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Is there a correlation between children's outdoor active mobility behaviour and neighbourhood safety? A systematic review of the evidence

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ABSTRACT

Objective To identify, summarise and evaluate evidence on the correlation between perceived and actual neighbourhood safety (personal and road danger) and diverse forms of outdoor active mobility behaviour (ie, active play, exercise, and travel) among primary-school-aged children.

Design A systematic review of evidence from observational studies exploring children's active mobility behaviour and safety.

Data sources Six electronic databases were searched: Google Scholar, PubMed, Scopus, Science Direct, ProQuest and Web of Science from study inception until July 2020.

Data extraction and synthesis Study selection and quality assessment were conducted independently by two reviewers. We expanded on a quality assessment tool and adopted a vote-counting technique to determine strength of evidence. The outcomes were categorised by individual, family and neighbourhood levels.

Results A total of 29 studies were included, with a majority of cross-sectional design. Higher parental perceived personal safety correlated with increased children's active mobility behaviour, but most commonly in active travel (eg, independent walking or cycling to a local destination). Increased concerns regarding road danger correlated with a decrease in each type of children's active behaviour; active travel, play and exercise. However, these correlations were influenced by child's sex/gender, age, car ownership, neighbourhood types, across time, and proximity to destination. Limited or inconclusive evidence was found on correlate of children's outdoor active mobility behaviour to 'stranger danger', children's perceived personal safety, race/ethnicity, socioeconomic status or measured safety.

Conclusion Children are restricted by perception of safety. Encouraging children's active travel may require future strategies to address characteristics relevant to types of the neighbourhood that promote a high sense of personal safety. Children and parents may embrace other types of active mobility behaviour if road danger is mitigated. Sex/gender and age-specific interventions and redesign of public places could lead to child-friendly cities. Future studies may benefit from adopting validated measurement methods and fill existing research gaps.

Strengths and limitations of this study

- This systematic review adapted a methodological quality appraisal that integrated studies' reporting and measurement methods along with a vote-counting technique to understand the strength of the evidence.
- To our knowledge, this is the first systematic review that comprehensively synthesises evidence on neighbourhood safety correlates to forms of primary school-aged children's outdoor active mobility behaviours.
- Peer-reviewed studies published in languages other than English were excluded, and meta-analysis review was not possible due to the heterogeneity in studies measurement methods and outputs.

INTRODUCTION

Children's daily active mobility behaviour is linked with profound long-term positive outcomes.[1] Recommended daily level of children's physical activity is primarily achieved through various forms of structured (ie, organised sport) or unstructured active behaviour (ie, active play in open spaces, walking, cycling or scootering to school and other local destinations).[2 3] Neighbourhood, the place where a child's majority of daily routines occur, has been identified as a primary venue for children to meet the daily physical activity recommendations.[2] However, variability in the neighbourhood (ie, residential, commercial, industrial and agricultural) have been found to affect types and extent of children's various shapes of active behaviour.[4 5] For example, different types of neighbourhood were linked to changed levels of active transportation in children aged 10–11 years living in Finnish urban areas.[6] Canadian children travel longer distance actively in residential or commercial areas than other types of neighbourhood.[5] Urban

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and road structures in The Netherlands reversed the negative effect of reduced active travel with longer distances.[7] Nevertheless, neighbourhood impact on other aspects of children's behaviour such as play and peer interaction is mixed.[8]

Safety, including personal and road danger,[9 10] is a complex concept.[3] Perceived (by parents or children) or measured safety (actual crime and traffic danger) may create obstacles resulting in children's lower confidence in exploring their surroundings,[2] or contributing to their community.[11] Lack of safety may have contributed to urban streets and public spaces becoming increasingly inhospitable environments. With more people living in urban settings than ever before,[12] and increasing safety concerns, children's territory for active outdoor mobility behaviour, such as walking, playing, cycling and scootering, has shrunk.[13–16] The damage caused by restricting children's active mobility behaviour may extend beyond their immediate physical health,[17] to overall social skills[18] and healthy brain development.[19]

Nevertheless, reviews that addressed neighbourhood safety and children's active behaviour have reported conflicting results. The disagreements could be due to: narratively investigating safety,[3] examining one shape of active behaviour such as active school travel[9 20–23] or independent mobility[24] or combinedly addresses safety with other environmental correlates and from a wide age range of children age (three or five to 18 years).[16 25 26] Over and above that, variability in measurement methods and output adds complexity in evaluating available evidence.[20 22] The absence of suitable checklists that account for measurement methods when assessing the quality of observational studies,[24] called research for alternatives approach to increase confidence in the synthesis of studies outcome[20 22] and inform evidence-based policy decisions. On the other hand, active school travel is a significant contributor to overall child active behaviour,[27] but other forms of activity incorporated into children's daily routines[24] are vital contributors to children's daily movement targets.[28] No review up to now has exclusively focused on the varying impact of measured and perceived safety in urban settings across primary-school-aged children's various forms of daily active mobility behaviours. Thus, this review aims to (1) systematically synthesise evidence of correlations between primary-school-aged children's outdoor active mobility behaviour (COAMB) and neighbourhood measured and perceived safety, and (2) derive the strength of the evidence by evaluating quality and methodological measurement method for each study and vote counting technique as justified from previous reviews.

METHOD

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The corresponding PRISMA checklist was completed during the review, as illustrated in online supplemental file 1. Though the search was planned, no protocol was registered.

Search strategy

A keyword search was designed and conducted to identify all relevant studies in six electronic databases: *Google Scholar*, *PubMed*, *Scopus*, *Science Direct*, *ProQuest* and *Web of Science*. All databases were searched between March 2019 and July 2020. The search algorithm included all possible combinations of keywords. Terms pertaining to this review were grouped by (1) target population, (2) AND active behaviour, AND (3) neighbourhood safety, OR (4) moderators and mediators, OR (5) spatiotemporal aspects (Global positioning system, GPS, geographic information system, GIS, out of school hours). The entire search thesauruses and strings are available in online supplemental file 2. Additional papers were identified from the citation lists of individual and review papers.

Eligibility criteria

Studies were included for review if they were: published in peer-reviewed journals, in English, were observational studies that collected data directly on participants aged between five and 12 years (primary-school-aged children), assessed neighbourhood safety (personal and road safety) either as perceived by parents and/or children or measured (crime or road conditions), and reported or measured children's active mobility outside school hours. Included publications were not restricted to a single geographic location or a specific time. Studies were excluded for failing to meet the inclusion criteria. Systematic, scoping, or narrative reviews, opinion and editorial pieces, and other non-original research publications were also excluded.

Study selection process

Using search terms developed for this review, one reviewer (RZ) screened titles and abstracts to identify those works that met the inclusion criteria. Abstracts of the downloaded papers were then reviewed by two independent reviewers (RZ, CX) against the selection criteria. The final list of included studies was agreed by consensus involving a third reviewer (RN). Studies that met inclusion criteria were reviewed in full by RZ.

Data extraction process

The first author (RZ) extracted, into an excel datasheet relevant information on: author(s) year of publication, year of data collection, location of study, sample size (separated by gender), age/school grade, characteristics regarding methods of measuring or assessing neighbourhood safety (perceived or measured), children's active behaviour and outcome measures (eg, body mass index (BMI) or medium-to-vigorous physical activity (MVPA)), child's neighbourhood, other variables accounted in studies analysis including cofounders (eg, sex/gender/family characteristics) and summary of findings. The data were collated into a systematic narrative summary table of the relevant papers.

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Patient and public involvement

No patients involved.

Data synthesis

Correlates between COAMB and safety were organised according to aspects of the socioecological framework (ie, individual, family, and neighbourhood). This framework is frequently used in active health behaviour research[29] as a conceptualisation tool. This tool provides a structure for organising and understanding multiple factors that cause changes in health behaviour. Additionally, to enable the review investigating influences specific to forms for active behaviour, the outcome of correlates were compared by grouping findings into one of four categories: active travel; school travel; active play; active play, travel and exercise. The subgrouping corresponds to children's main types of structured and unstructured active behaviour outside of school hours.[30]

Quality assessment

Two independent reviewers (RZ, BJ) appraised the selected studies using priori defined quality criteria. Previously practised quality assessment by Schoeppe *et al*[24] for active travel, Marzi and Reimers[31] on independent mobility, and by Lubans *et al*[27] on active school travel, were reviewed. We adopted 13 existing criteria used earlier that covers all pertinent studies quality reporting characteristics. We expanded on six items to the checklist based on findings from a recent systematic review of which methodological measures in observational studies were assessed and found to be fundamental to increase reliability in children's active behaviour research.[32] Those measures were covering: COAMB (objective or subjective), temporality elements such as change in time of day, weekdays or weekends (addressed in both perceptions of safety as well as COAMB), the delineation of the neighbourhood area (arbitrary or measured) and accounting for cofounders. We adopted the scoring system applied by Marzi and Reimers[31] and Schoeppe *et al*[24] to quantify study robustness. Each criterion in the quality assessment checklist was given the assigned score if coded 'yes', 0 if coded 'no' or unclear, and half the score if coded 'partial'. A total overall score out of eight points was assigned, showing in table 1. As included studies have employed a variety of tools and sometimes composite techniques to measure active behaviour, we adopted Marzi *et al* method for criterion number fourteen that was scored on a scale ranging from 0 to 1. For example, if a study employed an accelerometer and GPS, the study accumulates 0.5 points. However, when the study only used one measurement tool, it was assigned 0.25 points. A study variable that was measured appropriately but was not applicable to a specific criterion used for the quality assessment was discounted in the sum of total points used to derive quality score.[24] For example, the quality assessment criterion related to temporal and spatial measurement was not applicable for a paper where the primary outcome measure was BMI. In that instance, the criterion was removed from the total quality score of that paper.[24] The quality score for each study was calculated by converting the total accumulated score into a percentage (total accumulated score/8 (maximum possible score) × 100).[24] Adopting Schoeppe *et al* cut-off for levels of studies' quality, a percentage score of ≥66.7% was deemed robust, a score between ≥50 and<66.6% was considered moderate, and <50% was rated poor.

Evidence synthesis and strength

Evidence synthesis described by Rothman *et al*[22] and Ikeda *et al*[20] was used in this review. Each correlation and its direction (positive (+), negative (−), or inconclusive/no correlation(0)) was identified and coded in terms of statistically significant or non-significant findings organised by the socioecological levels. To facilitate synthesis of evidence, we performed a reverse coding of the original direction of associations (ie, positive to negative or vice versa) as necessary, depending on the wording used in each work.[20] A minimum of five studies with significant or non-significant findings was adopted to generate a consensus.[20 22] Evidence with less than five studies available for synthesis was rated as limited,[24] and with three studies was rated insufficient. Deriving strength of evidence was also adapted from previous reviews[24 27] using the proportion and quality of studies reporting a significant association. The ratio of studies found with robust quality in this review to those found in an earlier review[24] was used to rescale the quality thresholds. In a minimum of five studies, if ≥27% of the total synthesised significant evidence that agrees in a direction (ie, +, − or 0) was of robust studies, the evidence was rated strong, from ≥20%–<27% was moderate strength, and at <20% was rated weak.

RESULTS

Study selection

Following the title screening, a total of 231 papers across the six databases were initially identified that deemed potentially relevant. After removing 128 duplicates, the abstract review resulted in 64 articles that underwent a full-text review. Seven additional studies were identified from a manual search of individual reference lists. Following full-text review, a total of 29 studies met inclusion criteria, figure 1.

Study characteristics

The characteristics of the 29 studies, including settings, measurement methods and evidence output, are summarised in table 1 in online supplemental file 2. There were three longitudinal studies,[10 33 34] and the remaining (25 studies: 86%) had a cross-sectional design. Twelve of the 29 studies (41%) featured analysis using data from other larger scale or government projects (eg, the Children Living in Active Neighbourhoods study,[35 36] the Built Environment and Active Transport project[37] and the Spatio-Temporal Exposure and Activity Monitoring (STEAM) project[38]). Populations varied across

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Table 1 Criteria for quality assessment and scoring for each criterion adapted from previous published systematic reviews

Criteria		Description	Quality score per criterion
Adopted quality assessment characteristics	1. Study objectives	Are objectives clear?	(Yes=0.25-point No=0 of each criterion)
	2. Design	Was the study design appropriate for research undertaken?	
	3. Target population	has the target population defined?	
	4. Random sampling	Was a random sampling of the target population taken or was sampling appropriate for the study design?	
	5. Study participant number	Was the number of participants at each stage reported?	(Yes=0.25-point No=0 of each criterion)
	6. Participants' inclusion/exclusion	Were criteria for inclusion and exclusion of the participants used?	
	7. Study population	Was the study population sufficiently described, that is, sample size, gender, age, indicators of socioeconomic status?	
	8. Participant recruitment	Was participant recruitment described or referred to?	
	9. Response rate	Was the response rate 60% or more?	(Yes=0.25-point No=0 of each criterion)
	10. Data collection	Did the study describe data collection, that is, by mail, by interview, objective measure?	
	11. Data sources	Did the study describe source of data, that is, questionnaire, survey, focus group, accelerometer, GPS?	
	12. Missing data	Were numbers/percentages of the participants with missing active behaviour data reported, and did at least 80% of enrolled participants provide complete data to include?	
	13. Statistical method	Was it clear what was done to determine statistical or spatial statistical significance, for example, p-value, CI?	Yes=0.5 No=0
Methodological measures	14. Active behaviour measures	Did the study objectively measure active mobility, that is, activity tracking. Spatial technology or web application? Were measures reliable and valid for subjective measures?	GPS=0.25 (accelerometer)=0.25 questionnaire=0.25 Travel diary=0.25 N/A
	15. Temporal active behaviour measures	Was measured active behaviour related to temporal characteristics, that is, weekends vs weekdays or before and after school?	Yes=0.5/No=0 N/A
	16. perceived safety measures characteristics	Did the study account for spatial or temporal features of the safety feelings? (Weekdays vs weekends or daytime (before and after school)) Or was measured safety conducted using geocoding?	Yes=0.5 No=0
	17. Area of exposures	Did the study delineate the exposed area 'neighbourhood' objectively or evaluate arbitrarily?	Objectively=0.5 Arbitrary=0 N/A
	18. Evidence depicted temporal variation	Did the analysis account for the spatiotemporal behaviour of evidence?	Yes=1/No=0
	19. Adjustments (Cofounders)	Did the study account for cofounders of age, sex, ethnicity, and family characteristics?	Each is 0.25/Total=1

GPS, global positioning system.

studies, with both parents and children represented. The sample sizes ranged from 35 children[6] to 31 000 households.[39] Studies alternatively used age groups or school grade to refer to children's age, but the mean ages were within the specified range of 5–12 years. Included works examined associations between forms of COAMB and perceived safety (21 of 29 studies; 73%), measured safety (5 of 29; 17%) or both measured and perceived safety

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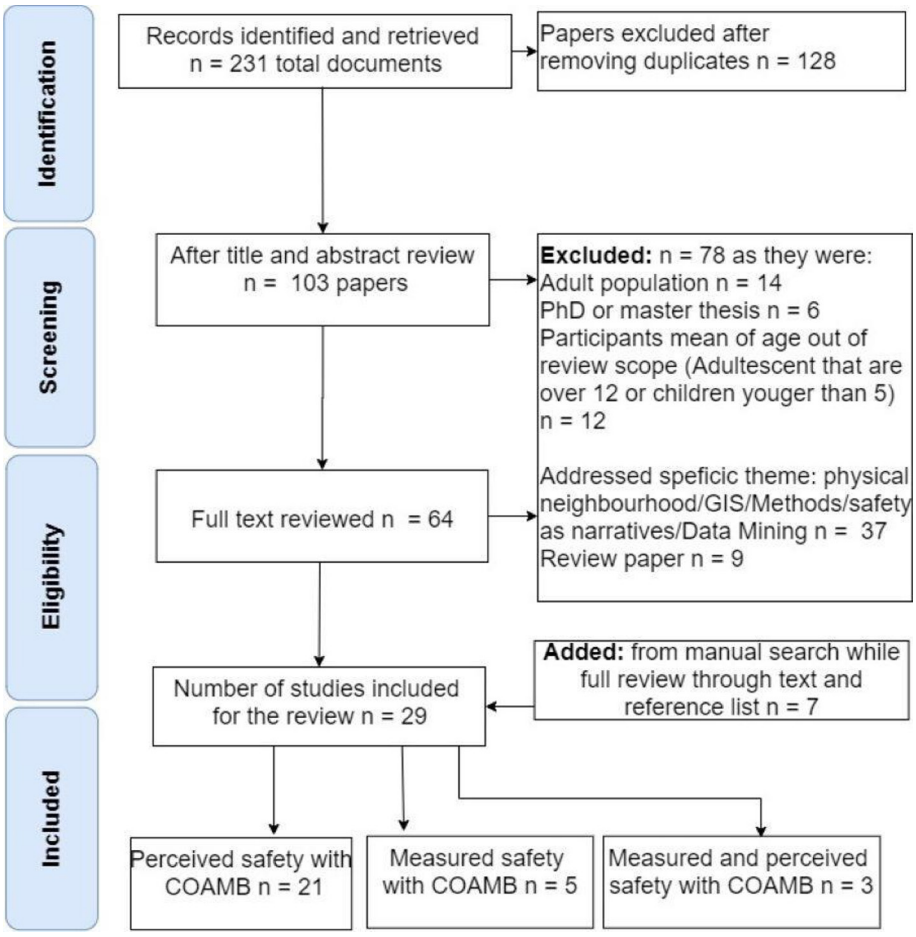

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for scoping review of neighbourhood safety correlates to children's outdoor active mobility behaviour (COAMB). GIS, geographic information system.

(3 of 29; 10%). Collectively, the publications spanned Asia, Europe, North America and Oceania, Diagram 1 of online supplemental file 2. Aside from two Iranian studies,[40 41] and one from Malaysia,[42] the remaining publications (26 of 29; 90%) addressed populations in developed countries, with five each from the USA[34 43–46] and the UK[10 47–49]; four each from Canada[5 33 37 50] and Australia[35 36 51 52]; two each from New Zealand[53 54] and the Netherlands,[7 55] and one each from Portugal,[56] Finland[6] and Austria.[57] Except for one study,[58] remaining papers were published between 2007 and 2020. Two studies used BMI[34 48] as a measure of children's active health indices, yet one article has combined BMI with self-reported physical activity. Subjective assessment was the most common method of measurement of children's active behaviour. Ten of 29 studies (34%) employed objective measures such as accelerometers,[35 36 45] pedometers,[52] GPS[6] alone or in combination with an accelerometer,[37 50 53] or GIS loggers.[33] In view of the heterogeneity in the measurement methods, disparity in studies' units of outcome were apparent as exhibited in Diagram 2 of online supplemental file 2. Of 24 studies which examined personal safety, the majority assessed safety as perceived by parents; however, 7 studies featured safety perception among children.[5 41 47 49 51 52 58] Five studies[7 10 36 50 53] examined objective measures of road safety and 12 studies assessed road danger as perceived primarily by parents. The findings in 25 of the 29 studies (86%) were reported separately for boys and girls.

Methodological quality assessments and strengths in evidence

Nine of 29 studies (31%) were rated of robust quality, 16 studies (55%) were of moderate, and four (14%) were rated as poor quality, as presented in table 2 in online supplemental file 2. Most studies focus on correlates of safety to active travel behaviour, such as independent walking or cycling to local destinations. Table 3 in online supplemental file 2 showed that active school travel was the focus in seven of 29 (24%), ten of 29 (34%) addressed active travel, and seven of 29 (24%) addressed active play, active school travel and exercise. Active play alone was investigated in 3 of 29 (10%) studies, and two (8%) used BMI, but one study combined BMI with self-reported physical activity, figure 2.

Synthesis of the evidence

Derived from table 4 in online supplemental file 2, we summarised below statistically significant and

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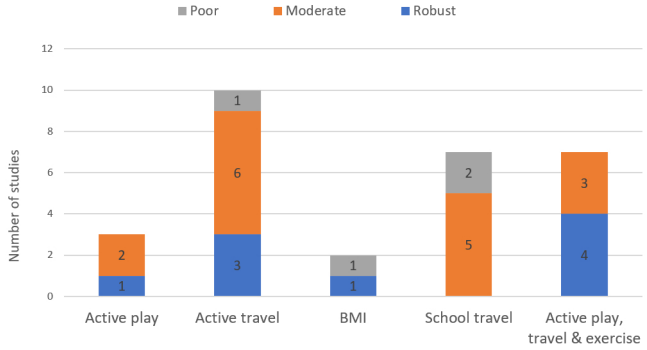

Figure 2 Studies grouped by the type of active behaviour indicating studies' level of methodological quality assessment. The x-axis represents studies as grouped by type of active behaviour examined in each study. y-axis denotes the number of studies giving the different levels of evidence 'strength' when total methodological review score was summed. Strength of evidence was robust when summing total score was ≥66.66% moderate sum was ≥50–<66.6% and poor when an accumulated score was <50%. Adapted from previous review by Schoeppe *et al*.[24]

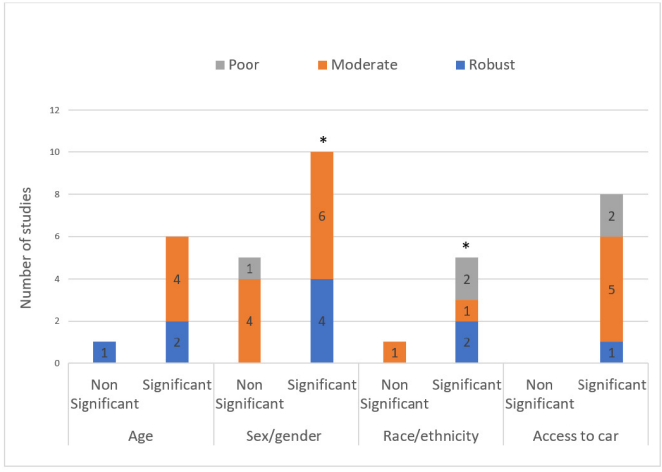

Figure 3 Correlation between individual (child) and family characteristics and children's active mobility behaviour. The x-axis represents variables that accumulated the minimum number of studies to synthesise evidence of correlates between COAMB and sex/gender, age, access to a car, and ethnicity. y-axis denotes the number of studies that examined the correlation showing accumulated significance or non-significance. Note: *=in sex/gender, we saw variability by temporal characteristics (ie, changes between weekdays and weekends or time of the day (before and after school)) in three studies and reduced COAMB by distance travelled in one study. *=In Race/ethnicity, one study with a significant correlate depicted temporal change (i.e., weekend/weekdays).

non-significant correlations in 29 studies examining influences on COAMB by aspects of socioecological levels that were.

Individual level

Without considering safety and supported by strong evidence (40% in 10 out of 15 studies reporting significance and agrees in the direction were of robust quality), we found a correlation between sex/gender and COAMB. A higher level of COAMB was accumulated by males than female children, figure 3. Boys had more active behaviour,[44] took more active trips,[35] accessed larger activity spaces,[52] and increased their active travel of walking or cycling to school,[10] or other destinations.[52] However, this correlates influenced by: temporal variation between weekdays and weekends,[37] time segments of the day (after dark)[51 52] or actual distance travelled.[6] Similarly, strong evidence (33.3% in 6 studies reporting a significant positive correlation were of robust quality) showed that children of older age groups or higher school grades accumulated more COAMB.

Family level

Eight studies found that correlates of COAMB and car ownership were consistently associated with lower levels of COAMB. Despite that, the level of evidence was weak, with only 12.5% of the total studies were robust quality. The inconsistent finding across five studies suggests no clear correlation between ethnicity/race or socioeconomic status (SES) and COAMB. Children of minority groups in the UK achieved lower levels of active behaviour,[47] whereas children of minority groups in the USA accumulated higher levels of active behaviour.[44] In New Zealand, children's active behaviour differed by race/ethnicity and the day of the week: Indian/Asian background had increased their physical activity levels of medium-to-vigorous (MVPA%) on weekends while Pacific, European and Maori children accumulated higher (MVPA%) on weekdays.[53] Findings on (SES) and COAMB were either: non-significant for female children (5–6 years); increased active behaviour in high (SES) groups[42 51]; inconclusive[59]; and increased BMI level in a high deprivation area yet reported higher self-physical activity.[48]

Neighbourhood level

We found strong evidence that increased parental perception of safety correlated with lower COAMB (29.4% of the 17 out of 18 studies reporting significant and agreeing in the direction were of robust quality), figure 4. We found limited and inconsistent evidence on the correlation of 'stranger danger' among parents to COAMB; no relationship,[54 56] reduced MVPA,[45] and has a temporal correlation (son weekdays).[37] We found moderate evidence (25% of the 11 studies were rated robust) but consistent in the direction of correlates of higher parental road safety concerns and decreasing levels of COAMB, including one study finding a gender difference (girls). Weak evidence yet consistent (i.e., agree in the direction of the significance) of lower levels of COAMB correlate with children's increased perception of danger from strangers, roads and personal safety. Limited (four studies) evidence related to children's perception of personal safety,[5 41 49 52] included a study that depicted variation by gender.[52] Perception of 'stranger danger'[51 55 60] was insufficiently (three studies) addressed. Road danger[47 49 51 52 58] depicted variation in two studies by sex/gender.[49 58] Regarding measured safety (i.e., crime

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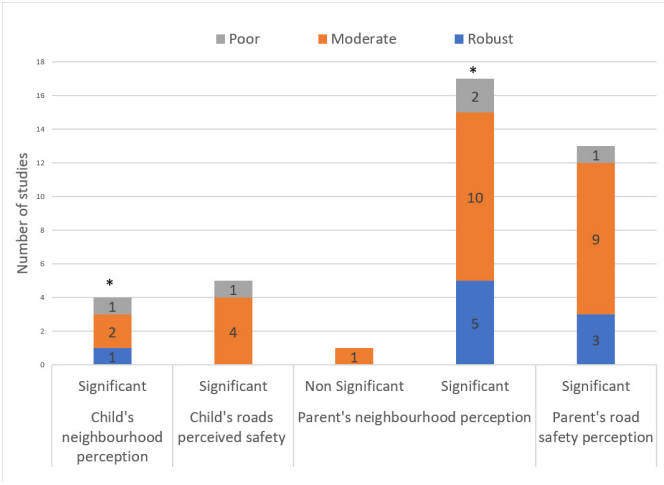

Figure 4 Perceived safety (parents and children) of personal and road danger correlates to reported and measured children's active mobility behaviour. The x-axis represents examined variables that accumulated a minimum number of studies to synthesise evidence for perceived personal and road safety by parents or children. y-axis denotes the number of studies that accumulated significant or non-significance. Note:*=Parents' perceived neighbourhood safety showing significant correlates included three studies depicting temporal characteristics (weekdays/weekends or before and after school), three studies varied by child's sex/gender and one study by age. *=For children, perceived personal safety varied by gender in one study.

or road conditions) and COAMB, a definitive conclusion cannot be drawn despite robust evidence (six out of nine studies are of robust quality),. A synthesis of four studies showed inconsistency in the direction of the relationship with measured personal safety,[33 34 45 46] as one study depicted increased active transportation in high crime areas.[33] Road danger[3 7 10 50] showed increased outdoor active play in highest traffic areas,[50] and one study lacked correlation to measured roads environment.[36] Other characteristics in the neighbourhood that are likely to be influenced by perceived safety were: strong evidence of distances travelled (perceived or objectively measured) with 10 studies and 40% of robust quality and variability in neighbourhood type (6 studies with 66.6% of robust quality). Other addressed variables demonstrated associations with COAMB, but insufficient evidence to conclude are in table 4 of online supplemental file 2.

DISCUSSION

A review of 29 studies investigating multifaceted influences on COAMB and neighbourhood safety prompted the discussion over three primary topics.

Inequality in opportunity for children's active behaviour

Differences in individual, family, and neighbourhood safety, created an unequal opportunity for COAMB that was ubiquitous across geographical regions, Diagram 3 of online supplemental file 2. Our review depicted variability of COAMB by sex/gender that was predominant in active play and exercise forms of active behaviour than in active travel. This explains lacking of agreement with previous reviews on independent mobility[61] and active school travel,[22] yet agreed with reviews on physical activity.[15 62]

Our review suggest that with more access to cars, parents conveniences,[22] or other influences such as weather conditions, children at young age are more likely, regardless of their sex/gender, to be driven more often than actively travelling (eg, school trips). However, variability in sex/gender becomes more apparent in physical activity as it is an elective form of active behaviour behind school or government jurisdiction. Increased COAMB with age undetected in previous reviews[15 62] could be owned to earlier reviews combining a broad range of children's age (3–12 years[61] or 3–18 years[15]). A longitudinal study suggested that some forms of active travel (such as school trip) become more prevalent with age, starting from 6 years.[60]

Studies variability restrained clear conclusions on family race/ethnicity or neighbourhood (SES) correlates to COAMB also concord with earlier reviews findings.[20 22] Children from low SES areas in the UK[48] were more active. However, children from wealthy families in Australia and Malaysia[42 51] had increased active behaviour. Children from less affluent areas may be active by necessity, whereas more accessibility opportunities to open spaces and recreational centres are offered to children from high (SES) areas. A study on obesity rates showed that migrant children (in lower SES) were more active than resident children with higher (SES).[63] This socioeconomic influence appeared to reverse its effect on COAMB by geographical location (between developed and developing countries). Nevertheless, we found variation in the correlates of COAMB to (SES) by gender (female children),[51 55 60] age group[55] and higher income people feeling safer, which in turn encouraged active school travel.[55] Despite an agreement with earlier reviews,[20 22] the decline in COAMB concerning family ownership of car conflicts with some studies suggesting that wealthier families are more active, thus calling for further investigation.

Every child is entitled to feel safe at all times. Nevertheless, findings of this review suggest a distinct inequality as children living in low perceived safe areas are declined the opportunity to be active. Our finding conflicts with two previous reviews on active travel[16] and physical activity,[15] respectively. The broad range of children age addressed in the two reviews may have contributed to the disagreements in findings. Parents have a larger influence on younger children's active health behaviour[9] and perhaps hold greater fears regarding road safety for younger children that may not contribute significantly in the older age group, as was explained by a longitudinal national study in the US.[64] However, concerns regarding personal safety are nuanced by gender (females),[6 35 52] temporal variations (on weekdays only[53] or weekends,[35] and intersect with gender (females) and temporality when after dark.[6] The prevalence effect of 'stranger danger' on COAMB among studies surveying children suggests that vulnerability to strangers' harm is more significant for children, particularly for girls.

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Influences on COAM are specific to the type of active behaviour

Child's sex/gender is correlated to COAMB, but most apparent in active play and physical activity rather than active travel. This review also depicted that perceived personal safety risk is most significant in restricting children's active travel, limiting their active space. This finding concurs with earlier research revealing shrinking children's active space with the rise of personal safety fears.[2] Nevertheless, parents' concerns over road danger restricted all types of COAMB, Diagram 4 of online supplemental file 2. More active travel was regarded in the urban residential and commercial neighbourhood, was also concluded previously[31] suggesting that dense urban area may offer a sense of safety, encouraging more active travel among children. The correlate was also confirmed by the reversed influence of reduced active travel correlates to perceived or measured distance occurred with changes to roads and infrastructure.[55]

Methodological challenges

The inconsistencies seen in studies investigating neighbourhood safety correlates to COAMB, limit the ability to draw definite conclusions in some areas. Our methodological quality assessment revealed that most studies fulfilled elements relevant to studies reporting but essentially lacked addressing components in the design, method of measurement, and analysis for evidence-based research on children's active health.[32] This may have resulted in the majority of studies were of moderate and poor quality. Subjective measures using questionnaires rely on human recall distant events.[65] Yet, we found some inconsistencies among studies employing objective measures. Although a review of measurement methods is out of the scope of this paper, the discrepancies in some of the outcome necessitate highlighting some critical research challenges for future research attention yet were elaborated further elsewhere by Zougheibe *et al*.[32] Study design is likely to affect the outcome. Longitudinal studies limit selection bias associated with cross-sectional design. Inconsistency in the direction of correlates among studies employed objective measures showed most problematic measurement methods were in (1) inconsistent inclusion of crime categories for measured personal safety studies or elements addressed roads conditions, (2) measuring COAMB using spatial activity tracking (i.e., GPS) was faced with an absence of standardised measurement protocols that caused variabilities in few areas such as the inclusion of surveyed days and threshold of counts per minutes of registered data, that could impact a true interpretation of results, (3) the spatial extent of the child's neighbourhood to derive safety exposures was primarily defined arbitrarily. Still, studies that adopted spatial measures had employed diverse methods, (4) inconsistent accounting for cofounders and (5) infrequent accounting for temporal safety and behaviour characteristics. We found scarcity in research on correlates of COAMB to variation of safety perceived by parents to children residing in the same neighbourhood and actual crime.

Implications of findings

Successful implementation of any intervention strategy to encourage parents and children to embrace an active mobility culture require collaboration among all levels of children, families, schools, community-based organisations, city planners, policy-makers and researchers.[28 66] The revealed multiple influences contributing to children's active behaviour guided our recommendations below.

Interventions for vulnerable groups of the population

Ignoring gendered primary-school-aged children's active mobility behaviour may result in only male adult's regarding physical activity as essential or accessible. Therefore, strategies to increase active behaviour must be sex/gender and age specific. Additionally, the indication of influence on COAMB by diverse (SES) and race/ethnic backgrounds suggests that a subgroup of the population is constantly inactive. Parental involvement in educational programmes to promote children's free play and active travel or children's encouragement in school and community programmes to participate in active travel and leisure active play could be useful. Earlier evidence also supports the positive influences of active parents[56] or positive peer influence.[67]

Promote child-friendly cities

Revitalise cities design may offer play opportunity and safer travel for children. Perceived low safety linked to declined children's active travel and its associate to neighbourhood types suggests that current cities and roads designs are maybe seen as unsafe for children to be outdoors actively playing and travelling safely to local destinations independently. Most importantly, interventions intended to encourage children to travel further actively call for redesign of urban structures to enable active travel and safety at the same time. This may include upgrading local features that promote walkability in desirable neighbourhood characteristics (eg, schools, shops, libraries) and active playing in local parks or exercise in an 'activity-friendly neighbourhood'.[68] More voices are calling for children and families to be included in designing new urban spaces. Improvements in road safety may increase overall COAMB and enable children and families to embrace an active mobility culture. Existing streets design is seen as unsafe and unappealing for children and their parents. Prompt policy interventions to address most concerned roads conditions(eg, heavy traffic, fast drivers, high-speed roads, lack of road signals, availability of sidewalks and cycling infrastructure) may alleviate parents' and children's concerns over road danger.

Advancing research

Methodological improvements to reduce inconsistency in the outcome and increase reliability in future research can better inform evidence-based policy. Namely: encouraging longitudinal study design and adopting a three-dimensional conceptual framework in research as suggested earlier[32] to account for critical elements of (1) what we measure: the determinants that affect the outcome and consistent accounting

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for cofounders (sex/gender, SES background, and ethnicity/race background), (2) how we measure: involves frequency and intensity for perceived safety[69–71] (personal and roads) and active behaviour whether reported or measured consistency in addressing crimes only relevant to personal safety, and (3) spatiotemporal characteristics (i.e., locality of active behaviour or safety incident, spatial extents of children neighbourhoods, and time).[72] Further research on COAMB correlates to variability in parents to their children safety perception or measured to perceived safety, and inequality in the neighbourhood (SES) would answer more profound research questions.

STRENGTHS AND LIMITATIONS

This review was limited to English-language and peer-reviewed observational studies. Despite every effort to identify all relevant studies through a variety of terms used, some relevant studies may have been omitted due to multiple synonyms used in works. The observed heterogeneity in study measures prevented a straightforward meta-analysis; thus, we conducted quantitative vote counting to overcome existing disparities in outcome and methods. The majority of studies were cross-sectional design and were of moderate or poor quality. Despite these limitations, this review has important strengths. This work synthesised findings and derived a quantitative understanding of evidence strength by combining a measurement of study reporting quality, involving critical characteristics that may improve reliability in future observation studies. This paper has comprehensively addressed the impact of safety in primary-school-aged children's active behaviour, eliminating inconsistencies resulting from a broad age range of study participants. To the best of our knowledge, this review is the first to consider the impact of perceived (by parents and children) and measured neighbourhood safety across multiple types of COAMB. Finally, this review was not limited to publication date or geographical region.

CONCLUSION

This systematic review of evidence revealed that there is inequality in COAMB by children's sex/gender and age and some indication regarding race/ethnicity and (SES) despite the evidence being inconclusive with regard to the latter two examined variables. Compared with safer neighbourhoods, children living in perceived unsafe areas correlated with lower outdoor active mobility behaviour and reduced active play. However, perceived personal safety risk has primarily restricted children's active travel to local destinations, whereas perceived danger from traffic reduced every type of COAMB. Nevertheless, the direction and strength of the correlates are affected by individual and family characteristics, distance travelled, and time (weekend/weekday/time of day). These findings were consistent across countries. There is a need to use validated measurement methods. Deeper understanding of safety (perceived or measured) correlates to race/ethnicity,(SES) variances and COAMB (spatial extent of active behaviour or intensity of physical activity) may answer more profound behavioural research questions. Current inequalities in children's opportunities to engage in active mobility behaviour require sex/gender and age-based interventions. Most importantly, interventions aimed at improving personal safety and engaging children in urban design to promote child-friendly cities may prompt children to travel further actively. Improvements in road conditions may increase overall COAMB and enable children and families to embrace an active mobility culture.

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Contributors RZ carried concept/design, data retrieval, screening of the literature for inclusion, quality rating, synthesised the findings, drafted, and finalised the manuscript. BJ assisted in rating of studies quality and contributed to proof editing the overall manuscript. RN, OG and AD reviewed and approved the manuscript.

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PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	P1 of manuscript
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	P2 of manuscript
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	P3 of manuscript
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	P3 of manuscript
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	P4 of manuscript
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	P4 of manuscript
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	P4 of manuscript
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	P4 of manuscript
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	P4 of manuscript
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Table 1 supplementary file 2
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Table 1 supplementary file 2
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	P5 of manuscript
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	P6 of manuscript
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	P6 of manuscript
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	P6 of manuscript

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	P6 of manuscript
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	P4 of manuscript
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	P5 of manuscript
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	P6 of manuscript
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	P6 of manuscript
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	P6 of manuscript
Study characteristics	17	Cite each included study and present its characteristics.	Table 2 supplementary file 2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Table 3 supplementary file 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Table 4 supplementary file 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	P6 of manuscript
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Table 4 supplementary file 2
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	P7 of manuscript
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Table 2supplementary file 2,
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	P7 of manuscript
DISCUSSION			

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	P8 of manuscript
	23b	Discuss any limitations of the evidence included in the review.	P8 of manuscript
	23c	Discuss any limitations of the review processes used.	P8 of manuscript
	23d	Discuss implications of the results for practice, policy, and future research.	P8 of manuscript
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	12 of manuscript
Competing interests	26	Declare any competing interests of review authors.	of manuscript
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	of manuscript

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

Search Terms Used

(1) **target population** using terms such as "Children" "youth" or "kids" or "primary school aged children", (2) **exposures of social neighbourhood** "Perceived safety from crime", "Social neighbourhood", "Neighbourhood safety", "Measured crime", "Fear of crime", or "Perception of crime", "road safety", "traffic safety". (3) **moderators and mediators** of "Parents' perception of safety from crime" "parents' and children's perception of safety from crime" or "children perception" "age 5-11" "gender", "ethnicity". (4) The **spatiotemporal** aspects: "spatiotemporal measures, Geographic Information Systems GIS, time geography", "space and time geography" "Objective measures" or "GPS". (5) the **outcome** such as "Active Mobility", "Free play", Medium to Vigorous Physical Activity". "Outside school hours". A combination of at least three keywords was alternated to find the possible variety of papers related that could be scanned and retrieved.

Search strategy in Scopus

Search by document type (ALL), Search in (Article title, Abstract, Keywords), Access Type (ALL), Limit is (Published all years). The source type is articles. Language is in English. Keywords (e.g., "Children" OR "primary school aged children" OR "youth", OR "Active mobility" OR "Active behaviour" OR "Physical activity" OR "Active play" OR "active travel") AND ("Neighbourhood") AND ("Safety" OR "Parents Perceived Safety" OR "Children Perceived Safety" OR "Road safety" OR "Crime") AND ("Outside school hours)" AND ("Spatial data" OR "GIS" Or "GPS" OR "Spatiotemporal").

Search strategy in Google scholar

Search by document type (Article), Search alternate keywords (e.g., "Children" OR "primary school aged children" OR "youth", OR "Active mobility" OR "Active behaviour" OR "Physical activity" OR "Active play" OR "active travel") AND ("Neighbourhood") AND ("Safety" OR "Parents Perceived Safety" OR "Children Perceived Safety" OR "Road safety" OR "Crime") AND ("Outside school hours)" AND ("Spatial data" OR "GIS" Or "GPS" OR "Spatiotemporal").

Search strategy in PubMed

Search Terms: Include related keywords terms of (e.g., "Children" OR "primary school aged children" OR "youth", OR "Active mobility" OR "Active behaviour" OR "Physical activity" OR "Active play" OR "active travel") AND ("Neighbourhood") AND ("Safety" OR "Parents Perceived Safety" OR "Children Perceived Safety" OR "Road safety" OR "Crime") AND ("Outside school hours)" AND ("Spatial data" OR "GIS" Or "GPS" OR "Spatiotemporal"). Select English language, Publication Year No limit

Search strategy in Science Direct

Search for peer-reviewed journal articles (including open access content)

Find articles with these keywords' terms of (e.g., "Children" OR "primary school aged children" OR "youth", OR "Active mobility" OR "Active behaviour" OR "Physical activity" OR "Active play" OR "active travel") AND ("Neighbourhood") AND ("Safety" OR "Parents Perceived Safety" OR "Children

Perceived Safety" OR "Road safety" OR "Crime") AND ("Outside school hours)" AND ("Spatial data" OR "GIS" Or "GPS" OR "Spatiotemporal"). No limit for Publication Autor(s) or Year(s)

Search strategy in ProQuest

Use command line to use search terms keywords such as (e.g., "Children" OR "primary school aged children" OR "youth") AND ("Active mobility" Or "Active behaviour" OR "Physical activity" OR "active play" OR "active travel") in Anywhere AND ("Neighbourhood Safety" OR "Parents Perceived Safety" OR "Children Perceived Safety" OR "Road safety" OR "Crime") in Anywhere. Add a row of AND ("Outside School Hours") in Anywhere. Add a row of AND ("Spatial Data" OR "GIS" Or "GPS" Or "Spatiotemporal"). Limited to (Peer reviewed), Publication date (All dates), Language (English).

Search strategy in Web of Science

Basic Search: Alternate search terms keywords such as (e.g., "Children" OR "primary school aged children" OR "youth", OR "Active mobility" OR "Active behaviour" OR "Physical activity" OR "Active play" OR "active travel") AND ("Neighbourhood") AND ("Safety" OR "Parents Perceived Safety" OR "Children Perceived Safety" OR "Road safety" OR "Crime") AND ("Outside school hours)" AND ("Spatial data" OR "GIS" Or "GPS" OR "Spatiotemporal"). Search in Topic. Timespan (all Years). Default Number of Search Fields to Display

Zougheibe R, *et al*. *BMJ Open* 2021; 11:e047062. doi: 10.1136/bmjopen-2020-047062

Table 1. Characteristics of included studies and findings of evidence of influences on children outdoor active mobility behaviour

#	Study's author(s)/year of data collection n = Participants number/ (sex/gender: number/% of M/F)/ Age (or mean age)/Grade	Country/ Study Design/ [Project]	Measures Safety (Perceived by)/ Measured/ Level of study	Active Behaviour Outcome / Measures	Definition of neighbourhood	Study accounted cofounders and other examined variables	Findings of Associations
1	Alton, Adab, Roberts, and Barrett (2007)/-/ n= 473 (250 M and 60 F)/ 9-11 years old/	United Kingdom Cross-section	Children/questionnaire on the perception of local environment + preferred travel method/ In Six primary schools in a range of socio-economic classification	Level of walking (high walkers, low walkers)/ Self-report Past 7-days	Local area	Sex/gender, race/ethnicity (Asian, black, Chinese, mix, others, white), family characteristics (cars ownership and number of rooms in primary residence) as a proxy for SES)	Child from ethnic minority walks significantly less. Perception of high parental concerns over road safety and heavy traffic associated with a higher walking level. The authors explained this unexpected correlate as children who are high walker may be often warned by their parents about road danger, and therefore children perceive roads as dangerous. Child perception of lack of suitable leisure space in the neighbourhood and worry about a stranger is associated with less walking levels. Child perceptions of the local environment correlate with walking level.
2	(Carver, Timperio, & Crawford, 2008)/between July and December 2004/ n = 188 (44% boys) 8-9 years old	Australia Cross-section from [CLAN] longitudinal study	Parents survey for personal characteristics +frequency of children walking and cycling to 15 destinations + Measured road safety[1]/ From 19 state primary schools of varying socio-economic states across Melbourne.	*MVPA Outside school hours Accelerometer for 8-days	800 m around participant home	Sex/gender, age + Active transport +MVPA + measured road environment	No association between children likelihood of making at least seven walking/cycling trips per week to neighbourhood destination and roads environment
3	Carver, Timperio, Hesketh, and Crawford (2010)/2001 n = 170 (51% M)/ 10-11 years old 15-17 years old (excluded) 2001-2005 longitudinal study	Australia Cross-section from [CLAN] longitudinal study	Parents questionnaire Indices for (avoidance and defensive behaviour, and perceived risk) + active transportation to 15 destination/ In 10 high and ten low socio-economic areas across Melbourne	*Active transport/MVPA outside school hours/ Accelerometer	Local area	Sex/gender + Parents (avoidance, defensive and perceived risk)	The lower level of active transport and lower level of MVPA in a neighbourhood outside school hours associated with constrained behaviour exhibited by parents on both boys and girls. Reduced MVPA associated with constrained behaviour on weekends for boys. Higher constrained behaviour associated with higher MVPA for girls (limitation of study)
4	(Carver, Panter, Jones, & van Sluijs, 2014)/T1 (April-July 2007) n= 1121 (9-10) years old (43%M) T2 (April-July 2008) n= 491 (39%M)	United Kingdom Longitudinal from [SPEEDY] study	Parents perception questionnaire (social/physical environment + rules regarding their children physical activity + perception of traffic safety concerns)/At 1600m of their school in urban/rural areas	Independent mobility to school/ from children questionnaire	Within 800 m pedestrian network buffer around the home (10 min walk)	Sex/gender, sociodemographic (siblings, cars ownership, parents' education) + environmental characteristics around the home and (within 100 m buffer of the shortest route to school	Car access is associated longitudinally with boys decreased odd of walking/cycling independently to school. The proportion of main roads in the neighbourhood and parental encouragements of walking/cycling associated longitudinally with girls walking/cycling to independently to school. Land use mix is associated positively with girls walking cycling independently to school. Boys that are allowed by their parents to play outside have higher odd to walk/cycle independently to school.
5	(Davis & Jones, 1996)/-/ n = 492 of children (not reported gender)/ 9-11-years-old 13-14 years old (excluded)	United Kingdom Cross-section	Children (focussed group discussion)./ From four schools in broadly working-class areas.	Independent mobility/ discussion	Local destination	Sex/gender, age + stranger danger and traffic danger	In children's view, traffic and stranger danger, social and cultural factors create barriers on children being active for both genders, especially for girls. Car escort journey developing unhealthy habits of sedentary living with its associated risks of increased cardiovascular illness.
6	(Fagerholm & Broberg, 2011)/ Sep.-Oct. 2009 n = 35 children (18M/17F)/ 10-11 years old	Finland Cross-section	Parents questionnaire (children and parent) mobility patterns + mobility licences, perceived safety./From two residential areas	*Active route (home to destinations)/ GPS + Travel diary for 7-days	Buffer 500-m from home	Sex/gender + Land use types	Gender difference shows in the distance and speed children travel actively to the boys' advantages. Land-use type associated with different mobility patterns (increase in urban areas). A high perception of safety from parents in residential areas resulted in a high level of independent mobility.

							Weekdays and weekends have different mobility patterns in term of proximity (near the home on weekdays) with more time out on weekends.
7	Faulkner, Mitra, Buliung, Fusco, and Stone (2015)/ April2010 – May2011 n = 736 (47% M and 52%F) included in the analysis/ (10-12 years old), grade 5-6	Canada Cross-section from [BEAT] project	Parents questionnaire (child outdoor active play + parents' perception of personal and road the neighbourhood safety)/ From 16 elementary primary/intermediate schools in the city of Toronto	*Outdoor playing time MVPA/ GPS + Accelerometer for 7-days	Neighbourhood	Sex/gender, age, SES of the neighbourhood (neighbourhood income) + neighbourhood perception (roads, personal safety, accessibility of facility)	Time spent outdoor was significantly associated with (MVPA) and with sex/gender, but age didn't play a role in this relation. Parental safety perception plays an inverse relation with the duration of outdoor play on weekdays. Parental concerns play a barrier role for children outdoor play. Association of outdoor play duration with the perception of safety (stranger danger and traffic safety), differ between weekdays and weekends.
8	(Janet E. Loebach & Jason A. Gilliland, 2016)/ During April and May of 2010 and 2011. n = 143 (49M/94F) two groups of 9- 11 and 12-13 years-old)/grade 5 - 8	Canada Cross-section from [STEAM] project	Parents & Children Questionnaires/ From seven schools in London	Neighbourhood Activity Space (NAS)/ GPS for 7-days	NAS found within 400, 800 m of home, the second set those found within 1,600 m.	Sex/gender, age, car availability + parents and children environmental perception + neighbourhood types + parental IM licenses to children	IM awarded to a child is associated with parents' perception of neighbourhood safety and a strong predictor for distance travelled. Distance to school predicts active travel. Gender or age was not associated with NAS size. No association between parents' perception of neighbourhood and child spend their time closer to home. Children perception correlate with time spend closer to home but were not as strongly predictive as parental mobility restriction. Neighbourhood types (Residential) was a predictor of time spend out and (commercial) to distance travelled (over 800 m). Smaller home to school distance facilitate active travel and more frequent and distant neighbourhood travel
9	(Helbich et al., 2016)/between December 2008 – April 2009/ n = 97 (60%F) /Aged 6 – 11 years	The Netherlands, Part of [SPACE] project	Road traffic Safety exposures within 100 m buffer width around using GIS/ From six elementary schools located in five neighbourhood	Active trips to school and transport mode of choice GPS for 8-days	Home to school trip	Sex/gender, age + active trips to school + built environmental variables (land use mix, density, closeness and in between indices) + traffic safety control variables (major roads availability, distance, the proportion of cycling path and road accidents) +street density) weather	Gender is significantly associated with AST. Age is significantly associated with AST. Negative association with the distance. Negative weak association of AST with major road. Traffic safety (exposure to major roads/highways) is negatively correlated with AST. Cycling path availability positively corollate with AST.
10	Lin et al. (2017)/between 2011 and 2012 n = 254 (100M, 133F) and 239 parents/ 8–13 years (mean age of 10.5)	New Zealand from [KITC]	CATI-Parents Survey (perception of neighbourhood cohesion using social cohesion scale, + neighbourhood social connection using intergenerational closure scale and parents' concerns of places that will not let their children go alone)/ From nine schools across Auckland	*Independent mobility /Travel diary for 7-days	Neighbourhood	Sex/gender, age, race/ethnicity, household profile + built environment (street connectivity, destination accessibility)	Shorter distance to school accounted for the effect of neighbourhood cohesion and connection associated with higher children independent mobility (IM). IM associated with having an older sibling and limited access to cars. Parent's perception is not associated with children independent mobility though concerns of safety which differed by ethnicity (pacific/Asian).
11	Mehdizadeh, Mamdoohi, and Nordfjaern (2017)/-/ 735 parents of (364M, 371F)/ 7-9-year-old in 9 schools of 735	Iran Cross-section	Parents questionnaire via their children/from nine schools	Perceived Walking Time to school (PWTS)/ questionnaires	Environment around school	Sex/gender, demographics, household characteristics (father/mother driving licence, car owner) SES	Perceived walking time to school (10 min) is the maximum threshold where the proportion of active mode started to decrease. Certain demographics: parental age, household income, accessibility to public transport, type of school (public or private), school service status and psychological factors (parents attitude towards walking in dirty, vandalised and unsafe streets), SES of children and household variables were significant predictors of a PWST to eligible school. Sex didn't have a consistent and definite role in active travel.
12	(Nguyen, Borghese, & Janssen, 2018)/ Jan. 2015 and Dec. 2016/ n= 458 (230M/228F)/ aged 10-12	Canada Cross Section	Parent's questionnaire (perceived pedestrian safety) + Objective measures of Pedestrian safety/ Recruited through social media and study flyer.	Average of minutes per day of active outdoor play/ Accelerometer + GPS in a smartwatch for 7-days	1 km buffer zone around participants home	Sex/gender Race (white, non-white) Family characteristics (single or dual parents' household, number of siblings, household income, parental education, parents' value of outdoor	No association between pedestrian safety measures and outdoor active play. No association between objective and perceived pedestrian measures. Perceived measures of traffic volume, traffic calming and pedestrian infrastructure were not associated with outdoor active play.

						and income) + Pedestrian safety (traffic volume, traffic speed, traffic calming and pedestrian infrastructure + season	Parents perceived moderate to high traffic speeds had higher outdoor active play value than children whose parents perceived low traffic speed. Objective measure of traffic volume, traffic calming and pedestrian infrastructure but not traffic speed was associated with outdoor active play.
13	Noonan, Boddy, Knowles, and Fairclough (2016), n = 194 children/ 9-10 years old Gender not reported	United Kingdom Cross-section	Parents questionnaire on environment perception using NEWS_Y + Children self-reported PA using PAQ-C. From 10 primary schools in Liverpool	IM/ Self-Reported PA	High and low deprived areas	Home environment, Area deprivation, parent's perception walkability Index	Home environment for HD provides more opportunities for sedentary behaviour and less opportunity for PA, less access to bedroom media equipment, and greater independent mobility were *strongly associated* with higher PA in HD and MD children, respectively.
14	Oliver et al. (2015)/ Between 2011 and 2012/ n = 236 (104 M/132) for weekday analyses, n = 210 (91M/119F) children for weekend days analyses. /age 9-13 Age mean 9.8 from 9 schools/grade 5-8	New Zealand Cross-section from [KITC] project	CATI-Parents questionnaire (Perceived parents safety) + measured roads connectivity/ From nine schools in Auckland	*% MVPA/ accelerometer + GPS for 7-days	Buffer of 800-1000 m around school	Sex/gender, age, race/ethnicity (New Zealand European, Maori, Pacific Island, Indian/Asian/Other Ethnicity), SES+ Neighbourhood street connectivity, street space, destination accessibility+ distance to schools + ratio of high-speed roads around schools + street connectivity. .	On weekdays: Females & access to car accumulated less %MVPA than males. On weekends: Female and ethnicity (Indian, Asian or "other" ethnic group) made less %MVPA. Street connectivity and distance to school were related to the proportion of active trips on both weekends and weekdays. The ratio of high-speed roads associated with %MVPA (weekdays after school). Improved streetscape for active travel was related to %MVP on weekdays. Ethnicity and %MVPA differ by day type. Age, access to cars was negatively associated with %MVPA. Inconclusive evidence of socio-economic association. Parent's perceptions of neighbourhood safety is positively associated with the proportion of active trips on weekdays.
15	(Oluyomi et al., 2014)/-/ n= 830 and their parents of 4th grade (412M/418F)	United States Cross-section from [T-COPPE] longitudinal project	Parents' questionnaire adapted from several surveys including the National Centre for Safe Routes to School Parents Survey, SPAN, (UH-PEAK), NEWS, and EnVivo) Personal safety + Traffic Safety/ From 81 elementary school across Texas	Walking to school (WTS) /parents' questionnaire of National Safe Route to School. Captured safety of en-route to school, home neighbourhood, and school environment)	Within walking distance of 3.2 km to school from the residential address of students	Race/ethnicity (the majority were Hispanic) car ownership, public assistance) Examined two environments (home neighbourhood and en-route environment to school)	Parents Perception of road safety (higher sidewalk availability, well-maintained sidewalks and safe road crossing) is associated with students more likely to walk to school. On route to school: parents' perception of sidewalk, Speed and amount of traffic and intersection along school route, also associated with WTS Parents reported safe walking to a school associated with reported higher children WTS. On Personal safety, parents concern about general neighbourhoods' safety, stray or dangerous animals and the availability of adults with whom child can walk associated with lower en-route to school.
16	(Page, Cooper, Griew, & Jago, 2010)/ between 2006 and 2008 n = 1307 (639 M, 661 F)/ 10-11 years old from 23 schools	United Kingdom Cross-section from [PEACH] longitudinal study	(computerised) children questionnaire perception of the environment (Aesthetics, Safety, Social Norms, Nuisance, constraints, accessibility, minutes of daylight from 3 pm till sunset)/ From 23 schools.	Frequency of participation in outdoor play, exercise and active travel home to school/ questionnaire	School-home	Age, sex/gender, race/ethnicity (white, non-white, but not accounted in analysis), + perception of the environment + the level of deprivation (using Index of Multiple Deprivation (IMD) and derived from seven categories of deprivation + daylight + pubertal status	Boys had a more positive perception of the environment than girls (personal safety and traffic safety) for Local-IM and Area-IM. No gender differences in school travel Boys scores significantly lower in the Constrained scale than girls Physical activity, structured sport and active travel to school weakly significantly correlate to each other. Boys who have greater independent mobility scores had more time of playing out than boys who played less. Girls with a higher positive perception of neighbourhood correlate with playing outdoor often. For boys and girls, and increased likelihood of walking or cycling to school was associated with higher levels of local-IM. Distance from home to school is a predictor for both boys and girls
17	Roberts, Knight, Ray, and Saelens (2016)/Sep.-Dec.2014/ n = 144(72M,72F)/7-12 years old (mean age of 9.7 children)/	United States Cross-section	Parents' questionnaire (perception of the environment)/ From nine counties and cities.	Active children (met the 60 min daily PA)/	Metropolitan area	Sex, demographics race/ethnicity (Hispanic/Latino, African American, American, Indian/Alaska Native, Asian American, White, Other) + perceived parents' safety	Parents' better perception of neighbourhood associated with active kids yet reported a high crime rate and being a victim of a crime of their neighbourhood. Parental perception of street barriers associates with children physical activity. Closer proximity to play areas was significantly associated with greater odd of children meeting the 60 min/day play. Gender (male more active) and race disparities associated with active behaviour.

18	(Santos, Pizarro, Mota, & Marques, 2013)/ 2010/2011 n= 354 (156M) of grade 6th (mean age 11.63) and their parents	Portugal Cross-section from [SALTA] longitudinal study	Parents questionnaire (parental physical activity, and perception (adapted from NEWS and previous studies) + Children questionnaire to derive mobility style/ From nine middle schools	IM/ questionnaire of previous week physical activity based on IPAQ	Local destinations	Age, sex/gender, family demography (parents age, education, parental PA, parents' perception of neighbourhood safety (sidewalk, street safety, fear from strangers, crime and traffic safety).	Parental perception of sidewalks and street safety is associated with IM Parents physical activity was significantly associated with more active children. Perception of fear from a stranger, crime and traffic safety was not significantly associated with child IM.
19	(Shokoohi, Hanif, & Dali, 2012)/ Jan.-Feb. 2009 /-/ Grades 3- 5 (48.8%M,51%F)	Iran Cross-section	Parents + children questionnaire on the perception of environmental factors that prevent children from walking to school/From 18 school sites	Walking to school from parent's survey. Differed the trips from home to school and from school to home.	Home-school	Socio-economic status (three income groups of parents)	Parents and children with a negative perception of neighbourhood safety tended to use motor vehicles or to escort their children while walking to and from school.
20	Stark, Frühwirth, and Aschauer (2018)/-/ n = 190 (49%F) from two public schools/ 6-9(10) years old	Austria Cross-section	Parents questionnaire. From two schools of different location in the outskirt of the city of Vienna	AIM/ One weekday and one weekend Travel Diary using (KONTIV-format)	School active travel	Parental attitude, Parents and household characteristics	The most influential variables on IM are: Shorter trip distance to school, higher age and parents perceived social safety and traffics. Working status of parents. The type of school (all-day/half-day primary school) is relevant. Parental attitude (Promoters, Pragmatists and Protectors) strongly influence the degree of AIM.
21	Stephanie H. Kneeshaw-Price et al. (2015)/between Sep. 2007 and Jan 2009 n = 145 (71M, 74F) / 6–11-years-old	United States Cohort study [NIK]	Police report crime + parents' prior crime victimisation survey + parents' perception (stranger danger, general crime, and disorder)	MVPA/ accelerometer for 7-days	Census block	Age, race/ethnicity (non-Hispanic white, Hispanic, and non-Hispanic non-white), Household income + NEWS + collective efficacy	Lower children's physical activity was associated with more neighbourhood crime but not with parents' perception of stranger danger, disorder and neighbourhood safety. Lower MVPA didn't account for race/ethnicity as the majority was non-Hispanic (white).
22	Suminski, Robson, May, Blair, and Orsega-Smith (2018)/ T1 n = 2108/50.5%F/ 5-11 years-old	United States longitudinal study	Measured crime using CRI Index (a higher number than 100 indicate a greater chance of crime) for each zip code in an urban neighbourhood	Body Mass Index/(BMI) score/ measured at baseline and three years later	Zipcode	(BMIz scores, Sex/gender, family characteristics (income, education Race/Ethnicity White, African American, Hispanic, Asian)	Actual, neighbourhood-level crime predicts changes in BMIz scores in white children This relationship varies as a function of race/ethnicity (i.e. in White children but not African American, Hispanic or Asian American)
23	Timperio, Crawford, Telford, and Salmon (2004)/ n = 291 (150M/141F)/ Aged 5–6 years n = 919 (424M/495F)/ aged 10–12 years from 19 primary schools	Australia Cross-section	Parents & Children Survey Compared parents to own children (aged 10-12) view	Frequency of walking and cycling/ parents survey	Local destinations	Sex, Family background: the first language spoken, marital status, parents' education (SES), cars' ownerships, siblings	Parents' perception of the neighbourhood is *associated* with a lower likelihood of walking or cycling (girls in particular). Children perceive parents' perception of their local neighbourhood safety more negative than their own. Children are reporting less concern about heavy traffic, stranger dangers and road safety and lack of parks or sports ground than parents. Age & SES is associated positively with the frequency of trips made to destinations. Sex is not associated with the frequency of active trips for the young group, but Boys are more still active than girls in the 10 – 12 years old.
24	(Tung, Ng, Chin, & Mohd Taib, 2016) n = 256 (42%M/58%F and their parents aged 9-12 years	Malaysia Cross-section	Parents perception using NEWS Constrained behaviour of parents	Children PA level 7-days questionnaire	-	Sociodemographic (age, parents' gender and ethnicity (Malay, Chinese, and were Indian), highest education level, parent's occupation and monthly income) + parents' perception+ children PA	Sex/gender associated with the level of PA (boys accumulate more than girls). Correlates found between parental perception of neighbourhood safety and constrained behaviour of children active play. Land use mix (access) was correlated positively with higher PA level
25	(van den Berg, Waygood, van de Craats, & Kemperman, 2020)/ Fall of 2018/(315M/341F)/ n= 660 children and parents/ aged 7 – 12/ grade 5-8 (mean age 9.5)	The Netherland Cross-section	Parents survey for perceived pedestrian safety Objective measures of Pedestrian safety/ From 14 primary school in the Netherland	Travel mode to school/ children survey (at school)	Participants were of Home-school Within 1 km distance	Age, Sex/gender Household (income, car ownership), weather, street connectivity	Parental perceptions are related to the child's age, income, perception of neighbourhood infrastructure, travel distance and social cohesion. Parents that are less concerned let their children travel actively
26	Vonderwalde, Cox, Williams, Borghese, and Ian Janssena (2019)/ between Jan. 2015 and Dec.2016/	Canada	Measured crime (person, Property) 24 months before measures of active behaviour	Active transportation/ GIS loggers	Crime in 1 km distance to	Sex/gender, age, race (85% white)	Children living in neighbourhoods in the highest neighbourhood crime rate quartile engaged in significantly more active transportation than children living in neighbourhoods in the lowest neighbourhood crime

	n = 387(185M, 182F)/ 10–13 years old (mean age 11.5)	Longitudinal from [Active Play Study]			participants home	family profile (single or dual-parent, parent income education), walkability index+ Season change	rate quartile and persisted after adjustment for several individual, family, and environmental covariates. Association of AS and crime against a person but not against a property.
27	Villanueva et al. (2012)/ July – December 2007/ n = 926 (463M,463F)/ 10-12 years old included in the analysis.	Australia Cross-section from [TREK]	Parent and Child Questionnaires/ Schools in neighbourhood within three socio-economic state (low, medium, high)	Activity Space/ steps count Pedometer + mapping activity for 7-days	within 800 and 1600 meter of child's home high and low walkable areas	Age, sex/gender, maternal education + School-specific walkability level	Children in high walkable neighbourhood's schools had larger AS. Girls had smaller AS for if parents perceived living on a busy road. Utilitarian destinations were associated with a smaller AS. Sex is associated with AS areas and daily pedometer. Boys' and girls' own confidence in travelling independently was positively associated with covering larger AS areas. Despite some environmental barriers, individual and social-cultural factors likely to encourage children to roam in their local environments.
28	(Waygood & Susilo, 2015)/ 2006 survey/ n = Roughly 31,000 households' participants (52% boys) aged 10-11 years	Scotland Cross-section	Parents survey/ from 2006 Household Survey	Walking to school	Home to school	Sex/gender, Family background +built environment, deprivation index	Car's availability is negatively associate with walking to school Distance to school was strong determinate for children walking to school. Parental perception Good local shops are positively associated with children active travel to school and slow traffic or safe was negatively associated variable,
29	Zhu and Lee (2008)/-/ Children from 73 elementary schools/-/	United States Cross-section	Measured Crime Geocoded 8 major crimes rate/ From 73 public elementary schools	Potential walkers/ neighbourhood-level walkability index	School attendance areas	Race/Ethnicity (Hispanic, non-Hispanic, and White), Poverty + Neighbourhood-level walkability + Neighbourhood-level safety SWI	Poverty associated with negative conditions and low perceived safety. Ethnicity associated with increased crime, traffic danger and poor safety. Unsafe neighbourhoods and poor street conditions may influence not only children's school travels but also their play activities and the overall physical activities of all residents.

Notes: /-/ = data was not reported, M = males, F = Female, BMI = Body Mass Index, IM = independent mobility, AST = active school transport, PA = physical activity, AS = activity space, SES = socioeconomic status, HD = high deprivation, MD = medium deprivation, WTS = walking to school, NAS = Neighbourhood Activity Space, CLAN = Children Living in Active Neighbourhoods, SES = Socioeconomic status, MVPA = Medium-to vigorous Physical Activity, SPEEDY = Sport, Physical activity and Easting Behaviour Environmental Determinants in Young People, BEAT = Built Environment and Active Transport, GPS = Global Positioning System, STEAM = Spatio-Temporal Exposure and Activity Monitoring, KITC = kids in the City, PAQ-C = Physical Activity Questionnaire for Older Children, NIK = Neighbourhood Impact on Kids, CRI = Crime Risk Index (measured crime using actual crime statistics) TREK = Travel Environment and Kids Project, CATI = Computer-aided Telephone Interview, KIC = Kinds in the City, T-COPPE survey = Texas Childhood Obesity Prevention Policy Education project, IMD = Index of Multiple Deprivation is a composite score based on seven categories of deprivation (income, employment, health and disability, education skills and training, housing and geographical access to service), PEACH = Personal and Environmental Association With Child's Health, SPAN = School Physical Activity and Nutrition, UH-PEAK = Urban Hispanic Perceptions of Environment and Activity Among Kids, En Vivo = TV reduction intervention study, NEWS = Neighbourhood Environment Walkability Scale, NEWS-Y = Neighbourhood Environment Walkability Scale for Youth used to assess parental perceptions of neighbourhood design, SALTA = Environmental Support for Leisure and Active Transport, KONTIV = format of travel diary survey for non-home activity patterns, GIS = geographic information systems, IPAQ questionnaire = International Physical Activity Questionnaire, Local-IM = destinations of best friend's house, school, local shops and park or playground, Area-IM = destinations of swimming pool, library, cinema, arcade, bus stop, sports and shopping centre, SWI = School Walkability Index derived from network connectivity and traffic volume, Neighbourhood-level walkability index derived from an (estimate of potential walkers, pedestrian facilities, residential density, street connectivity, land use mix), Neighbourhood-level safety = derived from (traffic danger and the crime rate in a year), TREK = Travel Environment and Kids

Studies denoted with * = Study measures and analysis accounted for temporal changes (weekend/weekdays or outside school, i.e., before and after school hours).

[1] = Objective road measures using GIS were: street network total length, local road index, No of intersections, the total length of walking track, no of speed humps, no of traffic /pedestrian lights, no of barriers

Table 2. Methodological measure quality assessments and output per study.

Study citation	Study Objectives, design, target population, random sampling (0.25 each)	study participants, inclusion/exclusion, study population, participants recruitments (0.25 each, total 1)	Response rate, data collection, data sources, missing data. (0.25 each, total 1)	Did the active behaviour data collection was objectively measured? (0.25 for each method, total 1 point,)	Did the measure of active behaviour account for temporal characteristics? (0.5 point)	Has the perceived safety measured the temporal characteristics? Or has measured safety used geocoded data in actual crime for personal safety or in road safety? (0.5 point)	Did the study delineate the exposure area "neighbourhood" objectively (0.5 point)	Did the study evidence Accounted For spatiotemporal behaviour in output (1 point)	Was it clearly described the statistical method and to assess significance association, or did the study describe the method of spatial analysis? (0.5)	Did the study account for the four cofounders (age, sex, ethnicity and family characteristics) (0.25 each, total 1 point)	Quality score total	%	overall rating of evidence Quality
(Alton et al., 2007)	1	0.75	0.5	0.25	0	0	0	0	0.5	1	4	50.0	Moderate
(Carver et al., 2010)	1	1	0.75	0.5	0.5	0.5	0	1	0.5	0.5	6.25	78.1	Robust
(Carver et al., 2014)	1	1	0.75	0.25	0	0	0.5	0	0.5	0.75	4.75	59.4	Moderate
(Carver et al., 2008)	1	1	0.75	0.25	0	0	0.5	0	0.5	0.75	4.75	59.4	Moderate
(Davis & Jones, 1996)	1	0.5	0.25	0.25	0	0	0	0	N/A	0.5	2.5	35.7	Poor
(Fagerholm & Broberg, 2011)	1	0.75	1	1	0.5	0	0.5	0.5	0.5	0.5	6.25	78.1	Robust
(Faulkner et al., 2015)	1	1	1	0.5	0.5	0	0	0.5	0.5	0.75	5.75	71.9	Robust
(Lin et al., 2017)	1	0.5	0.75	0.25	0	0	0	0	0.5	1	4	50.0	Moderate
(Janet E Loebach & Jason A Gilliland, 2016)	1	1	1	0.5	0.5	0	0.5	0	0.5	0.75	5.75	71.9	Robust
(Helbich et al., 2016)	1	0.75	0.5	0.25	0	0.5	0.5	0.5	0.5	0.5	5	62.5	Moderate
(Mehdizadeh et al., 2017)	1	1	1	0.25	0	0	0	0	0.5	0.75	4.5	56.3	Moderate
(Noonan et al., 2016)	1	1	0.75	0.25	0	0	0	0	0.5	0.25	3.75	46.9	Poor
(Nguyen et al., 2018)	1	1	0.75	1	0	0.5	0.5	0	0.5	1	6.25	78.1	Robust
(Oliver et al., 2015)	1	1	1	1	0.5	0.5	0.5	1	0.5	1	8	100.0	Robust
(Oluyomi et al., 2014)	1	1	1	0.25	0	0	0.25	0	0.5	0.5	4.5	56.3	Moderate
(Page et al., 2010)	1	1	0.75	0.25	0	0	0	0	0.5	0.75	4.25	53.1	Moderate
(Roberts et al., 2016)	1	1	0.75	0.25	0	0	0.25	0	0.5	0.75	4.5	56.3	Moderate
(Stephanie H. Kneeshaw-Price et al., 2015)	1	1	0.5	0.5	0	0.5	0	0	0.5	0.25	4.25	53.1	Moderate
(Santos et al., 2013)	1	1	0.75	0.25	0	0	0	0	0.5	0.5	4	50.0	Moderate
(Shokoohi et al., 2012)	1	0.5	0.5	0.25	0	0	0.25	0	0.25	0	2.75	34.4	Poor
(Stark et al., 2018)	1	1	0.75	0.25	0	0	0	0	0.5	0.5	4	50.0	Moderate
(Stephanie H. Kneeshaw-Price et al., 2015)	1	1	0.5	0.5	0	0.5	0	0	0.5	0.25	4.25	53.1	Moderate

(Suminski et al., 2018)	1	1	1	N/A	N/A	0.5	0.5	1	0.5	1	6.5	108.3	Robust
(Timperio et al., 2004)	1	1	0.75	0.25	0	0	0	0	0.5	0.75	4.25	53.1	Moderate
(Tung et al., 2016)	1	1	0.5	0	0	0	0	0	0.5	1	4	50.0	Moderate
(van den Berg et al., 2020)	1	0.75	1	0.25	0	0	0.25	0	0.5	0.5	4.25	53.1	Moderate
(Villanueva et al., 2012)	1	1	0.75	1	0	0	0.5	0	0.5	0.75	5.5	68.8	Moderate
(Vonderwalde, Cox, Williams, Borghese, & Ian Janssena, 2019)	1	1	1	1	0	0.5	0.5	0.5	0.5	1	7	87.5	Robust
(Waygood & Susilo, 2015)	1	0.75	0.5	0	0	0	0	0	0.5	0.5	3.25	40.6	Poor
(Zhu & Lee, 2008)	1	N/A	N/A	0	0	0.5	0.5	0	0.5	0.5	3	50.0	Moderate

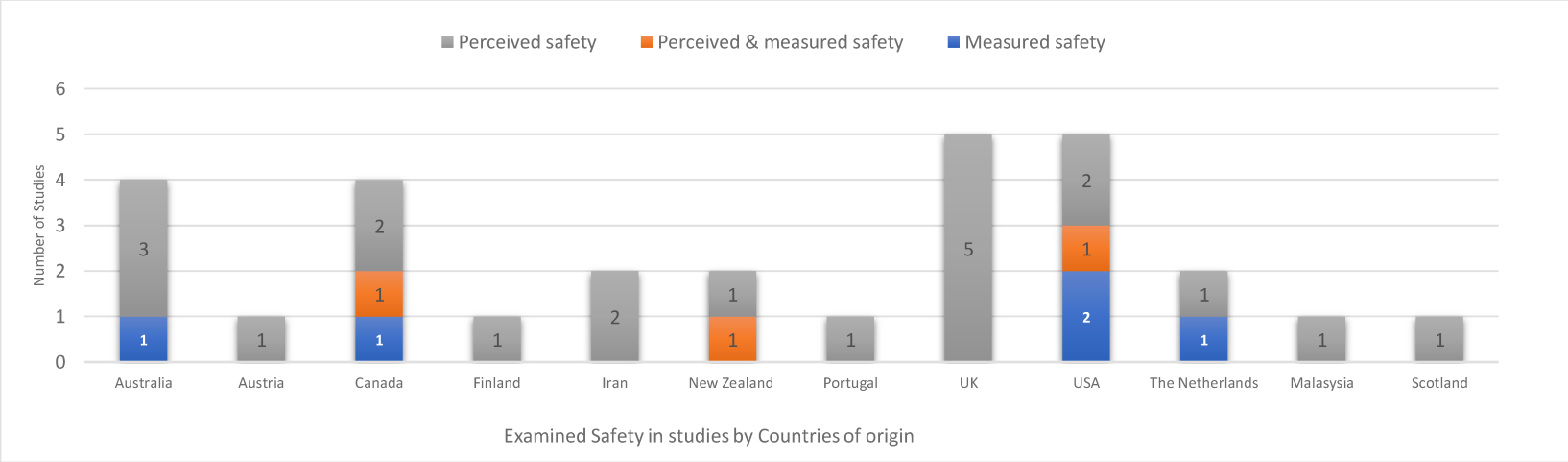

Diagram 1. Country of origin of the studies included in this review including examined neighbourhood safety types.

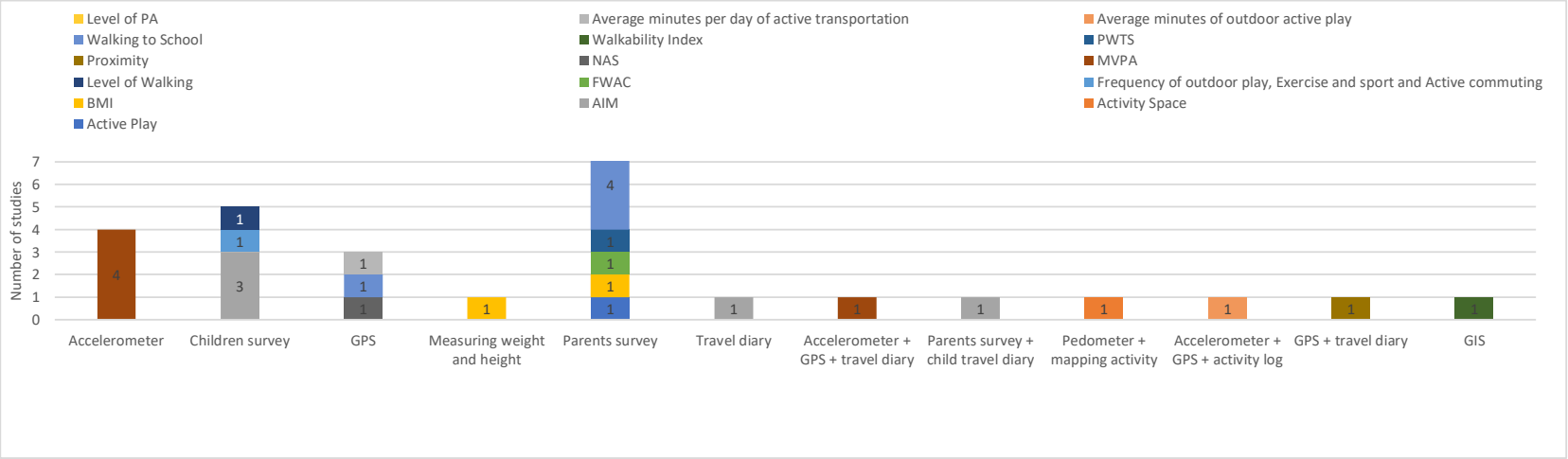

Diagram 2. Variances in measurement methods of children active mobility behaviour and the outcome of measures in 29 studies. Abbreviations: PA = physical activity, AIM = active independent mobility, BMI = body mass index, FWAC = frequent walking and cycling, MVPA = moderate-to-vigorous physical activity, NAS = neighbourhood activity space, PWTS = perceived walking to school, GPS = global positioning system, GIS = geographic information system

Diagram 3, 4 and 5 illustrated evidence of modified child active behaviour synthesised by individual and family, and neighbourhood safety.

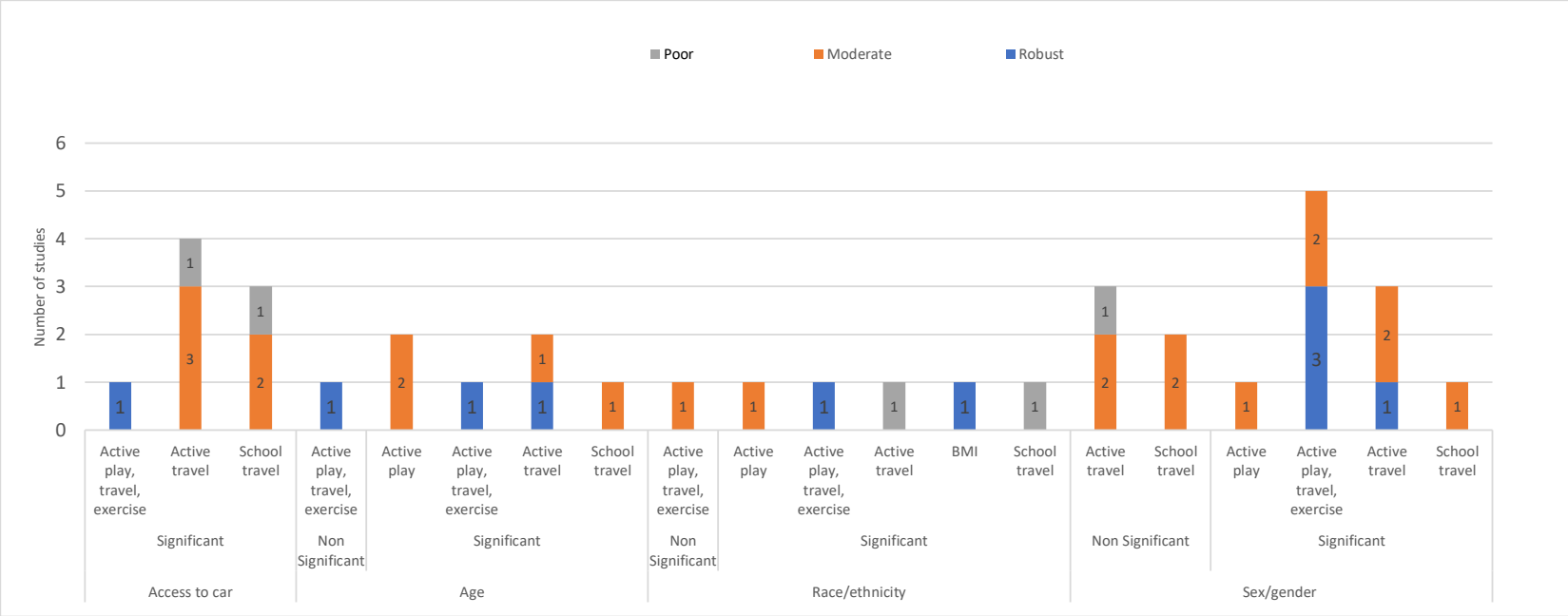

Diagram 3. Findings of Individual and family layers of association to children various type of active behaviour in studies examined neighbourhood safety. Studies were re-grouped each by the examined active behaviour into four categories of (Active travel, active play, school travel and active play, travel, and exercise) and as appraised by the methodological quality assessment. x-Axis depicted variable addressed at the individual and family level and the examined type of child active behaviour. y-Axis represents the number of studies accumulated.

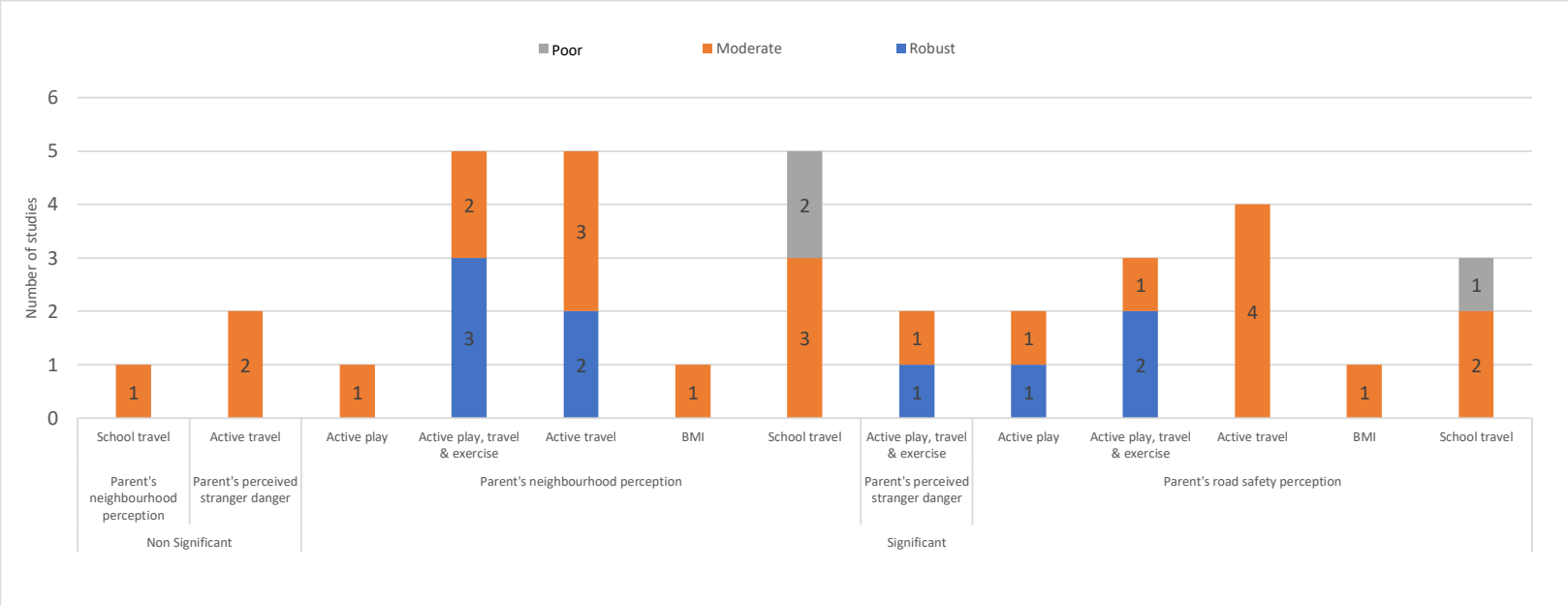

Diagram 4. Findings of parents perceived safety layers of association to children various type of active behaviour. Studies were re-grouped by active behaviour into four categories of (Active travel, active play, school travel and active play, travel, and exercise) and as appraised by the methodological quality assessment. x-Axis depicted variable addressed at the neighbourhood perceived level and the examined type of child active behaviour. y-Axis represents the number of studies.

Table 3. Studies re-grouped output measure of active behaviour to enable synthesis of evidence.

#	citation	Neighbourhood Safety	Active Type	Re-Grouped Active Mobility Behaviour
1	(Alton et al., 2007)	Perceived	Level of Walking	Active travel
2	(Carver et al., 2010)	Perceived	MVPA	Active play, travel & exercise
3	(Carver et al., 2014)	Perceived	AIM	School travel
4	(Carver et al., 2008)	Perceived & measured	MVPA	Active play, travel & exercise
5	(Davis & Jones, 1996)	Perceived	AIM	Active travel
6	(Fagerholm & Broberg, 2011)	Perceived	Proximity	Active travel
7	(Faulkner et al., 2015)	Perceived	MVPA	Active play, travel & exercise
8	(Helbich et al., 2016; Oliver et al., 2015)	Perceived	MVPA	Active play, travel & exercise
9	(Janet E Loebach & Jason A Gilliland, 2016)	Perceived	NAS	Active travel
10	(Lin et al., 2017)	Perceived	AIM	Active travel
11	(Mehdizadeh et al., 2017)	Perceived	PWTS	School travel
12	(Noonan et al., 2016)	Perceived	BMI	BMI
13	(Nguyen et al., 2018)	Perceived & measured	Average minutes of active outdoor play	Active play
14	(Oliver et al., 2015)	Perceived & measured	MVPA	Active play, travel & exercise
15	(Oluyomi et al., 2014)	Perceived	Walking to School	School travel
16	(Page, Cooper, Griew, Davis, & Hillsdon, 2009)	Perceived	Frequency of outdoor play, Exercise and sport and Active commuting	Active play, travel & exercise
17	(Stephanie H. Kneeshaw-Price et al., 2015)	Perceived & measured	MVPA	Active play, travel & exercise
18	(Roberts et al., 2016)	Perceived	Active Play	Active play
19	(Stark et al., 2018)	Perceived	AIM	Active travel
20	(Suminski et al., 2018)	Measured	BMI	BMI
21	(Shokoohi et al., 2012)	Perceived	Walking to school	School travel
22	(Santos et al., 2013)	Perceived	AIM	Active travel
23	(Timperio et al., 2004)	Perceived	FWAC	Active travel
24	(Tung et al., 2016)	Perceived	MVPA	Active play, travel & exercise
25	(van den Berg et al., 2020)	Perceived	Walking to School	School travel
26	(Villanueva et al., 2012)	Perceived	Activity Space	Active play, travel & exercise
27	(Vonderwalde, Cox, Williams, Borghese, & Ian Janssena, 2019)	Measured	Average minutes per day of active transportation	Active travel
28	(Waygood & Susilo, 2015)	Perceived	Walking to school	School travel
29	(Zhu & Lee, 2008)	Measured	Walkability Index	Active travel

Notes: we categorised each study as per the active behaviour examined in each study: If a study addressed total MVPA it is grouped under "Active travel, play and exercise". If walking to school, the study grouped under "Active school travel". If the addressed active behaviour is the frequency of walking or cycling or independent mobility travel (IM), the study categorised it as "active travel", and when addressed active playing behaviour, it is "active play". Assessed impact on BMI was left as "BMI". Then we grouped studies to synthesise evidence of influences on modifying types of COAMB.

Table 4. Findings of correlates across the socio-ecological levels and modified child types of outdoor active mobility behaviour.

Effective domains		**+ - 0**	**Correlation with children active mobility**
Individual (child)			
P_Survey Sex: Female	Carver et al. (2010)	+	avoidance behaviour[1]
	(Oliver et al., 2015)	–	%MVPA (F) weekdays
	(Timperio et al., 2004)	–	walking/cycling, after dark (F) of (10-12 YOLD)
		0	5- 6-year-old age group
	(Faulkner et al., 2015)	–	time outdoor (weekends and weekdays)
	(Villanueva et al., 2012)	–	activity Space (F)
	(Carver et al., 2014) greater land use mix (residence/retail outlets, sports facility) at T2	+	walking and cycling to school (F)
Sex: Male	Carver et al. (2010)	+	made more active trips (M)
	(Roberts et al., 2016)	+	active behaviour
	(Fagerholm & Broberg, 2011)	+	Distance travelled, and speed children travel
	(Villanueva et al., 2012)	+	walking/cycling, after dark (M) of (10-12 YOLD) Steps count
	(Mehdizadeh et al., 2017) (Helbich et al., 2016)	0 0	Perceived walking to school Active school travel
	(Carver et al., 2014) being allowed by parents to play outside	+	odd of walking/cycling independently to school
	(Tung et al., 2016)	+	PA (reported)
C_Survey Gender	(Alton et al., 2007)	0	walking trips
	(Page et al., 2010) playing and taking part in structured sport	+	local-IM: (M) more than F
	(Page et al., 2010)	0	Active commuting to school
Age Adult Survey	(J. Loebach & J. Gilliland, 2016)	+	time spend outdoor, distance & IM (older).
	(Stark et al., 2018)	+	IM with older children
	(Timperio et al., 2004) of age 5-6 compared to 10-12	+	walking or cycling with age in particular for (M).
	(Oliver et al., 2016)	+	%MVPA weekdays
	(Faulkner et al., 2015)	0	MVPA
	(Helbich et al., 2016)	+	ATS
	(van den Berg et al., 2020)	+	active school travel
Parents/Family background characteristics			
SES	(Timperio et al., 2004) (boys) 10 -12	+	Frequency of walking or cycling to public transport (active trips) in high SES more than in medium SES.
	(Timperio et al., 2004) 10- 12 F	+	walked and cycled more to school in high SES.
	(Timperio et al., 2004) age 5-6 years old) M	+	in high SES
	(Timperio et al., 2004) age 5-6 years old) F	0	association to SES
	(Tung et al., 2016) high SES	+	PA
	(Timperio et al., 2004)	0	concerns of stranger danger (F)
	(Mehdizadeh et al., 2017) mothers with driving licence		Reduced active travel to school
	(Oliver et al., 2016)	–	(Inconclusive)
	(Noonan et al., 2016) in high deprivation	+	BMI level
		+	self-reported PA
C_Survey And SES	(Timperio et al., 2004) concerns of traffic in (M)	x	found in children in low SES more than children in high SES
Poverty	(Zhu & Lee, 2008)	–	safety & walking
Household income P_survey	Mehdizadeh et al., 2017	+	perceived walking to school
	(van den Berg et al., 2020)	x	increased income & increased perception of safety
Mother driving licence	Mehdizadeh, Mamdoohi, & Nordfjaern, 2017)	–	active travel
Parental age	Mehdizadeh, Mamdoohi, & Nordfjaern, 2017)	+	perceived walking to school
Employments Status (mother)	(Stark et al., 2018)	+	IM licence
Home environment (access to Media)	(Noonan et al., 2016)	x	in High Deprivation
Having older siblings	(Lin et al., 2017)	+	IM
	(Carver et al., 2014)	+	IM
P_Survey	(Alton et al., 2007)	–	level of walking

Cars ownership/ access	(Davis & Jones, 1996)	–	IM
	(Lin et al., 2017)	–	IM
	(Mehdizadeh et al., 2017)	–	active travel
	(Oliver et al., 2015)	–	# of active trips (weekdays)
	(Timperio et al., 2004) Parent of 5-6 years old (F) who owned more than one car associated with	–	less likely of walking or cycling to destinations
	(Waygood & Susilo, 2015)	–	Walking to school
	(Carver et al., 2014)	–	odd of boys walking and cycling to school at T2
C_Survey rooms in the house	(Alton et al., 2007)	–	(significant only for 2.1%)
Parental attitude towards walking	Mehdizadeh, Mamdoohi, & Nordfjaern, 2017)	+	short perceived walking time to school
Parental Physical Activity	(Santos et al., 2013) Parental physical activity	+	independent mobility
Ethnicity	(Alton et al., 2007)	–	level of walking in minority
	*(Oliver et al., 2016)	+	%MVA Pacific, European and Maori accumulates (weekdays only). %MVA Indian/Asian/others (weekend days) than their counterparts/Pacific on weekdays
	(Suminski et al., 2018) crime risk index	–	BMI (white children)
	(Roberts et al., 2016)	+	in minority
	(Zhu & Lee, 2008) (Hispanic)	+	in crime & traffics
Access to public transport	Mehdizadeh, Mamdoohi, & Nordfjaern, 2017)	–	active travel
Attending Public School	(Mehdizadeh, Mamdoohi, & Nordfjaern, 2017)	–	perceived walking to school
Neighbourhood, Perceived (Personal and Road Safety)			
P_Survey low personal safety perception	(Fagerholm & Broberg, 2011)	–	Independent mobility after dark and by distance (only F)
	(Stark et al., 2018)	–	IM
	(Timperio et al., 2004)	–	frequency of walking
	(Mehdizadeh et al., 2017)	–	activity space after 10 min walking
	(J. Loebach & J. Gilliland, 2016)	–	time outdoor and travelled distance
	(Faulkner et al., 2015)	–	outdoor playtime (outdoor plat and MVPA)
	(Roberts et al., 2016)	+	active children
	(Villanueva et al., 2012)	–	Activity space F
	(Oliver et al., 2016)	–	active trips (weekdays)
	(Noonan et al., 2016)	–	outdoor play in MD
	(Carver et al., 2010)	–	active transport (M/F) in 10 -11 years old
	Constrained behaviour (avoidance and Defensive behaviours)	–	MVPA (M) weekends
	(Lin et al., 2017)	0	IM (though parents had concern of safety)
	(Oluyomi et al., 2014)	–	walking to school general neighbourhoods' safety, stray or dangerous animals and availability of adults
	(Carver et al., 2014)	–	walking and cycling to school at T1
	(Shokoohi et al., 2012)	–	walking to school
	(van den Berg et al., 2020)	–	children travel actively
	(Waygood & Susilo, 2015)	–	School active travel
	(Tung et al., 2016)	–	PA
C_Survey Low perceived safety	(Villanueva et al., 2012)	-	activity space
	(Janet E. Loebach & Jason A. Gilliland, 2016)	-	time spend close to home
	(Shokoohi et al., 2012)	–	walking to school
	(Page et al., 2010) positive perception	-	playing out for girls
	(Page et al., 2010) positive perception of the environment	-	greater IM
	(Page et al., 2010) exercising or doing sport every day associated	-	local-IM (boys)
P_Survey Perceived Stranger danger	(Faulkner et al., 2015)	+	on weekdays
	(Lin et al., 2017)	0	though parents have safety concerns
	(Stephanie H. Kneeshaw-Price et al., 2015)	–	MVPA
	(Santos et al., 2013)	0	IM
C-Survey Perceived Stranger danger	(Alton et al., 2007)	–	less walking
	(Davis & Jones, 1996)	–	in particular (F)

	(Timperio et al., 2004)	–	low SES (F) than high SES
P_Survey Increased social Cohesion/Social Norms	(Lin et al., 2017)	+	IM
	(van den Berg et al., 2020) increase perception of social cohesion	+	parents perceived safety
C-Survey Neighbourhood high aesthetics / Nuisance Social Norms	(Noonan et al., 2016) Neighbourhood aesthetics	0	self-reported PA
	(Noonan et al., 2016) Neighbourhood aesthetics	–	BMI
	(Page et al., 2010) higher score of social norms	+	frequency of outdoor play
P_Survey Perception of Road Safety Low perceived road safety	(Noonan et al., 2016)	–	independent mobility
	(Stark et al., 2018)	–	independent mobility (general traffic safety)
	(Timperio et al., 2004) Parents believe of (heavy traffic) in (5-6 years old) boys	+	Frequency of walking (sidewalks or bike lanes, safe crossing
	(Timperio et al., 2004) Parents believe (for M) of 10 – 12 years old of no lights or crossing.	–	walking and cycling
	(Timperio et al., 2004) The parental belief of F needs to cross many roads to reach play area 10 - 12	–	likelihood of walking or cycling
	(Villanueva et al., 2012) safe neighbourhood crossing	–	activity space in particular girls,
	(Faulkner et al., 2015) Fast drivers (weekdays),	–	MVPA (active play)
	(Roberts et al., 2016) if parents perceived a lack of sidewalk and signals on a busy street.	–	active children
	(Santos et al., 2013) perceived sidewalk and street safety	–	independent mobility
	(Oluyomi et al., 2014) road safety in the home environment of higher sidewalk availability, Speed, amount of traffic, intersection safety, road crossing problem and availability of crossing guard.	–	Likelihood of walking to school
	(Carver et al., 2014) concern about traffic.	-	likely for boys and girls to cycle independently
	(Tung et al., 2016) traffic hazards (perceived_)	–	PA
	(Waygood & Susilo, 2015) slow or safe traffic	+	Walking to school
	(Davis & Jones, 1996) traffic	–	Independent mobility
	(Nguyen et al., 2018) parents' perception of high or moderate traffic speed higher	+	outdoor active play
Perceived increased street connectivity	(van den Berg et al., 2020) increased connectivity	+	parental perception of safety
Destination accessibility	(Oliver et al., 2016)	+ –	the proportion of trips in active mode (weekdays) %MVPA (weekend)
Improved streetscape (measured)	(Villanueva et al., 2012)	+	Activity space
C_Survey Road safety	(Alton et al., 2007)	–	road safety and heavy traffic and level of walking
	(Villanueva et al., 2012)	–	activity space
	(Davis & Jones, 1996)	–	IM in particular F (traffic danger)
	(Timperio et al., 2004)	–	low SES (M) than in high SES
	(Page et al., 2010)	+	local and Area-IM with traffic safety (for girls) positive perception of road safety (+ IM) for girls
Neighbourhood's Safety –Perception of other elements related to safety in the Physical environment			
P_Survey Perceived **lack of leisure facility**, Parks and sport ground	(Timperio et al., 2004)	–	likely to walking &cycling three times a week (10-12) F
	(Alton et al., 2007)	–	with a crossing of no light or crossings
	(Faulkner et al., 2015)	0	duration of playout
Land use diversity: Residential/ Commercial/ Industrial/	(Fagerholm & Broberg, 2011)	+	mobility mainly in urban structure (residential, commercial and traffic areas)
	(Villanueva et al., 2012)	–	AS in utilitarian destination (within 800 m)
	(Janet E. Loebach & Jason A. Gilliland, 2016)	+	Time spend close to home (residential) and (+) distance travelled and time spends in commercial (beyond 800m).
		–	mobility in agricultural and industrial (on 400-800m buffer)
	(Faulkner et al., 2015)	+	time playing outside (Residential &Commercial)

	*(Oliver et al., 2016)	0	%MVPA
	(Helbich et al., 2016) urban environment and well-connected street and lights	+	Active school travel
	(Carver et al., 2014) (land use mix of residential, retail shops, sports centre)	+	walking/cycling independently to school (F)
Land use mix (access)	(Tung et al., 2016)	+	PA
P_Survey proximity to destinations	(Stark et al., 2018)	–	AIM
	*(Fagerholm & Broberg, 2011)	–	trajectory (with increased distance),
	*(Oliver et al., 2016) distance to school	–	the proportion of trips made in active mode, + distance to school
	(Lin et al., 2017)	–	AIM
	(Mehdizadeh et al., 2017) perception of more than 10 min walking	–	perceived walking to school distance and active travel
	(Roberts et al., 2016)	+	to play area, active behaviour
	(Janet E. Loebach & Jason A. Gilliland, 2016)	–	majority of time spent closer to home (400 m buffer around the home)
		–	school travel and neighbourhood travel
	(Helbich et al., 2016)	–	AST
	(Waygood & Susilo, 2015)	–	Walking to school
	(van den Berg et al., 2020)	–	school active travel
C_Survey proximity	(Janet E. Loebach & Jason A. Gilliland, 2016)	+	distance travelled and activity space near home
	(Page et al., 2010)	–	longer route and active commuting to school (for both boys and girls Active commuting
P_Survey perception of limited access to public transportation	(Timperio et al., 2004)	– –	likely of walking or cycling F of 5-6-year-old. likely of walking or cycling F of 10-12-year-old.
P_Survey Availability of Neighbourhood Amenities	(J. Loebach & J. Gilliland, 2016)	+	neighbourhood activity space
P_Survey High walkable neighbourhood	(Villanueva et al., 2012)	+	activity space
P_Survey High Neighbourhood aesthetics	(Roberts et al., 2016)	+	active children
	(Noonan et al., 2016)	–	BMI z-score and waist circumference
	Mehdizadeh et al., 2017	+	Perceived walking to school
P_Survey Owning a dog	(Timperio et al., 2004)	+	frequency of walking
C-Survey Accessibility to destination	(Timperio et al., 2004) child believe of no parks access to parks (F/M)	–	walking and cycling in 10-12 years old (M)
	(Page et al., 2010) easy access to range pf destination (Page et al., 2010) greater perceived accessibility	+ +	taking part in structured exercise/sport every day Active commuting to school
Neighbourhood– Measured safety			
Measured safety from crime (high level of actual crime)	(Stephanie H. Kneeshaw-Price et al., 2015)	–	MVPA
	(Vonderwalde, Cox, Williams, Borghese, & Janssen, 2019)	+	active transportation in High crime areas
	(Zhu & Lee, 2008)	–	walkability
	(Suminski et al., 2018)	+	BMI z-score
Road safety	(Nguyen et al., 2018) children from the highest traffic volume	+	outdoor active play
	(Carver et al., 2014) the proportion of main roads	–	odd of walking and cycling (F) walking and cycling to school independently
	*(Oliver et al., 2015) ratio of high-speed roads around schools (weekdays)	–	%MVPA
	street connectivity	+	the proportion of trips made in active mode (on weekend and weekdays)
	(Helbich et al., 2016) exposures to major roads/highway Availability of cyclist path	– +	AST AST
	(Carver et al., 2008)* measured road environment	0	Likelihood of making at least 7 walking and cycling active trips per week

Perceived and measured road safety	(Nguyen et al., 2018) perceived road safety	x	measured road safety
Perceived and measured personal safety	(Stephanie H. Kneeshaw-Price et al., 2015) Measured crime	0	with parents' perception
Parents to children perceived safety	(Timperio et al., 2004)		parent of 10 – 12 perception was more negative than their own children

Note: Association identified between safety and active mobility behaviour: (+) positive association, (-) negative association, (0) Non-Associated/Not Significant difference, x = association not to active behaviour. Abbreviation: P_Survey = studies examined the perception of safety among parents; C_Survey = studies examined the perception of safety among children. M = male (boys), F = female (girls), IM = independent mobility, MBI – body mass index, SES = socioeconomic status, HD = high depreciation, MD = Medium Deprived, CRI = Crime Risk Index, BMI Body Mass Index, SES = Socioeconomic level, * = behaviour show significant correlate on Weekdays, ** = Behaviour show on weekend, MVPA = Moderate to vigorous physical activity. [1] "Avoidance behaviour is where no further engagement in habits and activities due to perceived risk, e.g. parents driving children to school instead of walking or cycling., [2] Defensive behaviour is where habits are altered in an attempt to reduce perceived risk, e.g. parental accompaniment to children while walking to school", Ferraro, 1995.