling skills) (25)	1. Session: Ascending/descending, slow driving, braking, driving in a narrow lane and over obstacles, orientation 2. Session: Keeping distance, handling and driving over obstacles, slalom, orientation 3. Session: Adaptability, parcours	To perform: 1. Session: Old bicycle tires 2. Session: Little sandbags, pool noodles, self-made seesaw and other obstacles, pylons 3. Session: Old bicycle tires, little sandbags, pool noodles, self-made seesaw and other obstacles, pylons	Instruction on how to perform the behavior, behavioral practice/rehearsal, demonstration of the behavior
		Information about traffic rules (26, 27)	e.g., rights and duties, traffic signs, how to enter traffic, penalties, liability, roadworthiness, how to do an emergency call, blind spot	To provide students with: Booklet	Knowledge transfer, instruction on how to perform the behavior
		One cycle training session on-road (practicing social behavior) (26, 27)	e.g., unhurried driving style (adaptation of speed), keeping distance, how to pass a person/vehicle/bus stop, signaling and looking behind when turning left/right, crossing roads/intersections		Instruction on how to perform the behavior, behavioral practice/rehearsal, demonstration of the behavior, social support (practical), avoidance/reducing exposure to cues for the behavior, feedback on behavior, problem solving, reduce negative emotions, behavior substitution

(Continued)

TABLE 2 | Continued

Phases	Modules	Components	Descriptions	Materials	Behavior change techniques (11, 29)
		Final exam of basic cycling skills in the presence of parents (28)		To perform: Materials from ADAC To provide students with: Certificate	Information about antecedents, behavioral practice/rehearsal, problem solving, reduce negative emotions, feedback on behavior, material reward (behavior), involving parents
Practice	D	Voluntary bicycle train to cycle to school with peers before and after school with an arranged route and stops (incl. three events)		None	Demonstration of the behavior, behavioral practice/rehearsal, behavior substitution, habit formation, habit reversal, adding objects to the environment, social support (unspecified, practical, emotional), restructuring the physical and social environment, information about antecedents, avoidance/reducing exposure to cues for the behavior

ADAC, German Automobile Club; incl., inclusive.

variance of days per week students cycled to school between the three secondary schools in our concept mapping study (17), we assigned more than one secondary school to the IG and CG. No treatment will be delivered to the CG. In the main study, approximately 255 students belonging to five schools with two classes in grade(s) 7 and/or 8 will be in the IG and CG, respectively. However, approximately 150 students belonging to three schools will be in the IG and 100 students belonging to two schools in the CG when piloting the intervention.

Sample Size Determination

The optimal sample size for our chosen study design in the main study was calculated based on a formula by Rutterford et al. (34). This formula considers the confidence level (97.5%), power (80%), variance of days per week in cycling to school at the individual level [4.1 days (5)], our estimated clinically important difference in treatment means of days per week in cycling to school at the individual level (1.75 days), number of students per secondary school (based on the mean value in our concept mapping study: 51 students), and ICC of days per week students cycled to school at school level [0.2 days (17)]. According to this formula, the required number of students per intervention condition is 231. For the planned pilot study in the first instance, 10% of the main study's calculated sample size is recommended (35, 36) (i.e., 23 students per arm).

Measuring Instruments

To perform the effect evaluation of the planned intervention, several measuring instruments were chosen (see **Table 4**). Furthermore, the content of the process evaluation was defined.

To perform the pre- and post-measurement for the effect evaluation before and after the implementation of the intervention, participating classes will be divided into two small groups by the researcher and student assistants from TUM during two regular consecutive PE lessons with a total duration of 90 min. One group will answer the self-report questions in paper/pencil questionnaires, while the other group will perform a practical cycling skills exam off-road. Students who completed the questionnaire will be sent to the other group to complete the cycling skills exam and the other way around. At the end of the two regular consecutive PE lessons, accelerometers will be handed out and their handling will be explained to students (see **Table 4**). While wearing the accelerometers, weather conditions will be documented daily by a student assistant from TUM.

For the process evaluation during the implementation of the intervention, each art and PE teacher from each class that received the intervention will be asked to document in written form the dosage of their own intervention delivery (i.e., was the content of components implemented correctly), fidelity (i.e., what content of components was not implemented correctly and why), and any adaptions (i.e., what changes were made to the content of components during implementation). Thus, the dimension of the implementation of the intervention can be determined. Additionally, four willing students (two girls and two boys), four parents (two mothers and two fathers), and each art and PE teacher from each class that received the intervention will be asked in a structured online interview individually

TABLE 3 | Program implementation plan.

Phases	Weeks	Components	Locations	Time frame	Implementers	Tasks to be prepared
Preparation	1	Joint parents', teachers', and students' evening	School assembly hall and online	After regular school hours (1 × ca. 150 min)	Person of contact at school	1. Finding a possible date and communication to the researcher at TUM 2. Handing invitations out to students for their parents and to teachers 3. Preparing assembly hall (e.g., chairs, media)
					Researcher and student assistant from TUM	1. Drafting an invitation letter for parents and teachers 2. Preparing lecture/materials (i.e., booklet, video) 3. Preparing assembly hall (e.g., chairs, media)
	2	Bicycle inspection in the presence of parents and provision of required bicycle-related equipment	School's playground	After regular school hours (1× ca. 180 min)	Person of contact at school	1. Finding a possible date and communication to the researcher at TUM 2. Handing invitations out to students for their parents 3. Helping to prepare the event 4. Handing bicycle equipment out to students
					Researcher and student assistant from TUM	1. Contacting the ADFC, asking for a collaboration, and what is needed to perform the event 2. Drafting an invitation letter for parents 3. Preparing the event (e.g., materials) 4. Organizing missing bicycle equipment
					ADFC	Preparing and performing bicycle inspection
	2	Personalization of bicycle-related equipment	Classroom	During regular art lesson (1 × 45 min)	Art teacher	Supervision
	3–7	Cycle training sessions (incl. improvement of basic cycling skills, information about traffic rules, practicing social behavior)	Off-/on-road	Once per week during regular PE lesson (90 min): Off-road (3x), knowledge transfer (1x), on-road (1x)	PE teacher	Realization of lesson plans
					Researcher from TUM	1. Drafting detailed lesson plans 2. Preparing materials (i.e., obstacles, booklet) 3. Handing lesson plans and materials out to teachers
	8	Final exam of basic cycling skills in the presence of parents (incl. provision of a certificate)	School's playground	After regular school hours (1x ca. 180 min)	Person of contact at school	1. Finding a possible date and communication to the researcher at TUM 2. Handing invitations out to students for their parents 3. Helping to prepare the event
					Researcher and student assistant from TUM	1. Contacting the ADAC, asking for a collaboration, and what is needed to perform the event 2. Drafting an invitation letter for parents 3. Preparing the event (e.g., drafting certificates for each participating student)
					ADAC	Preparing and performing final exam
Practice	9–20	Voluntary bicycle train to cycle to school among peers with an arranged route and stops (incl. events)	On the way to/from school	5x to and 5x from school per week (i.e., before and after school) with 1 event per month	Researcher from TUM	Contacting the responsible police station, asking for a collaboration, and what is needed to perform the event
					Police	Supporting the cycling-to-school-events (e.g., kick-off event)

ADAC, German Automobile Club; ADFC, German Cyclist's Club; ca., circa; incl., inclusive; PE, physical education; TUM, Technical University of Munich.

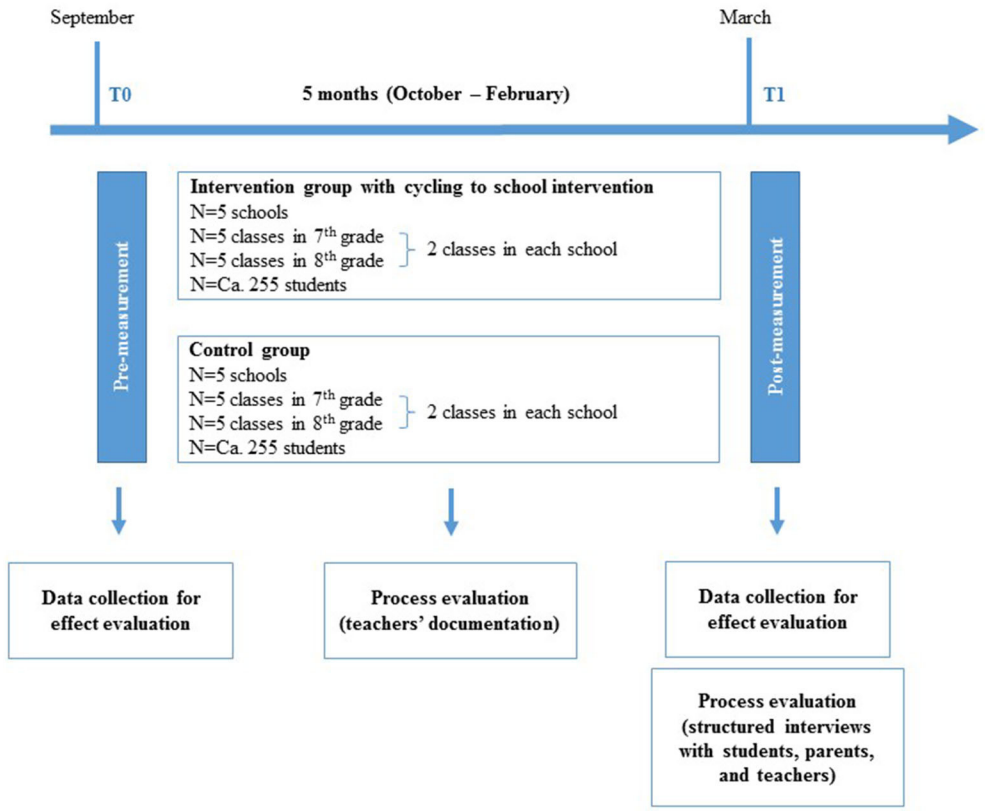

FIGURE 4 | Study design of the planned cycling to school intervention. *N*, sample size.

scheduled after the implementation of the intervention how they perceived the organization and content of the delivered intervention. They will also be asked to give feedback on their (dis)satisfaction regarding the intervention and to think about how it can be improved.

Data Handling, Storage, and Monitoring

Data will be collected using pseudonyms. Therefore, students will be instructed to create a six-digit ID code themselves to connect data throughout data collections and to ensure anonymity. Data collected for the effect evaluation will be entered in *SPSS*. Over a period of at least 10 years, data sets will be stored on central servers of TUM administered by the Leibniz–Rechenzentrum meeting the high standards of data safety in Germany. Only the researcher and manager of the ACTS project at TUM will get access to data sets, which means that anonymous data will not be made available for open access after the end of the study.

Statistical Analysis

To analyze the effectiveness of our intervention, a multiple group analysis considering the treatment factor (IG vs. CG) will be performed in a structural equation modeling using *R*. In this analysis, variances in the number of cycling days to school and MVPA due to belonging to different secondary schools will be considered in the following four levels: (a) repeated measurements for each student, (b) students, in which the repeated measurements are nested, (c) the class, to which each student belongs, and (d) the school, in which classes are nested. Subsequently, potential moderators (e.g., sociodemographic characteristics of the students) will be added to the model, and cycling to school will be regressed onto potential mediators (i.e., autonomy, competence, and relatedness) in levels (b–d). Furthermore, gender will be considered as a covariate in the analysis.

DISCUSSION

This study protocol describes the systematic planning process and design of the 5-month school-based ACTS intervention in Germany aiming to promote cycling to school among 12- to 15-year-olds. It used IM and a combination of the social–ecological model and the self–determination theory.

The decision to publish the detailed process of how our intervention was planned can be seen as a major strength as we demonstrate transparency of our structured procedure for other intervention planners. To the best of our knowledge, this is the first time that IM was used to plan an intervention aimed at the promotion of cycling to school. Our planned intervention has also several strengths: We chose the school setting for our intervention because it is regarded as ideal (50–53). According

TABLE 4 | Measuring instruments for the effect evaluation.

Outcomes	Variables	Instruments	Descriptions
Primary outcome	Mode, frequency, and duration of ACTS	Two valid self-report questions (37)	Behavior of cycling to school will be measured retrospectively for 5 weekdays: (a) Thinking about the last school week, how did you get to school/home from school each day?. Possible answers are walking, cycling, car, motorcycle, bus, underground/train/tram, or other. (b) Write beside the mode the journey start and end time.
Secondary outcome	Total MVPA in min per day	Accelerometers (ActiGraph wGT3X-BT)	On 7 consecutive days (38, 39), thigh-mounted (40) accelerometers with a sample rate of 30 Hz should be worn from waking up until going to bed except during water activities for a minimum of 8 h on a minimum of 3 weekdays and 1 weekend day (38, 39). Collected data will be downloaded using an epoch length of 1 s (38, 39). For wear time validation, the algorithm from Choi et al. will be applied (41). For data analysis, cut points from Hänggi et al. will be applied (42). For initialization and data processing of accelerometers, ActiLife will be used.
Moderators	Sociodemographic characteristics (5, 20)	Thirteen self-report questions	(a) Age/grade (b) Gender (c) Bicycle ownership/roadworthiness (d) Ability to cycle (e) Shortest distance from home to school by bicycle using Google Maps (43) (f) Zip code of the school (educational level, region) (g) Subjective socioeconomic status using the reliable "MacArthur Scale of subjective social status—youth version" (44) (h) Parents' restriction/allowance in terms of letting their child cycle to school (i) Family car ownership (45)
	Daily weather conditions (46)	Meteo Info	(a) Average rainfall in l/m^2 (b) Average wind speed in km/h (c) Relative humidity in % (d) Temperature in °C (average, minimum, maximum)
Mediators	Regulatory styles of motivation types (amotivation, extrinsic motivation, intrinsic motivation)	"German behavioral regulation in cycling to and from school" (BR-CS) as self-report questionnaire based on the valid and reliable "Behavioral regulation in active commuting to and from school" (BR-ACS) questionnaire (47)	Twenty-three items with three or four items per regulatory style will be rated on a five-point Likert scale ranging from strongly disagree, disagree, neutral, agree to strongly agree.
	Satisfaction of the three BPNs autonomy, competence, and relatedness	"German basic psychological needs satisfaction in cycling to and from school scale" (BPNS-CS) as self-report questionnaire based on the valid and reliable "Basic psychological need satisfaction in active commuting to and from school scale" (BPNS-ACS) (48)	Twelve items with four items per need will be rated on a five-point Likert scale ranging from strongly disagree, disagree, neutral, agree to strongly agree.
	Cycling skills	Reliable practical cycling skills exam off-road (49)	Seven basic tasks representing essential situations in road traffic will be examined (i.e., slalom, slow driving, ascending/descending, driving in a narrow lane, turning left, driving an eight with one hand, braking between two lines).

ACTS, active commuting to school; BPNs, basic psychological needs; MVPA, moderate-to-vigorous physical activity.

to the "Standing Conference of the Ministers of Education and Cultural Affairs" in Germany (54), the task to provide mobility and traffic education is assigned to schools, which we support with our planned intervention. Our intervention will contribute to closing the currently existing research gap by focusing on secondary schools where ACTS, especially cycling to school, is currently the least implemented activity (10) and generally, in an early development stage (9) with a lack of evidence for effectiveness in the majority of existing school-based interventions (11). We decided to focus on the promotion of cycling to school in winter (32) among the high-risk ACTS group of 12- to 15-year-olds (55) attending grade 7 or 8 (11) to expand the current state of research. As recommended, we chose a whole-of-school approach (56), a multi-level approach (21, 57),

and a combination of objective as well as subjective measuring instruments to accurately assess the PA level during cycling (58). To prevent negative experiences on-road (e.g., accidents), we will first provide some theoretical and practical components off-road. Instead of choosing a top-down approach, we partly chose a participative approach to consider the opinion of the target group (i.e., students) and relevant stakeholders (i.e., parents and teachers), to address the local context appropriately, and to ensure the feasibility of the implementation of the intervention. The success of this approach will be controlled in the process evaluation. Furthermore, we will initiate collaborations (e.g., with the ADAC and police) free of charge and provide all necessary materials so that schools could continue the work beyond the duration of the intervention, which will ensure sustainability. Finally, we determined the appropriate sample size for an adequately powered effect evaluation, will control for potential mediators and moderators in our analysis (57) and will pilot the intervention. The purpose of piloting is to pre-test the effectiveness, acceptance, and feasibility of the intervention, as it will later be performed in the main study, in accordance with the planned organizational procedure and chosen measuring instruments for data collection described in this study protocol but by using a smaller sample size and a weaker, that is, quasi-experimental, study design.

However, the following limitations have to be considered. In general, following the IM protocol was a time-consuming process making it difficult to fulfill each of its sub-steps (59). The time factor is also why the opinion of the target group could not be considered in every step (e.g., how students would design the intervention) but the IM protocol is normally only followed by researchers anyway (60). Besides, one demand mentioned in the needs assessment, that is, storage and changing room, could not be considered in the planned intervention. Moreover, this intervention was designed as an RCT providing a high evidence level (61) but without a follow-up. It will be characterized by a selective sample, that is, recruiting students of intermediate or high educational levels and regional restriction to (sub)urban areas in Southern Germany, and a moderate-term duration so that findings will not be generalizable.

Altogether, using the IM protocol to systematically plan an intervention is a time-consuming and complex procedure for researchers (59, 62, 63) but recommendable as it increases the chance to achieve the defined aim(s) of a planned intervention (12, 63). We suppose that the planned intervention adequately matches the needs of students aged 12–15 years grade 7 or 8 at secondary schools in Southern Germany, covering different educational levels (i.e., intermediate and high) and located in different municipalities urbanized to different levels. Thus, we expect that our effect evaluation will show increasing numbers of days on which students cycle to school and increasing total MVPA. As we considered the opinion from the target group and all relevant stakeholders in the planning process to a certain extent, we expect that the process evaluation will show satisfaction concerning components and the implementation of the intervention as intended.

ETHICS AND DISSEMINATION

Before the implementation of the intervention, we will apply for the intervention's approval by the Ethics Commission from TUM and the Bavarian State Ministry for Education and Cultural Affairs. Prior to participating in the intervention, schools, parents, and their 12- to 15-year-old children will have to provide signed consent forms, which will be collected from the person of contact at the participating secondary schools and forwarded to the researcher from TUM.

Any changes made to the methodological procedure described in this study protocol will be reported when publishing the findings of the pilot and main study in international peer-reviewed journals. In addition, the findings will be disseminated through formal presentations at conferences and informal meetings.

AUTHOR CONTRIBUTIONS

DS designed the concept of the intervention and drafted the manuscript. YD acquired funding for the project, supervised DS, and commented on the manuscript. PC, AM, and MP commented on the manuscript. All authors read, approved, and agreed to be accountable for the final manuscript.

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