Associations between Light Rail Transit and Physical Activity: A Systematic Review

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For Citation please use: Ravensbergen, L., Wasfi, R., Van Liefferinge, M., Ehrlich, I. Prince, S., Butler, G., Kestens, Y., & El-Geneidy, A. (2022). *Associations between light rail transit and physical activity: A systematic review*. Paper to be presented at the Transportation Research Board 101st Annual Meeting.

Abstract

Investment in public transport is on the rise as many cities around the world aim to reduce their carbon footprint and improve population health. One such investment is building or extending Light Rail Transit (LRT). Focusing on studies in the USA, Canada, Australia, and New Zealand, this paper reports the results of a systematic review on the associations between LRT and physical activity. Twenty studies were identified through a search of six bibliographic databases and a systematic Google search. Moderate certainty of evidence exists for the relationship between LRT and walking behaviour. Here, all studies, most of which were natural experiments (n = 6), found a positive association between LRT and walking behaviour, with LRT leading to an increase of 7-30% in walking in most studies (n=7 out of 8). A positive relationship between LRT and moderate-to-vigorous intensity physical activity (MVPA) and between LRT and cycling was also often identified; however, results were inconsistent, and certainty of evidence is low for MPVA, and very low for cycling. Further, some studies (n=3) identify differences in physical activity participation at different LRT stations, suggesting that station design, surrounding land use, and built environment play important roles in promoting physical activity around LRT.

Keywords: Light Rail Transit; Physical Activity; Literature Review; Walking; Cycling; MVPA

INTRODUCTION

In response to growing environmental (e.g., air quality, climate change) and population health (e.g., physical activity, quality of life, air pollution) concerns, many cities worldwide are increasing their investment in public transport systems. Indeed, public transport has many benefits to both individuals and communities: it can be an affordable travel mode (especially when compared to car use), it can reduce congestion, enhance social connectedness, improve air quality, and increase quality of life (Sener, Lee, & Elgart, 2016). Unlike driving, public transport also often requires walking to and from stops and is, therefore, expected to encourage physical activity through multimodal travel (Sener et al., 2016). One form of public transport that has become increasingly popular in recent years is Light Rail Transit (LRT) (Sinclair, 2019). In North America, the number of Light Rail projects under construction grew from one in 2012 to nineteen in 2019 (Sinclair, 2019). This increase in popularity of LRT may be due to its tendency to have lower capital costs and increased reliability compared to heavy rail systems or that it may encourage transit-oriented development in ways that other, less permanent forms of public transport, such as buses, are unable to do.

Two systematic reviews on public transport and physical activity have been published (Rissel, Curac, Greenaway, & Bauman, 2012; Xiao, Goryakin, & Cecchini, 2019), and one meta-analysis on the effects of rapid transit interventions on physical activity has been conducted (Hirsch, DeVries, Brauer, Frank, & Winters, 2018). Xiao et al. (2019) reviewed the impacts of building, extending, or improving local public transport options on physical activity and found that public transport investments are associated with approximately 30 minutes of additional walking (or other light to moderate physical activity) per week. No significant relationship between new transit and moderate-to-vigorous intensity physical activity (MVPA) was found. Similarly, Rissel et al. (2012) found 8-33 minutes of additional walking was attributable to the use of public transport among adults.

These existing reviews focus on all types of public transport, but LRT may yield different outcomes than other forms of public transport. For instance, riders may be willing to walk further to reach this form of public transport than others (e.g., a bus stop). If secure bicycle parking is available, it is possible that cyclists will travel even greater distances to use a station. Given this and the recent rise in popularity of LRT, this paper presents the results of a systematic review of studies examining the relationship between LRT and physical activity. By focusing on LRT, this paper builds on Hirsch et al. (2018)'s meta-analysis on the effects of rapid transit interventions on physical activity which found that while transport-related physical activity increased, overall physical activity levels decreased. Their meta-analysis examined LRT in conjunction with Bus Rapid Transit, and Rail Rapid Transit. Five studies were included in this meta-analysis, three of which evaluated the implementation of LRT. Therefore, the objective of this systematic review is to build upon the work of Hirsch et al. (2018), by focusing solely on LRT and expanding their scope by including all studies, regardless of design, which examined the relationship between this form of public transport and physical activity (e.g., walking, cycling, MVPA). The certainty of evidence for each physical activity outcome (e.g., walking, cycling, MVPA) was also assessed to provide policy makers with a clear indication of how confident they can be that LRT investments will result in different physical activity outcomes. Because research on LRT and physical activity originating from places with high public transport and active travel rates, such as many European and Asian cities, might find stronger evidence than that of cities with more auto-oriented urban planning legacies, the geographic scope of this paper is focused on LRT in the United States, Canada, Australia, and New Zealand to ensure policy makers in these contexts do not over-estimate the effect of this public transit investment. Further, this reduced scope allows for a rigorous exploration of the risk of bias in each paper and the certainty of evidence of the body of work. The secondary objective of our study is to document the different approaches used in this body of work. We do so by documenting the theoretical frameworks guiding the included studies, as well as whether previous research considered equity or self-selection, two important topics in research on travel behaviour.

METHODS

Context and Study Inclusion and Exclusion Criteria

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. A protocol for this review was prospectively registered on Open Science Framework (https://osf.io/ux5vn/) and PROSPERO (registration number: CRD42021254690).

Population: No age restrictions were placed on the participants in the studies. Only studies that evaluated the association between LRT and physical activity in the United States, Canada, Australia, and New Zealand were eligible. These countries were selected because their cities tend to have similar urban fabric and built environments and previous research has found similar factors influence walking to public transport in these countries, as opposed to differences in Asia and Europe (van Soest, Tight, & Rogers, 2020).

Exposure: Following guidelines put forth by Malouff (2015) and Johnson (2019), and Light Rail data provided by The Transport Politic (2021), LRT was defined as fully electric passenger urban rail transit that is partially or fully separated from vehicle traffic. Studies that concentrated on bus rapid transit or rail rapid transit were excluded from this systematic review. LRT could be assessed through self-reported use, objectively measured use, or proximity to LRT (e.g., living near a station). Studies that considered LRT use alongside other forms of public transport (i.e., did not separate the modes in the analysis) were excluded (Bopp, Gayah, & Campbell, 2015; Carlson, Watson, Paul, Schmid, & Fulton, 2017; Lachapelle & Noland, 2012; Lachapelle & Pinto, 2016; Langlois, Wasfi, Ross, & El-Geneidy, 2016).

Outcomes: The primary outcome was physical activity. Physical activity could be device-measured (e.g., pedometer, accelerometer), or self-reported (e.g., questionnaire with reported minutes of walking or biking or number of times engaged in an activity) and did not have to be as a direct result of using an LRT. Papers that examined the impact of LRT on BMI or body weight that did not look at physical activity separately (e.g., (Brown, Smith, Jensen, & Tharp, 2017)) were excluded as body weight is a complex outcome influenced by myriad factors that extend beyond physical activity. Studies of simulations (e.g., anticipated physical activity if LRT investment was made) were excluded, as they do not present real-world physical activity data. Secondary outcomes included documentation of the theoretical frameworks guiding the research, and whether the research considered equity and participant self-selection.

Study designs: All original studies that empirically examined the associations between LRT and physical activity in the selected countries were included, regardless of study design.

Publication status and language: Based on the authors' language capabilities, only publications in English or French were eligible. Abstracts without full texts were excluded. When two papers reported on the same data, peer-reviewed publications were prioritized (e.g., in the case of a dissertation and a peer-reviewed publication, only the peer-reviewed publication was retained), as well as the most recent source (e.g., newer publications prioritized before older publications).

Search Strategy

The search strategy was developed by the authorship team in consultation with a librarian specializing in systematic reviews. Two search strategies were developed: one for academic literature and one for grey literature. Searches were conducted in May 2021.

The academic literature search included five electronic bibliographic databases: Web of Science, Transport Research International Documentation (TRID), Scopus, Medline, and SPORTDiscus. Trial searches were run and expanded upon to ensure that pre-identified key papers were captured by the search strategy. Titles, abstracts, and keywords (when possible, TRID only allowed a title search) were searched for synonyms of LRT and physical activity. The full electronic search strategy, including all search terms, can be found in Appendix A.

The search of academic articles was complimented by a search of the grey literature. Firstly, the ProQuest Dissertations & Theses Global database, the world's most comprehensive collection of dissertations and theses, was searched. The same search terms used for the journal databases were used to search titles, abstracts, and keywords. Google searches were used to search for each city known to have LRT (Appendix B) by searching for the city's name alongside the terms 'light rail transit' and 'physical activity'. This was done on a browser with no previous history in incognito mode. The two reviewers reviewed the first two pages of the resulting search and compiled all potentially relevant reports. If a report was selected for inclusion, they continued their search to the following page. This was done until a full page with no selected reports were identified. The two reviewers then met to compare the resulting reports and to resolve which to include through discussion. Eligible reports needed to present data on the associations between LRTs and physical activity that were not already presented in the academic literature or dissertation search. The reference lists of all included studies, as well as all literature review papers identified through this screening process were hand searched to identify potentially eligible articles.

Selection of studies

For the academic literature, abstract and full-text screening was conducted by two independent reviewers using Rayyan software, an open-source systematic review manager. If conflicts arose, they were discussed with a third reviewer; the resulting articles' full texts were screened by both reviewers for inclusion. When conflicts arose, they were resolved through discussion. For the grey literature search, two reviewers independently examined the first two pages of the resulting search and compiled all potentially relevant reports. If a report was selected for inclusion, they continued their search to the following page. This was done until a full page with no selected reports were identified. The two reviewers then met to compare the resulting reports selected and to resolve conflicts through discussion. Eligible reports needed to present data that were not already present in the peer-reviewed published literature or dissertation search.

Data Extraction

Standardized data abstraction forms were independently completed by two reviewers using Google Forms. A Google Form was developed with detailed instructions to extract information from studies to minimize potential bias in extraction between reviewers. Extracted data included: authors, title, publication year, study setting (country and city), study context, seasonality of data collection, study design, population description, research question, LRT exposure measure, how exposure was defined, physical activity outcome measure, whether physical activity measure was self-reported or device-measured, confounders measured, theoretical framework, statistical methods used, results, whether the study considered equity in any way (e.g., gender, income, socio-economic status (SES) indicators, or race/ethnicity-based differences in physical activity or LRT exposure), future research recommendations, and policy recommendations. Once both reviewers completed data extraction, the extractors met to review and validate the data. Any disagreements that arose were resolved through discussion.

Risk of Bias

The standardized data extraction forms included a risk of bias assessment. Both reviewers completed the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (https://www.ephpp.ca/quality-assessment-tool-for-quantitative-studies/). The instrument assesses eight domains: (1) selection bias; (2) study design; (3) confounders; (4) blinding; (5) data collection method; (6) withdrawals/dropouts; (7) intervention integrity; and, (8) analyses. Reviewers rated each domain as strong, moderate, or weak. The tool was modified to better reflect the topic of this review and guidelines were established to help the reviewers give the papers consistent grades (Appendix C). Once complete, the two reviewers compared their risk of bias assessments. If disagreements arose, they were resolved through discussion. Each study received a global rating based on EPHPP criteria (i.e., 'strong' if no domains had a weak rating, 'moderate' if one domain had a weak rating, and 'weak' if two or more domains had a weak rating).

Evaluation of Certainty of Evidence

The certainty of evidence was then assessed using a modified GRADE (Grading of Recommendations Assessment, Development, and Evaluation) approach (https://gdt.gradepro.org/app/handbook/handbook.html). Certainty of evidence was assessed as 'high', 'moderate', 'low', or 'very low' for each outcome (e.g., walking behaviour, cycling behaviour, MVPA).

Each outcome was assigned an initial certainty of evidence based on study design. If the designs were randomized controlled trials/ natural experiment/ quasi-experimental studies the evidence was assigned an initial level of 'high', whereas cross-sectional studies were assigned an initial level of 'low'. The certainty of evidence for each outcome was assessed separately for the experimental and observational evidence. The final certainty of evidence was based on the evidence from the highest quality study design available (e.g., experimental above observational).

The certainty of evidence was based on the following: risk of bias, inconsistency, indirectness, imprecision, or publication bias. In instances where the certainty of evidence was not downgraded, it could be upgraded if the following were observed: large effect, dose response, or opposing bias & confounders (Balshem et al., 2011; Murad, Mustafa, Schünemann, Sultan, & Santesso, 2017). The specific evaluation criteria guiding the evaluation of evidence can be found in Appendix D[1]. One reviewer independently assessed the certainty of evidence, and a second reviewer verified the assessments.

RESULTS

The database search identified a total of 5,866 articles, 1,969 of which were duplicates. Title and abstract screening resulted in 38 potential articles whose full texts were screened by both reviewers for inclusion. After full text screening, twelve papers were included in this review. The grey literature search identified 440 dissertations and theses, three of which were included, and five eligible reports from the Google search (Figure 1).

[1] Because none of the outcome variables met the criteria to be upgraded, upgrading evaluation criteria are omitted from Appendix D.

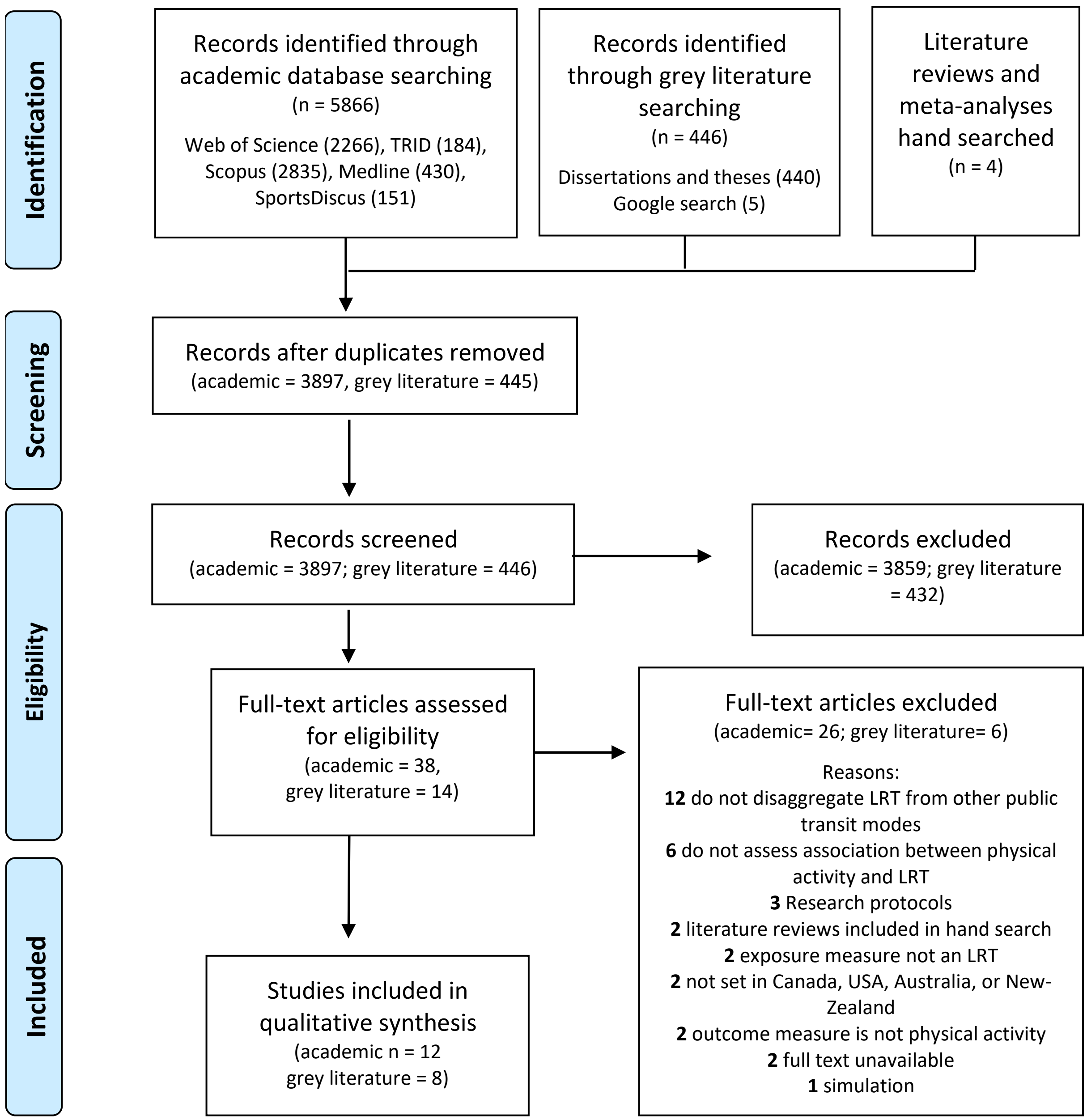

Figure 1. PRISMA flow diagram

Summary of Results

A summary of the papers, dissertations, and reports included in this review can be found in Table 1 (n=20). Most of the studies (n = 17) took place in the United States, including all twelve academic articles. The most frequent study setting was Salt Lake City (n=5).

Table 1 Summary of Findings

Paper	LRT location	Sample size analyzed	Comparative group	LRT exposure measure /Self-reported or measured	Physical activity measure/ Self-reported or device measured
Natural experiments					
Barbaric and Alizadeh (2017)	Australia, Gold Coast	NR	Before and after (time period NR)	Proximity to LRT/ unclear	Walking behaviour, cycling behaviour/ Unclear
MacDonald, Stokes, Cohen, Kofner, and Ridgeway (2010)	USA, Charlotte	498	Before and after (~1 year)	LRT use/ Self-reported	MVPA and recommended physical activity/ Self-reported
Hong, Boarnet, and Houston (2016)	USA, Los Angeles	204, & 73 accelerometer sample	Before and after (~1 year) Near and far	Proximity to LRT/ Measured	MVPA/ measured walking behavior/ Self-reported
Spears, Boarnet, and Houston (2017)	USA, Los Angeles	285 6 months before, 208 6 months after, & 173 18 months after	Before and after (6 and 18 months) Control v experimental	Proximity and use/ Self-reported	Walking behaviour, cycling behavior /Self-reported
Hampton Roads Transit (2015)	USA, Norfolk, Virginia	NR	Before and after (2 years)	LRT use/ Self reported	Walking and cycling behaviour/ Self-reported
Ewing and Hamidi (2014)	USA, Portland	65	Before and after (17 years) Near LRT v. control group	Proximity to LRT/ Measured	Walking behaviour, cycling behaviour/ Self-reported
Brown and Werner (2007)	USA, Salt Lake City	51	Before and after (one year)	LRT use/ Measured	MVPA/ Device
Brown, Smith, et al. (2016)	USA, Salt Lake City	536 (910 first wave)	Before and after (one year) Near vs. far	Proximity to LRT station/ Measured	Walking behaviour, cycling behaviour/ Device
Brown, Werner, et al. (2016)	USA, Salt Lake City	536	Before and after (one year) Four transit ridership groups	LRT use/ Measured	MVPA/ Device

Miller et al. (2015)	USA, Salt Lake City	536	Before and after (~1 year)	LRT use/ Measured	LMPA/ Measured
Huang, Moudon, Zhou, Stewart, and Saelens (2017)	USA, Seattle	198	Before and after (~2 years) Near and far	LRT use and Distance to LRT/ Self reported	Walking behaviour/ Measured
			Cross-sectional Studies		
Eady and Burtt (2019)	Australia, Melbourne	NR	Distance walked	LRT use, unclear	Walking distance/ Unclear
O'Sullivan (1995)	Canada, Calgary	1843	Different stations	LRT Use/ Measured	Walking distance / Self-reported
Appleyard, Frost, and Allen (2019)	USA, Charlotte, Dallas, Denver, Houston, Minneapolis-St. Paul, Phoenix, Portland, Sacramento, Salt Lake, San Diego, San Jose, and Seattle	NA - population-level variables across 357 stations in 12 metro areas	Categorizes and compares stations based on an array of variables	Proximity to LRT (half mile straight-line distance to light rail transit)/ Measured	behaviour, cycling behaviour/ Self-reported
Hess, Ray, and Attard (2014)	USA, Buffalo	1397	Free pass holders (n=643) vs. control group (754)	LRT use/ Self reported	Walking and cycling behaviour/ Self-reported
Kumar Maghelal (2007)	USA, Dallas	1022	Built environment at stations Near vs. far	Proximity to LRT/ Measured	Walking behaviour/ Self-reported
Schoner and Cao (2014)	USA, Minneapolis	1303	LRT corridors vs. control areas	LRT proximity/ Self-reported	Walking behaviour/ Self-reported
Noland, Ozbay, DiPetrillo, and Iyer (2014)	USA, New Jersey	1629	Near vs. far	LRT proximity (also asked about LRT use, but not in relation to PA)/ Self reported	Walking behaviour, cycling behaviour/ Self-reported
Crist et al. (2021)	USA, San Diego	6894	None	Anticipated use of LRT and distance to LRT/ Self reported	Walking and cycling behaviour /Self-reported
McAslan (2018)	USA, Seattle	249 surveys & 43 interviews	Not in relation to physical activity	Interviews = LRT use/ self-reported	Walking distance/ Self-reported

LRT = Light Rail Transit
LMPA= Light-to-moderate intensity physical activity
MVPA = moderate-to-vigorous intensity physical activity
NR = not reported
USA = United States of America

Primary Objective: LRT and Physical Activity

Eleven studies used a natural experiment research design (before and after) while nine were cross-sectional (Table 1). The natural experiment studies all examined physical activity before and after the introduction of a new LRT or LRT extension. Spears et al. (2017) was the only study to examine these effects at multiple time periods after opening (6 and 18 months after opening). Three of the natural experiments examined the effects of LRT on physical activity at different distances to the station (Brown, Smith, et al., 2016; Hong et al., 2016; Huang et al., 2017), while two compared the area around the LRT to a control group (Ewing & Hamidi, 2014; Spears et al., 2017). For instance, Spears et al. (2017) compared physical activity amongst residents living within walking distance of new LRT stations to that of residents living in a neighbourhood with similar built environment and socio-demographic characteristics further from the station. The use of comparative groups was common amongst the cross-sectional studies. The most common comparative analyses were by distance to LRT (Kumar Maghelal, 2007; Noland et al., 2014) and across stations or station typologies (Appleyard et al., 2019; Kumar Maghelal, 2007).

Nine studies utilized proximity to LRT as the exposure measure, while ten looked at LRT use and two studied both (Table 1). The LRT exposure was self-reported in nine studies and measured in 10 (two did not specify). The physical activity measures included walking behaviour, walking distance, cycling behaviour, walking and cycling behaviour combined, MVPA, light-to-moderate intensity physical activity (LMPA), and meeting recommended levels of physical activity (e.g., ≥150 minutes per week). Other studies compared physical activity across LRT stations.

The quality of the studies was evaluated using the EPHPP Quality Assessment Tool (Table 2). Using the EPHPP tool, two peer-reviewed papers received a 'weak' global rating, while seven of the eight grey literature documents received this 'weak' rating. Two best practices that were frequently omitted from the methods sections of these papers included comparing the study sample to the general population (e.g., by comparing the sample's characteristics to the census) and reporting the number and reasons for withdraws or dropouts in the natural experiment studies.

Table 2 Risk of Bias Assessment

Paper	Global Rating	Low Selection Bias	Study Design	Confounder	Blinding	Data Collection methods	Withdrawals/ Dropouts	Intervention Integrity	Analyses
Peer-Reviewed Journal Articles									
Appleyard et al. (2019)	Weak	Moderate	Weak	Moderate	Strong	Weak	NA	NA	Moderate
Brown, Smith, et al. (2016)	Strong	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Moderate
Brown, Werner, et al. (2016)	Strong	Moderate	Strong	Moderate	Moderate	Strong	Strong	Strong	Strong
Brown and Werner (2007)	Moderate	Weak	Strong	Moderate	Moderate	Strong	Moderate	Strong	Strong
Crist et al. (2021)	Moderate	Strong	Weak	Moderate	Moderate	Moderate	NA	NA	Strong
Ewing and Hamidi (2014)	Weak	Strong	Strong	Moderate	Moderate	Weak	Weak	Weak	Moderate
Hong et al. (2016)	Strong	Moderate	Strong	Strong	Moderate	Strong	Moderate	Moderate	Strong
Huang et al. (2017)	Strong	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong	Strong
MacDonald et al. (2010)	Moderate	Moderate	Strong	Moderate	Moderate	Weak	Strong	Moderate	Moderate
Miller et al. (2015)	Strong	Moderate	Strong	Moderate	Moderate	Strong	Moderate	Moderate	Moderate
Schoner and Cao (2014)	Strong	Strong	Moderate	Moderate	Moderate	Moderate	NA	NA	Moderate
Spears et al. (2017)	Strong	Strong	Strong	Strong	Strong	Moderate	Strong	Moderate	Moderate
Grey Literature									
Barbaric and Alizadeh (2017)	Weak	Weak	Weak	Weak	Moderate	Weak	Weak	Weak	Weak
Eady and Burtt (2019)	Weak	Weak	Weak	Weak	Moderate	Moderate	NA	NA	Weak
Hampton Roads Transit (2015)	Weak	Weak	Strong	Weak	Moderate	Weak	Weak	Moderate	Weak
Hess et al. (2014)	Weak	Weak	Weak	Moderate	Moderate	Moderate	NA	NA	Weak
Kumar Maghelal (2007)	Weak	Strong	Weak	Weak	Strong	Moderate	NA	NA	Strong
McAslan (2018)	Weak	Weak	Weak	Weak	Moderate	Weak	NA	NA	Weak
Noland et al. (2014)	Strong	Moderate	Moderate	Moderate	Moderate	Moderate	NA	NA	Strong
O'Sullivan (1995)	Weak	Moderate	Weak	Weak	Moderate	Weak	NA	NA	Moderate

The overall certainty of the evidence for each physical activity outcome discussed in the papers was assessed using the GRADE Evidence Profile (Table 3).

Table 3 GRADE Evidence Profile

Outcomes Across Studies	Study Design	Number of Studies	Number of Participants[1]	Relative Effect	Quality of Evidence (GRADE)
Walking behaviour	Natural Experiment	6	1176	Positive and statistically significant association between LRT and walking behaviour found in most (4/6) studies.	**Moderate** ⊕⊕⊕◯ Initial rating: High Risk of Bias: 0 Inconsistency: 0 Indirectness: 0 Imprecision: 0 Publication Bias: -1
	Cross-sectional	2	2932	Positive association between LRT and walking behaviour found in one paper, inconsistent evidence found in the other.	**Very Low** ⊕◯◯◯ Initial rating: Low Risk of Bias: 0 Inconsistency: -1 Indirectness: 0 Imprecision: -1 Publication Bias: 0
Cycling Behaviour	Natural Experiment	4	774	Positive association identified in most studies (3/4), but most results not statistically significant.	**Very low** ⊕◯◯◯ Initial rating: High Risk of Bias: -0.5 Inconsistency: 0 Indirectness: 0 Imprecision: -1 Publication Bias: -1
	Cross-sectional	1	1629	Positive association identified, but statistical significance not reported.	**Very Low** ⊕◯◯◯ Initial rating: Low Risk of Bias: 0 Inconsistency: NA Indirectness: 0 Imprecision: -1 Publication Bias: 0
Walking and Cycling Behaviour	Natural Experiment	1	NR	Positive association identified, but statistical	**Very Low** ⊕◯◯◯ Initial rating: High Risk of Bias: NA Inconsistency: NA Indirectness: -1

				significance not reported.	Imprecision: -1 Publication Bias: -1
	Cross-sectional	2	7537	Positive association identified, but results are not statistically significant in one study, and not reported in the other.	**Very Low** Initial rating: Low Risk of Bias: 0 Inconsistency: 0 Indirectness: -1 Imprecision: 0 Publication Bias: 0
MVPA	Natural Experiment	4	1158	2/4 studies find significant positive association. One study finds no association and the other finds negative, but statistically insignificant, association.	**Low** Initial rating: High Risk of Bias: 0 Inconsistency: -1 Indirectness: 0 Imprecision: 0 Publication Bias: -1
LMPA	Natural Experiment	1	536	Positive association identified between LRT and total LMPA (not significant) and transit related LMPA (significant).	**Moderate** Initial rating: High Risk of Bias: 0 Inconsistency: NA Indirectness: 0 Imprecision: -1 Publication Bias: 0
Recommended Physical Activity	Natural Experiment	1	498	Positive, but not significant, association identified	**Moderate** Initial rating: High Risk of Bias: 0 Inconsistency: NA Indirectness: 0 Imprecision: -1 Publication Bias: 0
Walking Distance to LRT stations	Cross-Sectional	3	2092	2/3 studies find that respondents walk further to reach LRT stops than other public transit.	**Very Low** Initial rating: Low Risk of Bias: -1 Inconsistency: 0 Indirectness: -1 Imprecision: -1 Publication Bias: -1
Physical Activity Across Stations	Cross-Sectional	3	2865	All studies find some variation in physical activity	**Very Low** Initial rating: Low

				across LRT stations.	Risk of Bias: -1 Inconsistency: 0 Indirectness: 0 Imprecision: -1 Publication Bias: 0

[1]When multiple samples were reported, most relevant or smallest included herein
LRT = light rail transit
MVPA = moderate-to-vigorous intensity physical activity

Walking behaviour

The most studied physical activity outcome was walking behaviour. Of the eight studies focused on the association between LRT and walking behaviour, six were natural experiments, and two were cross-sectional. Of the six natural experiment studies, all found evidence for a positive association between walking and LRT.

Four of these six studies found statistically significant evidence between the construction of LRT and increased walking behaviour. Drawing on a combination of GPS and accelerometer data, Brown, Smith, et al. (2016) found that residents living near LRT after construction were more likely to complete transit-related active transport trips (odds ratio near time 2/ near time 1: 0.61; $p \leq 0.02$) and took more walking trips in the complete street corridor ($p < 0.001$) than those before the LRT or living farther away. Specifically, a 13% increase in walking trips was observed amongst those living near LRT after it was operational, while a 7% increase was observed amongst those living further from a station. Further, the odds of taking non-transit walks post-construction was 0.28 (95% CI: 0.19 – 0.44) amongst those living far from the stations (1000 meters) when compared to those living near (> 800 meters). Drawing from a one-day travel diary, Ewing and Hamidi (2014) found that self-reported daily walking trips for all purposes increased in the LRT corridor after construction from 0.86 trips to 2.16 (an increase of 151%) ($p < 0.001$), and that there were more weekly walk trips in the LRT corridor after construction than the control corridor ($p = 0.018$). Living within a half mile buffer of LRT was also positively associated with self-reported walk trip for all purposes counts in Hong et al. (2016) where average daily walking trips increased from 1.00 to 1.29 after the LRT was operational (an increase of 29%) ($p < 0.05$). Though those living in the control area exhibited a lower number of walking trips (average daily trips = 0.79), this proportion was unchanged after the LRT was operational. Spears et al. (2017) was the only study that looked at the physical activity effects of light rail at two follow-up times. They found that average daily all-purpose walking trips increased from 1.58 to 1.75 (a 10.76% increase) amongst residents in neighbourhoods with an LRT stop six months after opening ($p<0.05$), but that no statistically significant change was identified after 18 months when the mean number returned to 1.58.

Two of the six natural experiment studies examined LRT and objectively assessed walking behaviour. In Huang et al. (2017), accelerometer-measured average daily walking minutes identified through GPS were actually found to decrease after the LRT opened from 36.2 to 25.1 ($p< 0.001$). Station area (defined as within one quarter Euclidean mile of an LRT station) walking (from 7.7 to 8.4 average daily minutes, $p = 0.413$) and percent station-area walking (from 0.20 to 0.26, a 30% increase, $p < 0.001$) did increase, though only the latter showed a statistically significant increase. Finally a report on the light rail corridor in Gold Coast, Australia found that pedestrian counts generally remained stable, however, they increased on light rail pedestrian links (how this was measured and the extent to which they increased was not reported) (Barbaric & Alizadeh, 2017).

In their cross-sectional study, Schoner and Cao (2014) found that travel attitudes, residential preferences, and built environment characteristics were associated with walking ($p<0.1$), but that living in a LRT area (quarter mile buffer) was not statistically significantly associated with walking to the store ($p>0.1$). Mean walking trips for leisure and to the store were consistently higher in the LRT coridor (3.68 mean strolling trips and 2.04 mean walking to the store trips) than the two suburban controls (3.22 and 3.52 (strolls) and 1.88 and 1.93 (store), but were not consistently higher than the two urban controls (3.67 and 3.51 (strolls) and 1.96 and 2.35 (store)). Noland et al (2014) examined how distance to LRT stations influenced self-reported active travel behaviour (walking and cycling). Walking-specific results indicated that walking frequency, walking as a commute mode in the last week, walking as an access mode for transit, and percent of walking to other destinations (restaurant or coffee shop, food or grocery shopping) was higher amongst those living near the station (within ½ mile) than those living further away (½ mile – 2 miles). Further, the frequency of walking outdoors for five or more minutes was consistently higher amongst those living near LRT (within ½ mile) than farther (½ mile – 2 miles) (58.2% v. 41.8%); this difference was not statistically tested.

For walking behaviour, there was moderate certainty of evidence for a positive association with LRT. Across studies that reported quantitative results, LRT was generally associated with a 7-30% increase in walking, with one study reporting a 151% increase.

Cycling Behaviour

The relationship between LRT and cycling behaviour was less extensively studied compared to walking behaviour ($n = 5$). The results are also less consistent amongst both natural experiments and cross-sectional studies. In Brown, Smith, et al. (2016)'s natural experiment, there was a 2% increase in cycling behaviour amongst residents living near a LRT after construction, but the relationship was not statistically significant except when compared to residents living far from the LRT *and* before construction ($p = 0.04$). Similarly, weekly bicycle trips did not change significantly after LRT construction in Ewing and Hamidi (2014) (i.e., bike trips even decreased from 0.12 to 0.11, $p = 0.88$). Further, bicycle trips were only marginally greater in the LRT corridor than the control corridor (0.24 v 0.11, $p < 0.1$). Spears et al. (2017) also found that bicycle trips did not significantly increase after LRT construction (0.17 mean cycling trips vs. 0.34 at six months and 0.24 at 18 months), however, LRT users were found to complete more bicycle trips than non-users both before the LRT was built and at two time points afterwards (6 months and 18 months). Barbaric and Alizadeh (2017) did find that cyclist-counts increased after LRT construction, however, the extent of the increase, and the statistical significance were not reported. Only one cross-sectional study examined cycling behaviour associated with the LRT system in New Jersey (Noland et al., 2014). The study found that using a bicycle as the access mode for transit was more common amongst those living near LRT stops than those who live farther (33.3% vs. 66.7%, statistical significance not reported) (Noland et al., 2014).

Taken together, fewer studies examined cycling behaviour than walking behaviour and while they tended to find the expected positive association between LRT and cycling, this result was rarely statistically significant. The overall certainty of evidence for cycling behaviour is 'very low' (Table 3).

Walking and Cycling Behaviour

Three papers combined walking and cycling behaviour. Focusing on self-reported transport related physical activity (walking and cycling combined) in a university setting, Crist et al. (2021) identified a positive, though not significant, relationship between distance to LRT station and both the odds of participating in and duration of transport-related physical activity ($p>0.1$). Further, a report examined the impacts of a free transit pass on LRT ridership and associated physical activity in Buffalo, New York (Hess et al., 2014). Here, 58% reported walking or cycling more during their commute after the introduction of a free transit pass. Of these, 18% reported an increase in their walking or cycling by 11-15 minutes per day, while 19% reported an increase of 16-20 minutes per day. Finally, a report examining the impacts of the LRT in Norfolk, Virginia found that 73% of riders travelled to the transit stop by foot or bicycle (Hampton Roads Transit, 2015). As was the case for studies examining cycling behaviour, the expected positive relationship was found, but its statistical significance was either low or not reported.

Overall, there was 'very low' certainty of evidence for a positive association between LRT and walking and cycling behaviour (Table 3).

Walking Distance

A further three studies examined the distance walked to LRT. An older study set in Calgary, Canada, found that residents were willing to walk further to reach an LRT stop (422.3m) compared to the City's walking distance guidelines (400m) (O'Sullivan, 1995). This study also found that those who walk frequently to or from LRT stations walk further than those who do not. This result points to the variation in walking distances across people using the same LRT system. A more recent study in Seattle, USA, interviewed respondents that stated they would walk farther to reach a LRT stop than a bus stop (McAslan, 2018). The third study, however, found that residents in Melbourne, Australia walked a mean distance of 390 meters to reach a bus stop, but less (360 meters) to reach a LRT stop (Eady & Burtt, 2019).

Based on the GRADE evaluation, there is very low certainty of evidence for a positive association between LRT and walking distance, whereby individuals are more likely to walk further to access LRT than other forms of public transport.

MVPA

Four natural experiments examined MVPA, three of which measured this outcome through accelerometry (Brown & Werner, 2007; Brown, Werner, et al., 2016; Hong et al., 2016). In a study focusing on Los Angeles, participants' average daily minutes of MVPA decreased from 23.09 minutes before LRT to 21.52 after LRT, however, this change was not statistically significant ($p>0.05$) (Hong et al., 2016). In Brown and Werner (2007), mean bouts of moderate intensity physical activity did not change (0.06 at before and after), but self-reported rail ridership was related to bouts of moderate activity both before and after LRT construction. In Brown, Werner, et al. (2016), MVPA was significantly higher amongst continuing riders (33.62 minutes of MVPA per 10hr), former rider (28.78), and new riders (23.84) compared to never riders (17.33). Further, in both Brown and Werner (2007) and Hong et al. (2016), MVPA was higher amongst those living near LRT both *before* construction and after, suggesting the potential for residual confounding due to self-selection. MacDonald et al. (2010) was the only natural experiment study to use self-reported MVPA. The odds of meeting recommended physical activity levels were significantly increased with the introduction of LRT (odds ratio = 3.32, $p<0.1$). Noland et al. (2014) was the only cross-sectional study that examined MVPA, however it was only analyzed in relation to self-reported health.

There is low certainty of evidence for the relationship between LRT and MVPA. Though half the studies (2/4) find a significant positive association, the others wither find no relationship or an insignificant negative association.

Other physical Activity Measures

Two additional physical activity outcomes were examined. Moderate certainty of evidence exists for each, however, each was only measured in one study. MacDonald et al. (2010) was the only study to examine the relationship between LRT and the odds of meeting recommended physical activity levels (vigorous activity 3 times a week, ≥20 minutes a time; or walking 5 times a week, ≥30 minutes a time). Results indicate that the odds of meeting recommended physical activity levels were higher with LRT use, but not statistically significant.

Miller et al. (2015)'s study in Salt Lake City found that LMPA (total and in relation to transit use) decreased amongst those that discontinued using transit and increased amongst those who began using transit (average LMPA in minutes amongst new riders increased from 22.03 to 27.30). The relationship between LRT-use and total physical activity was not statistically significant, but the relationship with transit-related physical activity was ($p<0.001$). LMPA generally encompasses walking; therefore, these results can be used to support the evidence on the associations between LRT and walking behaviour.

Physical Activity across Stations or Station Typologies

Three studies compared walking or cycling across LRT stations, rather than measuring the associations between LRT and these behaviours. Appleyard et al. (2019) categorized LRT stations in 12 metro areas as emerging (infrequent transit, limited transport connectivity, and segregated/low intensity land uses), transitioning (moderate transit frequency, moderate street connectivity, moderate-to-high intensities, and some mixes of uses), or coordinating (high transit frequency, high connectivity, moderate-to-high intensity, and a mix of complementary uses). Here, both self-reported walking and cycling were significantly higher at coordinating stations than emerging stations (on average, 18.05% walked to coordinating stations while 3.83% did so at emerging stations and 4.35% cycled at coordinating stations while 1.71% cycled at emerging stations).

Two studies focused solely on walking behaviours. Kumar Maghelal (2007)'s dissertation compared walking behaviour across LRT stations, this time in Dallas, Texas, and with a focus on built environment characteristics. No significant relationship between built environment variables and walking to transit was identified at half a mile from the station, however, density was found to explain walking to the station at one quarter of a mile ($p<0.05$). Finally, a study in Calgary, Canada found that people walked farther to reach suburban stations than downtown stations (average = 651.4m v 326.4m) (O'Sullivan, 1995). Only three studies compared stations, and the certainty of evidence is very low, however this research highlights the importance of considering station design when measuring the effects of LRT on physical activity.

Secondary Objectives: Theoretical frameworks, equity, and self-selection

Most studies did not specify a theoretical framework. Of those that did, the most common was the socio-ecological model where physical activity is understood as the outcome of dynamic interrelations among personal and environmental factors at different scales (Brown, Smith, et al., 2016; Brown, Werner, et al., 2016; Crist et al., 2021). Appleyard et al. (2019) drew on Smart Growth and livability principles to develop an evaluation typology. McAslan (2018) framed their work on the theory of urban fabrics. This theory highlights how cities comprise multiple urban fabrics based on travel modes (walking, transit, car, etc.), that each requires its own planning approach to alter the automobile urban fabric to improve transit accessibility and walkability.

Few studies explicitly examined whether the physical activity outcomes of LRT were distributed equitably amongst the population, though most included socio-demographic variables in their models (e.g., sex, income, race/ethnicity, education, etc.). For instance, after controlling for preferences, perceptions, and the built environment, Schoner and Cao (2014) found that having a lower income was associated with utilitarian pedestrian trips. One exception is Appleyard et al. (2019) who examined how measures of social vulnerability and exclusion (unemployment, education, poverty, linguistic isolation, and race/ethnicity) varied between different station typologies in California. Results indicate that stations with the highest transit frequency, connectivity, and intensity of land uses had lower social vulnerability and exclusion. These stations were also associated with higher levels of walking and cycling. Further, current studies focus on adult populations. In cases where data on youth or older adults was collected, it was not presented separately from that of adults.

Few articles explicitly discussed residential self-selection, the possibility that people who are already active or prefer to use and walk/cycle for transport purposes select to live in areas with good access to public transport (Cao, Mokhtarian, & Handy, 2009). Only one article explicitly controlled for self-selection (Schoner & Cao, 2014). Though LRT had no significant effect on walking after controlling for demographics, travel attitudes, and residential preferences, the models found significant effects of built environment characteristics on walking. Three mention this as a limitation of their study (Appleyard et al., 2019; Ewing & Hamidi, 2014; MacDonald et al., 2010) and another three state that natural experiments can reduce concerns about self-selection as the people surveyed chose to live in their neighbourhoods before there was an LRT station (Hong et al., 2016; Huang et al., 2017; Spears et al., 2017).

CONCLUSIONS AND DISCUSSION

This systematic review summarizes and assesses research on the associations between LRT, an increasingly popular public transport investment, and physical activity. The physical activity outcomes most studied were walking behaviour, cycling behaviour, walking and cycling behaviour combined, and MVPA.

A moderate certainty of evidence found a positive association between LRT and walking behaviour. Studies found that LRT were generally associated with a 7-30% increase in walking with up to a 151% increase reported in one study. A strength of this work is the high proportion of natural experiment studies, as well as studies that calculated walking behaviour using devices. However, the studies included often report different types of walking behaviour (e.g., total walking, walking in an area, utilitarian walking, etc.) which makes direct comparison difficult. Given this, urban planners can be relatively confident that LRT investments will result in increased walking behaviour. It is also recommended that future research should consider recruiting bigger samples to solidify the evidence for policy makers.

Three studies examined the distance walked to LRT stations, two of which found that people walk – or are willing to walk- further to access LRT than buses. If future studies replicate this finding, the longer distances walked to LRT can be used to advocate for this form of public transport.

The certainty of evidence for a mixed relationship between LRT and MVPA is low; findings were often not statistically significant. These less robust results may be because LRT primarily encourages physical activity through walking to/from stations, a form of physical activity generally considered as lighter intensity. This may explain why overall physical activity decreased in Hirsch et al. (2018)'s meta-analysis while transport-related physical activity increased. As Hirsch et al. (2018) note, the 'ActivityStat hypothesis', when people change their usual activity patterns to compensate for increased active travel, may also exist. Further, some studies found that baseline MVPA was associated with MVPA after LRT construction suggesting that those who are already physically active prior to the construction of LRT are likely to be more active post-construction – it is not clear if there was a shift amongst the population who are previously inactive. Though these studies were natural experiments, self-selection may confound the results (i.e., those who are more active to begin to live in neighbourhoods that are the sites of LRT investments). It is important to note that switching from private vehicle to LRT may result in other health, economic, and societal benefits, even if it does not result in an increase in MVPA.

Very low evidence exists for the relationship between LRT and cycling behaviour. Few use bicycles as a station access/egress mode in cities with low overall cycling rates (Pucher & Buehler, 2009; Ravensbergen, Buliung, Mendonca, & Garg, 2018). Perhaps the studies included did not consistently capture a significant relationship between LRT and cycling behaviour because cycling participation is already low prior to LRT construction. Alternatively, cyclists may replace some of their cycling trips after an LRT is built or extended. Future work should examine whether stations in areas with higher cycling rates might exhibit a stronger relationship between physical activity from cycling and LRT use and/or proximity. The integration of cycling with public transit in cities dominated by the private automobile has been discussed as both a challenge and a great opportunity (Bachand-Marleau, Larsen, & El-Geneidy, 2011; Krizek & Stonebraker, 2010;

Ravensbergen et al., 2018). Challenges include the lack of built environment characteristics that support cycling such as bicycle lanes, high quality parking, or even station design that accommodates bicycles (e.g., elevators withs pace for bicycles, a train car devoted to bicycles, etc.) (Ravensbergen et al., 2018). Perhaps changes in cycling behaviour take longer to develop than walking behaviour as the neighbourhood and station changes that might be required to enable cycling behaviour may take several years to develop. Given that cycling is a healthy and environmentally friendly travel mode that extends station catchment areas when compared to walking and reduces parking costs when compared to driving (Ravensbergen et al., 2018), the very low certainty of evidence identified herein should not discourage planners from designing LRT stations to encourage cycling. Future studies that carefully examine the connection of LRT stations to the existing cycling network and available bicycle parking are needed to better understand the rationale behind low cycling rates.

A further three studies examined walking and/or cycling behaviours across different LRT stations. All found some evidence that walking behaviour varies across LRT networks. Though this literature is limited, the results highlight the importance of considering the built environment and design features at LRT stations. In other words, it is possible that not all LRT or LRT stops are created equal when it comes to encouraging physical activity. Past research has examined how station design influences, amongst other things, access to jobs (Lahoorpoor & Levinson, 2020) and accessibility for people living with disabilities (Unsworth, So, Chua, Gudimetla, & Naweed, 2019). More research on how LRT station design influences physical activity (for instance, see: Loutzenheiser (1997)) is recommended and urban planners and policy makers are encouraged to consider how the built environment and station design influence physical activity as they plan LRT.

Amongst the papers included in this review, strengths include the large number of studies using a natural experiment design to evaluate the introduction of a new LRT or LRT extension. Amongst cross-sectional studies, controlling for confounders, or comparing experimental groups to control groups was also common, however, only one study explicitly controlled for neighbourhood self-selection. Further, the use of both self-reported and device-measured physical activity data was complimentary providing both support for perceived behaviour, as well as movement intensity (Colley, Butler, Garriguet, Prince, & Roberts, 2018).

In terms of limitations, only one study included herein assessed physical activity at more than one time period after construction (Spears et al., 2017). Given that the association between LRT and physical activity was stronger after six months than after 18 months, there is a need for longitudinal research with repeated measure designs. Further, few studies reported measures of variation, including confidence intervals, for physical activity outcome increases, a best practice in the field of public health. Finally, few studies explicitly examined whether the physical activity outcomes associated with LRT are distributed equally, and no studies examine how these outcomes affect children, youth, or older adults. Therefore, more research that examines the equity implications of LRT on physical activity among different age groups is needed.

Several research protocols for the evaluation of LRT on physical activity were identified. Though protocols were excluded from the review, many show promise for informing the gaps identified in this review, such as whether the impact of LRTs are distributed equitably (e.g., Roberts, Hu, Saksvig, Brachman, and Durand (2018) and Durand et al. (2016)), as well as explicitly measuring the impacts of LRT on physical activity amongst youth (Roberts et al., 2018).

Taken together, this paper expands on past reviews examining the associations between public transport and health and Hirsch et al. (2018)'s meta-analysis on the relationship between rapid transit and physical activity. Given the heterogeneity in the reporting of the data, a comprehensive review of the association between LRT and physical activity is presented, rather than a meta-analysis. A moderate certainty of evidence for a positive association between LRT and walking is identified. Further, low certainty of evidence for the mixed associations with MVPA and very low certainty of evidence and a lack of statistically significant association between LRT and cycling, and walking and cycling behaviour combined was identified. Therefore, practitioners can be relatively confident that LRT investments will lead to changes in walking behaviour but should be cautious in assuming they will result in cycling or MVPA rates. There is a continued need for research examining the relationship between LRT and cycling behaviour, as well as experimental evidence with repeated measures that control for self-selection bias. Practitioners may also need to incorporate more considerations for cycling while planning for LRT by ensuring stations are accessible by safe bicycle infrastructure and include secure bicycle parking. Research examining whether the physical activity outcomes of LRT are distributed equitably, including how they impact different individuals and populations, such as children or older adults, as well as how physical activity varies across LRT stations would also contribute to the literature. Finally, while this paper provides practitioners with the certainty of the evidence between LRT and different types of physical activity, future work can compliment this review by replicating this analysis for different types of public transport or in different contexts. This would allow for comparison between the physical activity benefits of LRT and other modes, as well as those associated with LRT in car-oriented contexts compared to contexts more conducive to active travel.

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Appendix A: Database search strategy

Database	Limits	Search Terms	
		LRT	Physical Activity
Web of Science (n= 2266)	TS (topic)	“Light Rail Transit" OR "Light Rail" OR LRT OR "light metro" OR "Urban rail" OR subway OR metro	physical activit* OR exercise* OR walk* OR bik* OR cycl* OR bicycl* OR LMPA OR MVPA OR METS OR metabolic rate*
TRID (n= 184)	Title Search	Light Rail Transit OR Light Rail OR LRT OR light metro OR urban rail OR subway OR metro	physical activit* OR exercis* OR walk* OR bik* OR bicycl* OR cycl* OR LMPA OR MVPA OR METS OR metabolic rate*
Scopus (n= 2835)	Title, Abstract, Keywords	Light Rail Transit” OR “Light Rail” OR LRT OR “light metro” OR “Urban rail” OR subway OR metro	"physical activit*" OR exercise* OR walk* OR bik* OR cycl* OR bicycl* OR LMPA OR MVPA OR METS OR metabolic rate*
Medline (n=430)	Title, abstract, keyword heading	Light Rail Transit OR Light Rail OR LRT OR light metro OR Urban rail OR subway OR metro	physical activit* OR exercise* OR walk* OR bik* OR cycl* OR bicycl* OR LMPA OR MVPA OR METS OR metabolic rate*
SportsDiscus (n=151)	Title, Abstract, Keywords	Light Rail Transit OR Light Rail OR LRT OR light metro OR Urban rail OR subway OR metro	physical activit* OR exercise* OR walk* OR bik* OR cycl* OR bicycl* OR LMPA OR MVPA OR METS OR metabolic rate*

Web of Science (2266), TRID (184), Scopus (2835), Medline (430), SportsDiscus (151)

Appendix B. Cities with LRT Included in the Grey Literature Search

Country	City
Australia	City of Adelaide City of Melbourne City of Gold Coast City of Newcastle City of Sydney City of Canberra
New Zealand	City of Auckland (LRT under construction)
U.S.A.	City of Baltimore City of Boston City of Buffalo City of Charlotte City of Cleveland City of Dallas City of Denver City of Houston Jersey City City of Los Angeles City of Minneapolis City of Newark City of Norfolk City of Philadelphia City of Phoenix City of Pittsburgh City of Portland City of Sacramento City of St-Louis Salt Lake City City of San Diego City of San Francisco

	City of San Jose/ Santa Clara City of Seattle
Canada	City of Calgary City of Edmonton City of Kitchener- Waterloo City of Ottawa

Appendix C. Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies

Criteria Type	Criteria	Evaluation
Components Rating		
Selection Bias	(Q1) Are the individuals selected to participate in the study likely to be representative of the target population? 1 Very likely 2 Somewhat likely 3 Not likely 4 Can't tell (Q2) What percentage of selected individuals agreed to participate? 1 80 - 100% agreement 2 40 – 79% agreement 3 less than 40% agreement 4 Not applicable 5 Can't tell	Strong = Sample's socio-demographic characteristics are compared to the general population (e.g., through the census) and little discrepancy is identified OR 60% or more agreed to participate Moderate = Sample's socio-demographic characteristics are compared to the general population (e.g., through the census) and some discrepancy is identified OR use multiple data sources, some of which are highly representative (e.g., the census) OR representative sampling strategy Weak = No comparison to general population and very small sample (under 100)
Study Design	Indicate the study design Was the study described as randomized? No/Yes	Strong = Natural experiment design

	If Yes, was the method of randomization described? No/Yes If Yes, was the method appropriate? No/Yes	Moderate = Randomized cross-sectional design Weak = Cross-sectional design with no randomization
Confounders	(Q1) Were there important differences between groups prior to the intervention? 1 Yes 2 No 3 Can't tell The following are examples of confounders: Race, Sex, Marital status/family, Age, SES (income or class), Education, Health status, Pre-intervention score on outcome measure (Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)? 1 80 – 100% (most) 2 60 – 79% (some) 3 Less than 60% (few or none) 4 Can't Tell	Strong = Compared groups and found minimal differences Moderate = Compared groups and found some differences OR controlled well for confounders Weak = Did not compare groups OR did not control well for confounders
Blinding	(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants? 1 Yes 2 No 3 Can't tell (Q2) Were the study participants aware of the research question? 1 Yes 2 No 3 Can't tell	Strong = Authors state the participants were not aware of research question during data collection Moderate = Unclear whether participants were not aware of research question during data collection Weak = Paper states participants were aware of research question during data collection
Data Collection Methods	(Q1) Were data collection tools shown to be valid? 1 Yes 2 No 3 Can't tell (Q2) Were data collection tools shown to be reliable? 1 Yes	Strong = data collection tools result in measured data (accelerometry) Moderate = self-reported, but vigorous, survey

	2 No 3 Can't tell	Weak = Self-reported through poorly described survey OR data originate from different sources
Withdrawals and Drop-Outs	(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group? 1 Yes 2 No 3 Can't tell 4 Not Applicable (i.e. one time surveys or interviews) (Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest). 1 80 -100% 2 60 - 79% 3 less than 60% 4 Can't tell 5 Not Applicable (i.e. Retrospective case-control)	Strong = Withdrawal and drop-outs reported (numbers and reasons), minimal differences identified between withdrawals and sample Moderate = Withdrawal and drop-outs reported (numbers and reasons) with some differences identified OR 60% or more participants completed the study Weak = Withdrawals and dropouts not reported. Less than 60% completed the study Not applicable = all cross-sectional research designs
Intervention Integrity	(Q1) What percentage of participants received the allocated intervention or exposure of interest? 1 80 -100% 2 60 - 79% 3 less than 60% 4 Can't tell (Q2) Was the consistency of the intervention measured? 1 Yes 2 No 3 Can't tell (Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results? 4 Yes 5 No 6 Can't tell	Strong = Consistency of intervention measured (e.g., distance to LRT) AND no reason to believe participants received an unintended intervention beyond regular daily life Moderate = No reason to believe participants received an unintended intervention beyond regular daily life Weak = Reason to believe participants received an unintended intervention beyond regular daily life Not applicable = all cross-sectional research designs
Analyses	(Q1) What statistical methods are used? (Q2) Are the statistical methods appropriate for the study design?	Strong = Utilizes statistical modelling

	1 Yes 2 No 3 Can't tell	Moderate = Utilizes descriptive statistics Weak = Presents results with no statistical analysis or unclear analysis
Global Rating		
List all component Ratings		Strong = no 'weak' ratings on any component Moderate = one 'weak' rating on a component Weak = two or more 'weak' ratings on any components

Appendix D. GRADE Evaluation of Evidence Criteria

Domain	**Assessment**	**Score**	**Criteria**
Risk of Bias	No or little risk of bias	0	At least 75% of peer-reviewed papers scored moderate or strong on the following Risk of Bias Assessment indicators: Confounders, Blinding, Data Collection Methods, Withdrawals and Drop-Outs, and Intervention Integrity
	Moderate risk of bias	-0.5	50-74% of peer-reviewed papers scored moderate or strong on any of the following Risk of Bias Assessment indicators: Confounders, Blinding, Data Collection Methods, Withdrawals and Drop-Outs, and Intervention Integrity
	High risk of bias	-1	Less than 50% of peer-reviewed papers scored moderate or strong on any of Risk of Bias Assessment indicators: Confounders, Blinding, Data Collection Methods, Withdrawals and Drop-Outs, and Intervention Integrity
Inconsistency	No or little inconsistency	0	At least 75% of studies identify the same expected direction of effect (e.g., positive association between physical activity and LRT). In the case of only one study per outcome, inconsistency was not relevant.
	High inconsistency	-1	Less than 75% of studies identify the same expected direction of effect (e.g., positive association between physical activity and LRT)

Indirectness	Little concern	0	At least 75% of studies score strong or moderate on Selection Bias (i.e., how generalizable the results are Q1) in Risk of Bias Assessment
	High concern	-1	>75% of studies score strong on Selection Bias in Risk of Bias Assessment
Imprecision	No or little imprecision	0	Optimal information size at least 1000[1] for natural experiment OR 6500[2] for cross-sectional
	High imprecision	-1	Optimal information size under 1000 for natural experiment OR 6500 for cross-sectional
Publication Bias	No or little publication bias	0	Sample size is larger than 400[3] in 75% or more of studies that show expected associations
	Potential publication bias	-0.5	Sample size is less than 400 in 75% or more of studies
	High publication bias	-1	In at least 75% of studies, sample size is smaller than 400. Only cross-sectional studies show positive associations.
Original Level of Certainty	**Grade**		**Final level of certainty**
High	0.5 – 1 point deducted		Moderate
	1.5 – 2 points deducted		Low
	2.5+ points deducted		Very Low
	No points deducted		High
Low	Any points deducted		Very Low
	No points deducted and eligible for an upgrade		Moderate

[1]Based on recommendations in Guyatt et al. (2011)
[2]Threshold deemed reliable in the models developed by Zhang, Liu, Li, and Khattak (2021)
[3]Threshold derived from the "rule of thumb" for survey research, single topic in Daniel (2012)