Physical Activity Levels and New Public Transit: A Systematic Review and Meta-analysis

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Context: Physical inactivity is a public health concern as it contributes to the rising burden of non-communicable diseases. Introducing new public transportation options, such as extending or building new light rail or bus rapid transit stations, could encourage commuters to walk to and from public transit stops, thus increasing their physical activity levels. Despite previous research generally finding positive associations between public transit usage and physical activity levels, few have summarized the association between introducing new public transportation options and different intensities of physical activity. This study aimed to systematically review the current evidence and perform a meta-analysis on this association.

Evidence acquisition: Ten databases were systematically searched for studies published between 1997 and 2017. To ensure comparability, study outcomes were converted to MET hours/week. A random effects meta-analysis and sensitivity analysis were then conducted.

Evidence synthesis: Nine studies were identified to be included in the systematic review, of which five were eligible for meta-analysis. Pooled results suggest that building new public transit options is associated with a statistically significant increase in light to moderate physical activity levels by 1.76 MET hours/week (95% CI=0.19, 3.32, *p*=0.03). This is equivalent to increasing walking and other light to moderate physical activity by about 30 minutes per week, relative to baseline. No significant effect was found for the moderate to vigorous physical activity outcome.

Conclusions: Results show new public transit options can substantially contribute to increasing low- to moderate-intensity exercise levels, which has the potential to improve health on a population scale.
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CONTEXT

Physical inactivity is the fourth-leading risk factor linked to global mortality, leading to nearly 3.2 million deaths each year.[1] Although physical activity (PA) is beneficial, about a third (31%) of individuals worldwide aged 15 years and older did not reach the WHO-recommended level of regular PA in 2008.[2]

PA can be categorized into different intensities—light, moderate, vigorous, or in their various combinations, such as light to moderate PA (LMPA) and moderate to vigorous PA (MVPA). These activities are characterized by the amount of METs required to perform a specific PA. METs denote the energy cost of certain PAs, with higher MET values denoting more intense PA. For instance, one MET is the energy equivalent of a person seated at rest, whereas walking for transportation at 2.8−3.2 miles per hour (4.5−5.1 kilometer/hour) has a MET of 3.5. Light PA is defined as activity requiring less than 3 METs,[3] moderate PA is defined as activity requiring 3−6 METs,[4] and vigorous PA is defined as activity requiring more than 6 METs.[4] LMPA encapsulates lighter PA, such as walking for leisure or commute, whereas

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MVPA includes more intensive PA, such as cycling or running.

The WHO recommends at least 150 minutes per week of MVPA or 75 minutes per week of vigorous PA for adults aged 18−64 years, and 1 hour/day of MVPA for children aged 5−17 years.[5,6] Although WHO does not explicitly mention LMPA in their guidelines, LMPA does include moderate types of PA, such as brisk walking, emphasized by WHO as beneficial to health. Promoting LMPA (and the associated health benefits) may also be easier than more vigorous types of PA, as LMPA usually happens incidentally in daily living.[3]

In addition to various other benefits, public transit networks have the potential to positively impact the health of many individuals, given that two thirds of the world's population is projected to live in cities by 2050.[7] Indeed, studies have suggested that some features of the built environment, such as public transit, may increase uptake of PA.[8−10] Taking public transportation has also been associated with an increased probability that individuals will meet PA recommendations through walking.[11−15] For instance, public transit users were found to spend 5−33 more minutes walking per day than those who commute by car.[11,16−22] Moreover, public transportation use can lead to a better risk factor profile; MacDonald et al.[23] found that new light rail transit (LRT) users reduced their BMI by an average of 1.18 compared with non-LRT users over a 12- to 18-month period.

Three systematic reviews and one meta-analysis have examined effects of public transit on PA. One systematic review examined only cross-sectional associations between active travel and PA levels,[16] whereas the other two did not quantitatively assess changes in PA levels.[24,25] Finally, a recent meta-analysis by Hirsch and colleagues[26] reported an increase of 6.7 minutes/week (95% CI= −10.1, 23.5) of transit-related PA and a reduction of 80.4 minutes/week (95% CI= −157.9, −2.9) in what they called total PA (the sum of walking and cycling minutes/week). The study in this article differs from the study by Hirsch in several important respects. First, the intensities of different types of PA are considered, allowing one to ascertain whether these interventions facilitate meeting PA recommendations. For instance, Hirsch et al. used transit and total PA as their main outcomes, whereas this study focused on transportation-related PA, which was further categorized into LMPA and MVPA as the main outcomes. Second, the authors of the current study explicitly consider the actual (or potential) effect of these interventions on PA levels in both intervention and control groups, thus enabling a more robust difference-in-difference (DID) estimation approach. Third, a number of

sensitivity checks were conducted, which is important as additional assumptions were made to conduct the meta-analysis.

The aim of this study is to conduct a comprehensive systematic review and meta-analysis on the effectiveness of new public transportation options, such as LRTs, busways, and subways, in promoting different intensities of PA, while also taking into account the changes in the amount of PA in both intervention and control areas. The primary outcome examined is the amount of time people spend on LMPA and MVPA in minutes. To ensure inter-study comparability, this outcome was subsequently converted into a common measure of MET hours/week.

EVIDENCE ACQUISITION

Data Sources and Search Strategy

In July of both 2017 and 2018, ten databases were systematically searched, including CINAHL, Embase, Google Scholar, Ovid, PubMed Central, PsycINFO, PubMed, Science Direct, SPORT-Discus, and Web of Science. Search terms included (*LMPA* OR *MVPA* OR *cycl** OR *exercise* OR *walk** OR *physical activity*) AND (*public transportation* OR *mass transit* OR *public transit* OR *bus rapid transit* OR *intermodal transportation* OR *transitway* OR *busway* OR *light rail*) AND (*construction* OR *natural experiment*).

Inclusion and Exclusion Criteria

To be included, studies needed to fulfill the following eligibility criteria: (1) be published in the last 20 years, or between 1997 and 2018; (2) consider the effect of building, extending, or improving local public transit options; (3) measure as an outcome variable levels of PA in minutes, steps, or distance per set period of time; (4) have relevant comparison groups; (5) have an RCT, longitudinal, quasi-experimental, or a before-and-after study design; (6) report pre- and post-PA levels, change in PA in at least the intervention group, or differences between the intervention and control group with corresponding 95% CIs and SDs; and (7) be written in English. Studies that fulfilled all inclusion criteria and had results that could be pooled with other studies were included in the meta-analysis.

Risk of Bias

The Effective Public Health Practice Project was used to evaluate study quality.[27] This tool has been used for public health research, including public health intervention studies.[28,29] Study quality was determined based on six criteria: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Of the nine included studies, all were rated moderate in the study design dimension as they were observational studies (Appendix Table 1, available online). Most studies had issues with selection bias, low study participant recruitment, and dropouts; in several studies, however, the confounders dimension was rated as strong either because there were no important differences between groups prior to the intervention or they controlled for confounders (Appendix Table 1, available online).

Statistical Analysis

Although nine potentially relevant studies were identified in the systematic review (Appendix Table 2, available online),[30−37,40] only five were eligible for meta-analysis because of the lack of comparable study outcomes and study design duplication.[32,34−36,40] When two studies were found to examine the same population and intervention, only the most recent one was included in the meta-analysis. Because the outcome variable differed between studies, they were all converted based on the WHO PA guidelines or the 2011 Adult Compendium of Physical Activities[4,38] into a standard outcome variable, or MET hours/week (Appendix Table 3 [available online] provides more information about conversion factors).[a] Time was converted into LMPA if the study reported walking activity, and into MVPA if the study reported cycling activity,[32,35,40] whereas two other studies directly reported on either LMPA or MVPA.[34,36] When studies reported both LMPA and MVPA outcomes, results for each outcome were considered as an independent study. LMPA and MVPA outcomes were stratified when conducting the meta-analysis to determine if public transit affects these two PA levels differently. Extracted data from the studies included number of participants, study duration, and the mean and SD of number of minutes spent on LMPA and MVPA for both intervention and control groups.

A DID analysis was conducted to determine the overall intervention effects along with their SEs and CIs.[39] Studies provided either already weighted DID estimates,[36] or pre- and post-intervention data (which were transformed into DID estimates) for both intervention and control groups.[32,34,35,40] Appendix Text 1 (available online) provides more information about the estimation methodology.

To calculate the differences in PA levels over time, the intervention and control groups were defined for each study. Most studies (four of five) used distance from new public transit stops as a measure of exposure, with the median catchment area being 0.7 kilometers (range, 0.4−30 kilometers).[32,34,35,40] Thus, those who lived within these areas were considered the intervention group, whereas those who lived beyond these areas were the control group. The only exception was the study by Miller et al.,[35] where the intervention group was considered to be new public transit riders (those who did not ride public transit the first year) and the control group was continuing riders (those who rode public transit both years).

The results of five studies[32,34−36,40] were pooled together to estimate a summary effect size along with its 95% CI for both LMPA and MVPA. The "metan" package was used in Stata, version 14.0, to create a meta-analysis model, which places more weight on studies with larger sample sizes. A less restrictive random effects estimator was used. Study heterogeneity was calculated by using a visual inspection of the forest plots and the I^2 statistic. Publication bias was then examined using a funnel plot and the Egger test using the "metabias" Stata package.

Sensitivity Analysis

The robustness of the findings was assessed by conducting several sensitivity checks. Specifically, studies that were considered to have a weak cumulative score or global rating as determined by the Effective Public Health Practice Project tool were removed. Furthermore, studies that had <1 year of follow-up were removed in a separate sensitivity analysis to allow for sufficient time for traveling habits to form and to account for seasonal effects. In addition, a fixed effects analysis was conducted. Finally, two meta-regressions were run to test any potential effect on the PA effect size produced by modifying either the follow-up length or the catchment area.

EVIDENCE SYNTHESIS

Search Strategy and Study Identification

In the first round, the titles and key words of 2,640 studies were screened according to the criteria outlined above (Figure 1). The screening excluded a large proportion of duplicate studies (*n*=713), which left 1,946 studies to be screened by title. A total of 241 studies were left to be screened through their abstracts. A further 144 studies were excluded, leaving 97 full texts to be examined. There were 88 studies ineligible because of various reasons, such as no relevant intervention (*n*=30); no relevant outcome (*n*=30); reviews that were used for references (*n*=22); studies that were inaccessible (*n*=3); protocol papers (*n*=2); or the study design was duplicated in another published study (*n*=1). Nine studies were considered for the qualitative analysis, of which five were included in the quantitative meta-analysis. The remaining four studies either duplicated another study's study design and population or reported the outcomes in medians or IQRs, which could not be pooled together with the other studies. It is also worth noting that the Foley and colleagues[40] study intervention is described in a report of a larger series of studies examining a new bus rapid transit (BRT) system.[41]

Qualitative Review

All nine studies eligible for systematic review were published between 2013 and 2017 and included subjects from the U.S. (*n*=5); United Kingdom (*n*=2); Canada (*n*=1); and Mexico (*n*=1; Appendix Table 2, available online).[30−37,40] All studies had a quasi-experimental longitudinal before-and-after research design. Follow-up time between baseline and post-intervention surveys varied between 5 months and 2 years (mean=13.89 months, SD=6.17). There was a total of 4,249 subjects included in both pre and post phases of the studies, and sample sizes varied greatly, from 71 to 2,487 subjects (mean=472.11, SD=783.41). Interventions included adding LRT stations to extend existing LRT systems,[30,31,34−36] or adding BRT lines.[32,33,37,40]

In all reviewed studies, the outcomes were measured in either minutes per day or per week. The majority (*n*=6) assessed PA duration and intensity using a combined sensor (Actiheart) or accelerometers (GT1M or
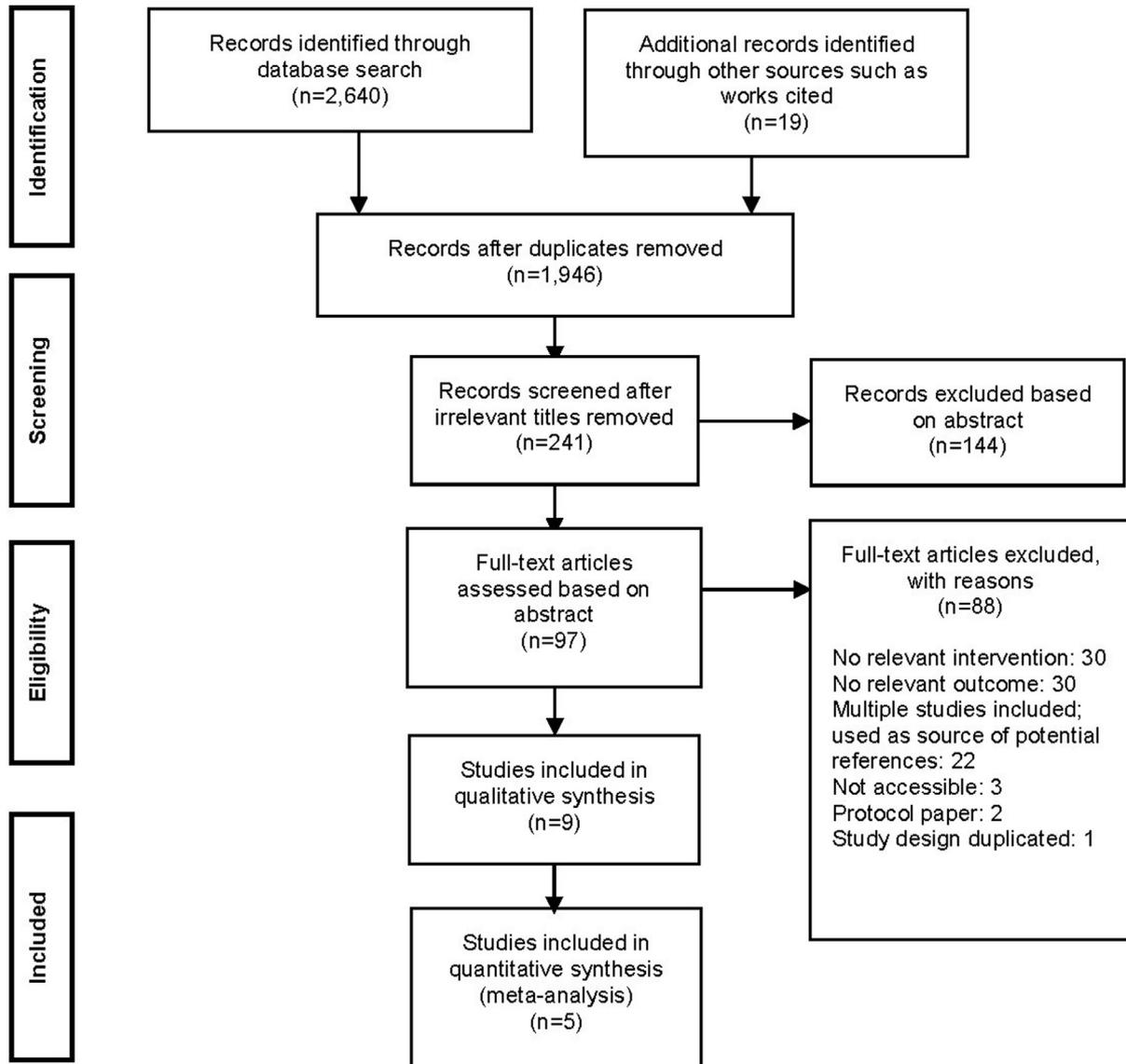
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[a]Formally, 1 MET is equal to the cost of oxygen consumption while sitting quietly, or 3.5 mL O$_2$/kg /min. More intuitively, 1 MET of energy spending is equal to 1 kilocalorie/kilogram/hour.

Figure 1. Systematic review search strategy.

GT3x+, Actigraph) along with GPS loggers (GlobalSat DG-100),[30,31,34−36,40] whereas the remainder used self-reported data collected from surveys (*n*=3).[32,33,37] All studies using GPS and accelerometer devices collected PA data for 1 week after the end of the follow-up period.

Intervention Effects by Intensity of Exercise
In some studies, the effect on both LMPA and MVPA was reported.[30−32,34,35,37,40] Eight of nine studies selected for systematic review reported one of the LMPA-associated measures as an outcome.[30−33,35−37,40] Walking time was one of the most prevalent outcomes. All studies found a positive effect of new public transportation options on time spent in PA, though not all were statistically significant. Two studies in the United Kingdom

found an insignificant increase in LMPA.[37,40] Of the three studies examining the construction of new LRT stops in the U.S., one found an insignificant increase in the number of walking minutes compared with before the intervention[30]; the significance of the change in time spent on PA in the other two articles was not reported.[31,35] Another study conducted in the U.S. found that living closer to the new transit station was significantly associated with increased walking and PA among individuals who had previously low walking and PA levels.[34] In Canada, introducing three new express transit service routes significantly increased transit ridership from 5.5% to 8.5% (*p*<0.001) among university employees, with transit riders—defined as those who walk to and from the bus stop—accumulating an average of

50 minutes/week of commute-related PA more than those who commuted entirely passively.[33] In Mexico, introducing a new BRT line increased the walking duration for individuals living closer to the intervention by almost 30 minutes/week.[32]

Of the studies reporting MVPA outcome estimates, cycling was one of the most prevalent forms of MVPA. Two studies found a statistically insignificant negative effect of increasing public transit access on MVPA.[34,40] One of the studies did find, however, that when controlling for baseline MVPA levels, there was a significant increase in activity for participants who had previously low levels of MVPA living closer to the station, compared with those who already had high levels of MVPA, suggesting potential effect modification.[34] The five remaining studies found a positive effect, though only two found statistically significant results.[31,37]

Four studies found through the systematic review were not included in the meta-analysis because of the limitations of study design and incompatibility of outcome measures reported with the other studies in the meta-analysis. For instance, Collins and Agarwal[33] did not report a baseline PA measure to be able to compare with post-intervention results. Panter and colleagues[37] found that individuals increased their cycling time by a median of 10 minutes. However, from a statistical standpoint, it is not possible to pool this median with the mean values reported in other studies without additional information about the distribution of the study sample. The studies by Brown et al.[30] and Miller and colleagues[31] had nearly identical study designs and subjects, differing mainly in the estimation approach. Likewise, studies by Boarnet et al.[35] and Huang and colleagues[36] had nearly identical designs and subjects, with only the outcome measures being different. Of these four studies, only the studies by Miller et al.[35] and Huang and colleagues[36] were included in the meta-analysis model as they are more recent. Thus, a meta-analysis was conducted on five eligible studies,[32,34−36,40] with some studies reporting independent LMPA and MVPA outcomes (Table 1).[32,35,40]

Table 1 and Figure 2 presents the overall effect of introducing new public transportation options on either LMPA or MVPA. All LMPA studies exhibited positive

Table 1. Meta-Analysis Results

Study	Physical activity type	Effect size minutes/week (95% CI)	Effect size MET hours/week (95% CI)	SE	% Weight	I²	*p*-value
Light to moderate physical activity outcome							
Chang et al. (2017)[32]	Walking for transport and/or recreation	38.05 (18.50, 57.60)	2.22 (1.08, 3.36)	0.58	16.28	—	—
Foley et al. (2015)[40]	Walking	0.90 (−17.29, 19.09)	0.05 (−1.01, 1.11)	0.54	16.81	—	—
Huang et al. (2017)[36]	Station area walking	34.30 (−10.08, 78.68)	2.00 (−0.59, 4.59)	1.30	8.22	—	—
Miller et al. (2015)[35]	Light to moderate physical activity	56.84 (17.85, 95.82)	3.55 (1.12, 5.99)	1.23	8.83	—	—
Subtotal random effects pooled effect size			**1.76* (0.19, 3.32)**	—	50.13	73.60%	0.03
Moderate to vigorous physical activity outcome							
Chang et al. (2017)[32]	Cycling for transport	3.48 (−3.91, 10.87)	0.39 (−0.44, 1.23)	0.43	18.26	—	—
Foley et al. (2015)[40]	Cycling	−10.90 (−36.53, 14.73)	−1.24 (−4.14, 1.67)	1.47	7.09	—	—
Hong et al. (2016)[34]	Moderate to vigorous physical activity	−0.32 (−5.47, 4.83)	−0.04 (−0.59, 0.52)	0.28	19.84	—	—
Miller et al. (2015)[35]	Moderate to vigorous physical activity	46.69 (10.99, 82.39)	5.06 (1.19, 8.92)	1.95	4.68	—	—
Subtotal random effects pooled effect size			0.33 (−0.71, 1.38)	—	49.87	61.60%	0.53
Overall random effects pooled effect size			**1.06* (0.12, 2.01)**	—	100.00	74.10%	0.03

Note: Boldface indicates statistical significance (*p*<0.05; **p*<0.01; ***p*<0.001).
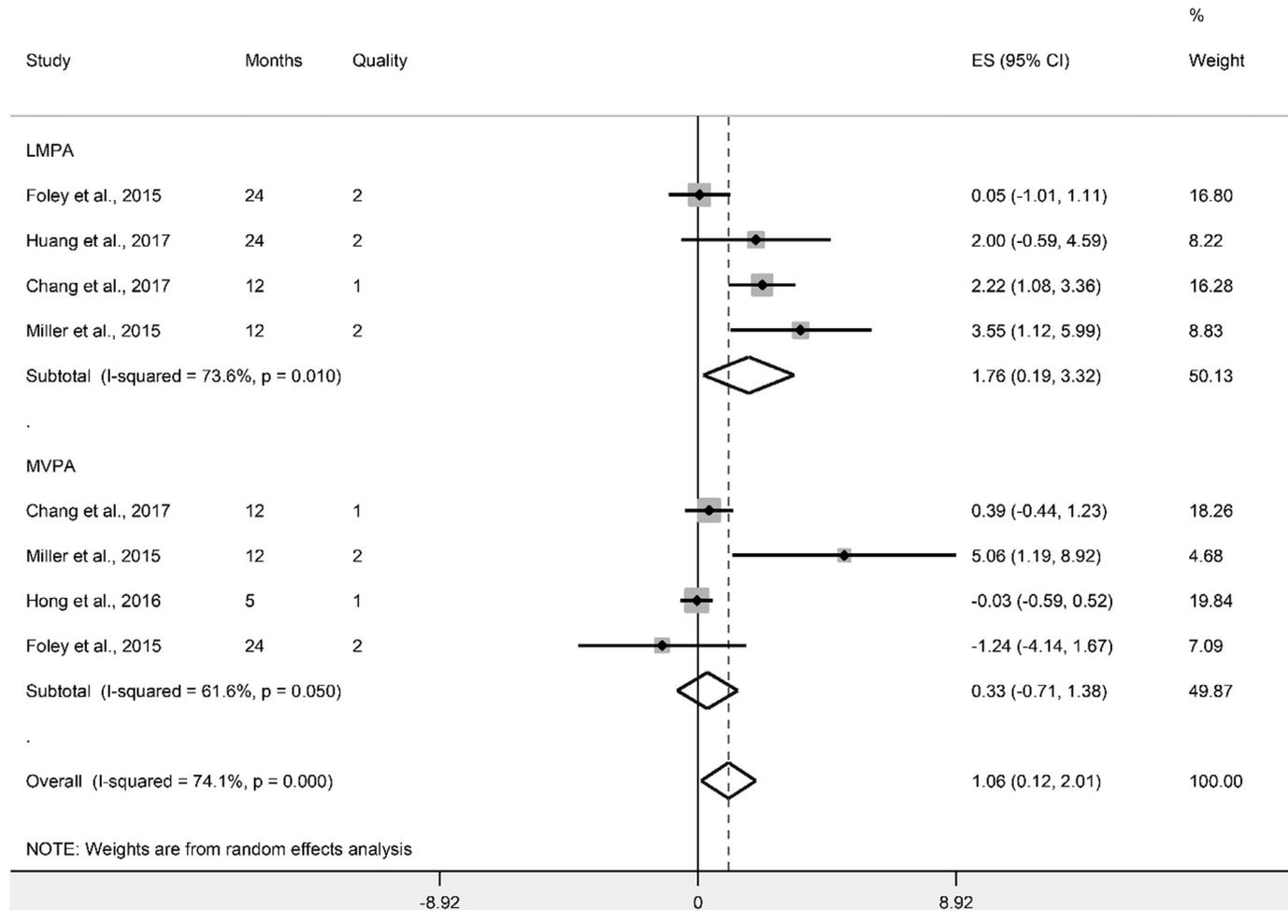
Figure 2. Forest plot of natural experiment studies with light to moderate physical activity outcomes (MET hours/week) after transit interventions.

Note: Quality refers to the global rating of the study quality as determined in Appendix Table 1 (available online), with 1 denoting "Weak" and 2 denoting "Moderate." The overall pooled effect is positive and statistically significant (1.062 MET hours/week; 95% CI=0.116, 2.009; *p*=0.028). This finding was mainly driven by the statistically significant effect of introducing public transportation options on light to moderate physical activity (1.757 MET hours/week; 95% CI=0.190, 3.324; *p*=0.028). The pooled effect size for the moderate to vigorous physical activity studies was not statistically significant (0.332 MET hours/week; 95% CI= −0.712, 1.377; *p*=0.533).

Table 2. Sensitivity Analysis of Studies

Sensitivity test/physical activity type	Effect size (95% CI)	Significance
None (studies=5)		
Light to moderate physical activity	1.757 (0.190, 3.324)	0.028
Moderate to vigorous physical activity	0.332 (−0.712, 1.377)	0.533
Overall	1.062 (0.116, 2.009)	0.028
Only moderate-quality studies[34,36,37] (studies=3)		
Light to moderate physical activity	1.653 (−0.598, 3.904)	0.150
Moderate to vigorous physical activity	1.777 (−4.385, 7.939)	0.572
Overall	1.623 (−0.358, 3.604)	0.108
Studies with at least a 1-year follow-up[32,34,36,37] (studies=4)		
Light to moderate physical activity	1.757 (0.190, 3.324)	0.028
Moderate to vigorous physical activity	0.998 (−1.616, 3.612)	0.454
Overall	1.380 (0.216, 2.545)	0.020
Fixed effects (studies=5)		
Light to moderate physical activity	1.342 (0.631, 2.054)	0.000
Moderate to vigorous physical activity	0.133 (−0.322, 0.589)	0.566
Overall	0.485 (0.101, 0.868)	0.013

effects, two of which were statistically significant,[32,35] whereas only one study had a statistically significant effect in the MVPA category.[35] The overall pooled effect was positive and statistically significant (1.06 MET hours/week, 95% CI=0.12, 2.01, *p*=0.03), but there was evidence of heterogeneity (I^2 =74.10%, $P_{heterogeneity}$=0.000; Appendix Table 4, available online). The increase in PA was mainly driven by the statistically significant effect of introducing public transportation options on LMPA (1.76 MET hours/week, 95% CI=0.19, 3.32, *p*=0.03). Some evidence for heterogeneity was observed for LMPA studies (I^2 =73.60%, $P_{heterogeneity}$=0.01; Appendix Table 4, available online). The pooled effect size for the MVPA studies was statistically insignificant (0.33 MET hours/week, 95% CI= −0.71, 1.38, *p*=0.53; Appendix Table 4, available online).

The Egger test of the null hypothesis of no small-study effects for LMPA and MVPA was 0.82 and 0.68, respectively (Appendix Figure 1, available online). Thus, it can be assumed that smaller studies did not exhibit different or larger treatment effects than larger studies. Moreover, the funnel plot suggests little evidence for publication bias, though because of the small number of articles included, bias results should be treated with caution (Appendix Figure 2, available online).

Sensitivity Analysis

Table 2 presents results from the sensitivity checks based on quality of study, follow-up duration, and fixed effects assumption. Including only moderate-quality studies (Appendix Table 1, available online) as indicated by the risk of bias global rating decreased the LMPA effect size and increased the MVPA effect size from 0.332 to 1.777.

This resulted in a nonsignificant LMPA and overall pooled effect, whereas the MVPA pooled effects remained nonsignificant. When studies were restricted to those with >1 year of follow-up, one study was removed from the MVPA group (and none from the LMPA group), which did not change the significance of the effect size. Using a fixed effects meta-analysis model, none of the pooled groups changed significance. Furthermore, results from meta-regressions between PA effect size and either study follow-up length or catchment area (Appendix Table 2, available online) showed no significant differences (*p*=0.446 and 0.312, respectively; Appendix Table 5, available online).

DISCUSSION

This systematic review and meta-analysis demonstrated that constructing new public transit options is likely to result in a sizeable increase in the amount of LMPA performed, but not for MVPA performed. Specifically, this meta-analysis has shown that in response to the introduction of new public transit options, public transit users could increase their PA levels (averaged over LMPA and MVPA) by 1.06 MET hours/week and by 1.76 MET hours/week for LMPA.

The WHO recommends performing at least 150 minutes of moderate PA. From the assumption that LMPA activities are performed, on average, at the lower bound of energy expenditure for moderate activities (MET=3.0), the findings from this study show an increase of about 35 minutes, or approximately one fifth of the WHO recommendation. Because such an increase would be in addition to the amount of PA already

undertaken, individuals can substantially benefit from increased access to public transit. Furthermore, switching from car to public transit use can have a number of other benefits, such as improvements in psychological well-being,[42] reduction in traffic-related air pollution, better air quality, and subsequent improvements in respiratory health outcomes.[43]

The results for the MVPA outcome were not significant, which may be due to the fact that individuals are more likely to walk than to cycle to public transit stops—in part because cyclists need appropriate cycling infrastructure, such as bicycle parking or lockers. At the same time, this finding suggests that isotemporal substitution is unlikely to be an issue: Although people may compensate for walking more to travel to public transportation stops by reducing their other types of PA, the results in this study found that although LMPA increases, MVPA did not decrease. This is corroborated by another study that found positive associations between time spent on leisure PA and active transportation time.[44]

In one systematic review on a similar topic, Rissel et al. found that public transit users gain 8−33 more minutes of walking per day (56−231 minutes of LMPA per week) than car riders.[16] The estimates found in this meta-analysis are at the lower end of this range; this may be because the values in the range given by Rissel and colleagues are based on cross-sectional studies, which are less likely to identify causal effect.

The meta-analysis by Hirsch and colleagues[26] found an insignificant increase in transport-related PA, though they combined walking and cycling activities into one time measure. Thus, the current study provides additional information on changes in energy expenditures separately for LMPA and MVPA dimensions, likely to be causally attributed to the introduction of new public transportation options.

This study has several strengths. First, the number of articles included in the meta-analysis was maximized by converting all outcomes into a single measure of PA or MET hours/week. Second, all the studies reviewed were longitudinal and of natural experimental design, and therefore more likely to identify causal effect, compared with studies that compare PA levels cross-sectionally. Third, the pooled effect was estimated separately for LMPA and MVPA outcomes, and therefore took intensity of the exercise into account. Fourth, the majority of studies included used objective means of reporting PA, with only one study using the self-reporting International Physical Activity Questionnaire (IPAQ). Lastly, several sensitivity checks were conducted to take into account the effect on findings of study quality, length of follow-up, catchment area, and fixed effect analysis. The

findings were also robust to a range of assumptions on the within-group correlation coefficient (Appendix Table 6, available online).

Limitations

One of the limitations of this meta-analysis was the number of studies that could be included; thus, conclusions drawn from this study should be treated with caution. Furthermore, only observational studies could be included, which may be subject to some degree of bias resulting, for example, from nonrandom assignment of transport infrastructural investments.[b] However, this was unavoidable because of the nature of the intervention. On the positive note, results from such studies are more likely to be indicative of real-world policy applications.

Other limitations included the inability to perform a country-specific analysis because of a limited number of studies. Studies also had different lengths of follow-up, with catchment areas varying between 400 m and 30 km. However, as seen in the meta-regression between PA effect size and either follow-up length or catchment area, there were no significant differences between studies (Appendix Table 5, available online). In one study,[36] intervention and control catchment areas were defined as people living within 0.25 and 0.75 −1 miles away from the new mass transit stations, respectively. However, the control catchment area may still include people who are affected by the station proximity, for which the effect of the new transportation infrastructure may be underestimated. Furthermore, intervention and control groups in the Miller et al. study should be treated with caution as they were not as clearly defined as in the other selected studies, and because the study compared new and existing transit users before and after the introduction of the intervention.

In some studies, additional features such as new bike lanes or sidewalks were also included,[35,37,40] which makes it more difficult to attribute the estimated effect exclusively to the construction of new public transit. Furthermore, the effect sizes could have differed depending on the number of stops added, whether there was existing public transit infrastructure, and whether new infrastructure was well connected to places of interest in the city. However, such information was either unavailable or impossible to take into account in the meta-analysis.

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[b]For example, wealthier areas may be more likely to receive such investments. If prior trends in average PA levels differ between poorer and richer areas (because people living in the latter may have healthier lifestyles), then DID estimates may be confounded if such trends are not controlled for.

Although almost all the reviewed studies collected objectively measured PA information, one study in the meta-analysis used self-reported data from surveys, such as the IPAQ,[32] which often correlate strongly with walking but overestimate moderate PA trip duration compared with more objective activity monitors, such as GPS.[45,46] However, this study did not report a particularly outlying result. Finally, when outcome measures were in minutes per day, the same level of PA was assumed for every day of the week, which may not always be accurate because individuals have different work and leisure PA habits on different days of the week.

CONCLUSIONS

This systematic review and meta-analysis found that public transit interventions can increase PA levels by up to one fifth of the recommended PA levels by the WHO. Further investigations using high-quality research designs are needed, particularly studies that improve subject retention with longer follow-up to allow commuting habits to form, as well as studies with well-defined and comparable intervention and control areas from a wider selection of countries.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found, in the online version at https://doi.org/10.1016/j.amepre.2018.10.022.

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