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Evidence synthesis

Where are children and adults physically active and sedentary? – a rapid review of location-based studies

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Abstract

Introduction: Geographical positioning systems (GPS) have the capacity to provide further context around *where* physical activity (PA) and sedentary time (ST) are accrued especially when overlaid onto objectively measured movement. The objective of this rapid review was to summarize evidence from location-based studies which employed the simultaneous use of GPS and objective measures of PA and/or ST.

Methods: Six databases were searched to identify studies that employed the simultaneous use of GPS and objective measures of PA or ST to quantify location of movement. Risk of bias was assessed, and a qualitative synthesis completed.

Results: Searching identified 3446 articles; 59 were included in the review. A total of 22 studies in children, 17 in youth and 20 in adults were captured. The active transportation environment emerged as an important location for moderate-to-vigorous intensity physical activity (MVPA) in children, youth and adults. In children and youth, the school is an important location for MVPA, especially the schoolyard for children. Indoor locations (e.g., schools, homes) appear to be greater sources of lighter intensities of PA and ST. The review was limited by a lack of standardization in the nomenclature used to describe the locations and methods, as well as measures of variance.

Conclusion: Evidence suggests that the active transportation environment is a potentially important contributor of MVPA across an individual's lifespan. There is a need for future location-based studies to report on locations of all intensity of movement (including minutes and proportion) using a whole-day approach in larger representative samples.

Keywords: *motor activity, sedentary time, location, built environment, active transportation*

Highlights

- The active transportation environment is an important location for physical activity in children, youth and adults.
- Among children and youth, the school (especially the schoolyard) is an important location for physical activity.
- Indoor locations (e.g., schools, homes) appear to be greater sources of lighter intensities of physical activity and sedentary time.

Introduction

Greater physical activity (PA) and lower sedentary time (ST) have been shown to independently play a role in the prevention of chronic conditions (e.g., cardiovascular disease, diabetes, obesity and cancer).[1,2] While the importance of these health behaviours is largely acknowledged, the majority of children and adults do not meet current PA guidelines and spend most of their days engaged in sedentary behaviour.[3-5] Further, PA levels decline with age, and sex differences in PA are often observed.[6,7] The built environment refers to our physical surroundings and includes for example parks, workplaces, schools, active transportation infrastructure, and homes among many others. The built environment has been associated with levels of PA and ST.[8,9]

Much of the evidence around the relationship between the built environment and PA/ST has come from cross-sectional studies which obtain contextual information (e.g., presence of parks in the neighbourhood) from either self-report perceptions of environment or by using geographical information systems (GIS) and associations with movement (largely based on self-report).[10-12] While this information can provide an assessment of environmental exposure, it cannot always infer direct causality for *where* an individual's behaviour actually occurs. Context-specific patterns of movement refer to movement that occurs within specific domains or locations. Context-specific studies have examined behaviours which occur in locations such as neighbourhoods[13] or parks[14] through direct observation or mapping and can provide detailed information about what parts of the environment individuals interact with (e.g., paths within a park, play structures, etc.). However, these studies are often limited to one location/domain and can be time and resource intensive to conduct.

The advent of newer technologies to track an individual's location such as geographic

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positioning systems (GPS) have the capacity to provide further context around *where* PA and ST are accrued.[15-17] Additionally, the overlay of GPS onto objectively measured movement data allows for a more robust quantification of behaviour within locations and has the capacity to provide a more comprehensive picture of an individual's activity space.[18] Providing greater context can facilitate a better understanding of the locations in which behaviours are undertaken and whether they differ across the life span and between sexes. The objective of this review was to identify and summarize evidence from location-based studies which employed the simultaneous use of GPS and objectively measured PA or ST.

Methods

A rapid review was employed; the protocol was prospectively registered with PROSPERO (see: https://www.crd.york.ac.uk/prospero/; #CRD42018084640). A rapid review employs general systematic review methodology but allows modifications for a quicker time to publication. This rapid review employed systematic review methodology but relied upon a single screener and data abstractor with support from data verification checks.

Criteria for considering studies for this review

Population

Data from high-income Organization for Economic Co-operation and Development (OECD) countries[19] and apparently healthy populations were included. Findings were grouped into children (3–11 years), youth (12–17 years) and adults (≥ 18 years).

Exposures

The review included studies that used GPS information to objectively identify location of movement behaviour. GPS technologies included the Global Navigation Satellite System to determine location, direction and speed of the device.[20] For the purpose of the review, active transportation was included as a location term to define the location of behaviours that were specific to transportation, that weren't reflected by other locations (e.g., journey from home to school).

Outcomes

Studies must have used an objective measure of movement including pedometers, heart rate monitors and accelerometers to define time spent sedentary, time spent in light intensity physical activity (LPA), in moderate intensity physical activity (MPA) and in vigorous intensity physical activity (VPA).

Study design

Observational (prospective cohort, cross-sectional and case-control) and experimental (randomized controlled trials, pre-post and quasi-experimental) studies were included. Reviews and qualitative studies were excluded.

Publication status and language

Only publications in English or French, and published studies and indexed dissertations were eligible.

Search strategy

A comprehensive search strategy was developed in collaboration with two research librarians. The following six bibliographic databases were searched: Ovid MEDLINE(R) In-Process (1946 to January 5, 2018); Ovid EMBASE (1974 to January 5, 2018); Ovid PsycINFO (1806 to January Week 1, 2018); EBSCO CINAHL (1982 to January 5, 2018); EBSCO SportDISCUS (1830 to November Week 2, 2017); and, ProQuest Dissertations & Theses Global (1743 to January 5, 2018). The search strategy used for MEDLINE is included in Table 1. Bibliographies of key review papers were also searched.

Selection of studies

Articles were imported into RefWorks (RefWorks, Bethesda, MD, USA) and, after removal of duplicates, exported to Microsoft Excel for screening. A single reviewer (SAP) screened the titles, abstracts and full texts of all studies. In the event that the reviewer was unsure, a co-author (GPB) was consulted.

Data extraction and analysis

Data abstraction forms were completed in Microsoft Excel by one reviewer (SAP) and a random 10% sample verified by another (AM). Information extracted included: publication details (author, year, location); sample size; study design; participant characteristics (age, sex, population); data collection period (e.g., seven days of wear); GPS monitor; movement monitor and cut-points (e.g., ST < 100 counts/minute); locations assessed (e.g., home, work, school, transportation, park); outcome assessed (e.g., ST, LPA, moderate-to-vigorous intensity physical activity [MVPA], steps); and, description of outcome.

Due to heterogeneity in reporting outcomes across studies and lack of reporting on variance, the review uses a qualitative synthesis. Insufficient data was available to examine differences by level of socio-economic status, location cost or by country. Sex differences are discussed where available.

Risk of bias appraisal

The risk of bias of individual studies was assessed using a modified version of the *Cochrane Collaboration's Tool for Assessing Risk of Bias.*[21] Studies were assessed for potential biases including: selection bias

TABLE 1
Ovid MEDLINE search strategy

#	Searches	Results
1	("global positioning" or "gps" or "geographic information system?" or "GIS" or Garmin or Qstarz or Geostats or NAVSTAR).tw,kf.	32 312
2	Geographic Information Systems/	7 617
3	1 or 2	34 947
4	(acceleromet* or inclinomet* or pedomet* or stepscount or piezo* or yamax or "digiwalker*" or "digi walker*" or "digi-walker*" or lifecorder* or accusplit or actigraph or actical* or actimet* or actiheart* or bodymedia or geneactiv* or activinsights or fitbit* or polar* or omron).tw,kf.	249 142
5	exp Accelerometry/	6 695
6	Monitoring, Ambulatory/	8 147
7	((activity or exercise or step? or move*) adj3 (monitor* or track* or count*)).tw,kf.	31 451
8	or/4-7	285 476
9	3 and 8	945

(sampling methods); performance and detection bias (measurement issues); attrition bias (incomplete follow-up and > 10% missing data), selective reporting bias (selective/incomplete reporting, rated high if secondary data analyses); and other possible sources of bias (i.e., inadequate adjustment for sex and wear time).

Results

Description of studies

Figure 1 provides details of the literature search and screening process. Of the 3446 originally identified citations, 945 were identified in MEDLINE, 953 in EMBASE, 619 in PsycINFO, 207 in CINAHL, 260 in SPORTDiscus, 459 in Dissertations and Theses, and 3 from other sources. A total of 59 studies met the eligibility criteria. Study characteristics and findings are presented in Table 2. The review includes studies published over a 13-year period (2005 to 2017) and conducted in 12 countries with the majority from the United States (US) and the United Kingdom (UK); three were Canadian. The most widely used GPS and activity monitor devices were the QStarz Q-1000XT and ActiGraph, respectively. The most common locations included: home, school, workplace, active transportation, parks/playgrounds, and green spaces. Many locations were defined using buffers around the centre of an address (e.g., 50 m around home). MVPA was the most studied behaviour. There are a total of 22 studies in children,[22-43] 17 in youth[44-60] and 20 in adults.[28,61-79] Sample sizes ranged from 12 to 1053; 39% were small (N ≤ 100).

Risk of bias assessment

Risk of bias results are summarized in Figure 2. Just over half of the studies had a high risk of selection bias as many included convenience samples. About a quarter had no description of how the study sample was derived. The majority had a low risk of performance and detection bias since they mostly employed GPS technology overlaid using GIS and used accelerometers with valid cut-points to define ST, LPA and MVPA. However, some studies had a high risk of performance bias as there was potential for misclassification of location based on the decisions of coders and/or the use of 'buffers' to define spaces. Slightly less than half of the studies had a high risk of selective reporting; many conducted secondary analyses for which the primary objective of the study was not to examine location of movement. Finally, most studies had a high risk of 'other' bias which included the lack of adjustment for wear time and sex in analyses.

Location-based findings for children (3-11 years)

The most commonly reported locations in the child studies were: homes, schools, parks, active transportation, and streets/roads. Results suggest that the active transportation and school environments are important locations for MVPA, while the home environment is less of a contributor.

Many studies focussed on movement patterns within specific sub-sets of environments rather than total-day movement. For example, several studies examined or reported exclusively on time spent in travel to-and-from school.[26,32,34,41] In these studies, a substantial proportion of time (31-37%) spent commuting to school was spent in MVPA[26,34] and contributed to 11-22% of total MVPA (especially among walkers).[32,41] Children who walked to school tended to live closer than those who use passive modes of transit.[26]

FIGURE 1
Flow diagram of the literature search and screening process

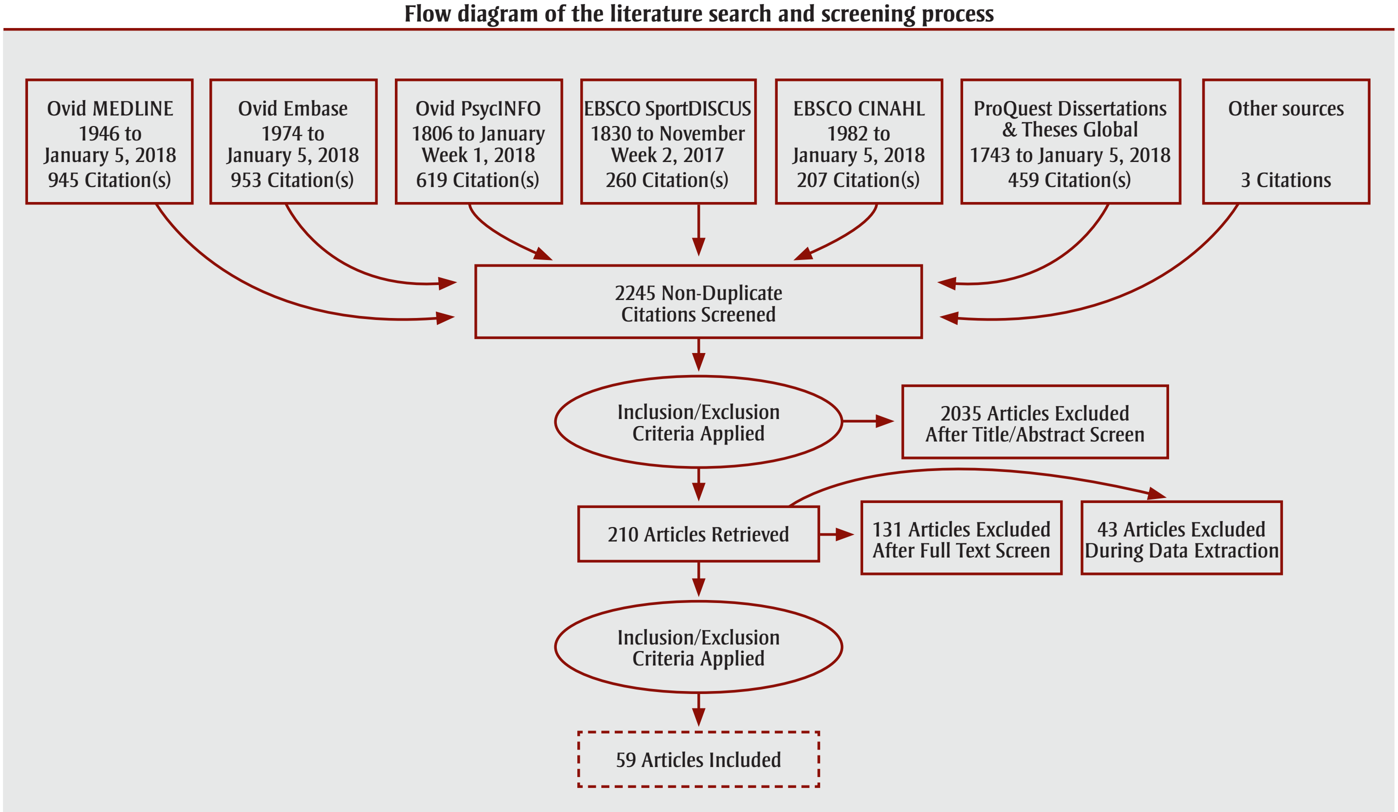

TABLE 2
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Children							
Almanza, 2012[22]	USA, Healthy PLACES	208 (51–54%)	8–14	ActiGraph GT2M/GloblSat BT-335, 7 days	MVPA (> 500 cpm, continuous)	Home (30 m buffer) and NB (500 m buffer) greenness (vegetation using NDVI data)	**ST** • Often occurred in the home. **MVPA** • Often occurred in proximity to green areas. • Children that experienced > 20 min/day of green space had almost 5 times more MVPA.
Burgi, 2016[23]	Switzerland NR	83 (48%)	8.5 (0.3), 7–9	ActiGraph GT3X/ BT-QStarz Q1000XT, 7 days (median 12.6 h/day)	ST (< 101 cpm), MVPA (≥ 2296 cpm, continuous)	Home (30 m buffer), own school (10 m buffer*), other school (10 m buffer*), sports facilities (10 m buffer*), streets (10 m buffer*), public parks and playgrounds (10 m buffer*), other (others' home, shopping, restaurants), outside urban area * = drawn around the polygons	**Median weekly minutes (IQR) and proportion (IQR) of time per location spent sedentary:** • Home = 529.7 (255.0–798.5) and 60% (52.4%–64.5%) • Own school = 597.7 (509.0–731.7) and 51.7% (47.8%–56.6%) • Other school = 46.7 (4.7–87.3) and 41.2% (30.8%–55.1%) • Park = 15.7 (1.7–57.8) and 37.6% (25.9%–52.2%) • Sport = 8.5 (0.0–52.2) and 42.5% (21.3%–62.4%) • Street = 234.5 (173.3–378.2) and 46.0% (39.9%–49.7%) [may be a result of motorized transport] • Other = 206.5 (130.5–304.2) and 50.3% (43.4%–58.0%) • Outside = 26.5 (0.0–129.8) and 52.5% (42.0%–68.2%) • The locations with the most time spent sedentary were the home (60.0%), own school (51.7%) and outside (52.5%). **Median weekly minutes (IQR) and proportion (IQR) of time spent in MVPA in each location:** • Home = 57.3 (32.2–91.8) and 6.3% (4.8%–9.3%) • Own school = 121.5 (86.2–184.3) and 10.0% (8.1%–13.4%) • Other school = 13.0 (3.3–28.2) and 15.4% (7.1%–23.8%) • Park = 9.3 (1.5–29.5) and 17.3% (7.2%–25.8%) • Sport = 4.3 (0.3–21.3) and 15.4% (5.9%–33.1%) • Street = 90.5 (56.0–127.0) and 15.7% (11.7%–19.7%) • Other = 42.5 (24.7–78.7) and 11.1% (7.8%–15.6%) • Outside = 3.3 (0.0–19.5) and 8.4% (3.2%–16.1%) **Proportion of total weekly MVPA:** • Own school = 30.8% • Streets = 21.4% • Home = 15.2%

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Cerin, 2016[24]	USA, NR	66 (42%)	4.5 (0.8)	ActiGraph GT3X/QStarz Q100X, 1 week (average wear time NR)	ST (< 152 cpm), MVPA (≥ 1680 cpm, continuous)	Home (30 m buffer), childcare/school/daycare (30 m buffer), park/playground (30 m buffer), other without outdoor play area (30 m buffer), other with outdoor play area (30 m buffer). All locations include indoor and outdoor time.	**Proportion of time per location (SD) spent sedentary:** • Home = 45% (50%) • Other locations in apartment complex = 32% (47%) • Other residential home = 41% (49%) • Childcare/school/daycare = 51% (50%) • Childcare/school/daycare in enrolled children only = 51% (50%) • Park/playground = 24% (43%) • Other without outdoor play area = 47% (50%) • Other with outdoor play area = 49% (50%) • Indoors = 46% (50%) • Outdoors = 43% (50%) • In vehicle = 64% (48%) • Children less likely to engage in ST outdoors vs. indoors.
							Proportion of time per location (SD) spent in MVPA: • Home = 12% (33%) • Other locations in apartment complex = 15% (35%) • Other residential home = 13% (34%) • Childcare/school/daycare = 8% (27%) • Childcare/school/daycare in enrolled children only = 7% (26%) • Park/playground = 30% (46%) • Other without outdoor play area = 9% (29%) • Other with outdoor play area = 9% (29%) • Indoors = 11% (35%) • Outdoors = 14% (35%) • In vehicle = 2% (15%) • Children most active in parks/playgrounds and least active in childcare/school settings. • Children more likely to engage in MVPA outdoors vs. indoors.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Coombes, 2013[25]	UK, SPEEDY	100 (53%)	9–10	ActiGraph GT1M/Garmin Forerunner 205, 4 non-school days (i.e., holidays and included 2 weekend days)	ST (≤ 100 cpm), LPA (101–1999 cpm, continuous), MPA (2000–3999 cpm, continuous), VPA (≥ 4000 cpm, continuous), MVPA (≥ 2000 cpm, continuous), MVPA (5 min bouts)	Beaches, woodland, grassland, farmland, parks, domestic gardens (home yard), roads and pavements, other built land use, buildings. Identified using land-use datasets; each GPS data point was assigned a land use category based on the land parcel it fell within.	**Proportion of total daily LPA:** • Buildings = 24.1% • Domestic gardens = 29% (26 min per day) • Roads/pavement = 13.2% **Proportion of total daily MPA:** • Buildings = 20% • Domestic gardens = 27% (7 min/day) • Roads/pavement = 11.8% **MVPA** • Differences in the percentage contributions of land uses to MVPA were observed when bout and non-bout activity compared: significantly greater percentage of non-bout activity undertaken in buildings (*p* < .001, 21.5% vs. 6.9%), equating to +5 min/day; other built land use (*p* = 0.015, 15.7% vs. 10.6%), equating to +3 min/day; domestic gardens (*p* < .001, 29.2% vs. 20.6%), equating to +6 min/day. • Significantly greater percentage of bout activity undertaken on roads and pavements compared to non-bout activity (*p* < .001, 17.1% vs. 9.1%) = 36-second difference. **Proportion of total daily VPA:** • Buildings = 17.9% • Domestic gardens = 31% (4 min per day) • Roads/pavement = 9.1% **Sex differences** • Boys spend more time in domestic gardens, roads/pavement and farmland vs. girls.
Cooper, 2010[26]	England, PEACH Study	137 (66%)	11.3 (0.3)	ActiGraph GT1M/Garmin Foretrex 201, 2 days of combined wear; between 8:00 and 9:00 a.m.	MVPA (> 3200 cpm, continuous) during journey to school	AT (journey to school – identified as points outside of playground polygon), school playground (polygon drawn around playground)	**MVPA** • MVPA levels during journey were significantly higher vs. playground (2131.3 vs. 1089.7 cpm, p < .001). • One third of journey time was spent in MVPA (1.6 min, 30.8%), remaining time spent on playground (0.6 min or 10.0% in MVPA). • Children who walked to school more active compared to those who travelled by car. • Shorter linear distance to school in walkers (0.5 miles) vs. car (0.9 miles) and bus (1.12 miles) users.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Dessing, 2013[27]	Netherlands, SPACE study	76 (58%)	8.6 (1.4), 6–11	ActiGraph GT1M/ QStarz BT-1000X, 7 days (average wear time of 11.2 h/day)	MVPA (> 2296 cpm, continuous)	Schoolyard (10 m buffer of schoolyard polygon), school building (points during class time), outside school environment (> 10 m buffer around school)	**Daily minutes (SD) and proportion (SD) of time per location spent in MVPA:** • **Boys**: schoolyard = 8.8 min (5.1) and 27.3% (12.7%) • **Boys**: inside school = 4.9 min (5.2) and 2.1% (2.1%) • **Girls**: schoolyard = 7.0 min (5.1) and 16.7% (10.4%) • **Girls**: inside school = 7.1 min (8.2) and 2.8% (3.2%) • Very small proportion of time inside school was spent in MVPA. **Proportion of total daily MVPA:** • Children most active on schoolyard during recess though children only present in schoolyard for 6% of time and contributed to 17.5% and 16.8% of boys' and girls' MVPA time. **Sex differences** • Boys are more active on the schoolyard vs. girls especially during recess.
Dunton, 2013[28]	USA, NR	291 (53%)	11.2, 8–14	ActiGraph GT2M/ GlobalSat BT-335, 7 days (mean = 4.5 days with 310.8 min/day of matched parent-child pairs)	Parent-child ST (< 100 cpm) and MVPA (age-specific thresholds using 4 METs)	Residential (500 m buffer around home neighbourhood, e.g., houses, apartments, condos), commercial (e.g., retail stores, restaurants, personal services, private health club/gym, motels), open space (e.g., parks, gardens, wildlife preserves), educational (e.g., schools), public facilities (e.g., government, health care, religious, libraries, community centres), other (e.g., roads, water)	**Proportion of total parent-child ST:** • Residential = 76% • Commercial = 10% • Open space = 8% • Educational = 2% • Public facilities = 3% • Other = 1% • Parents and children spent 92.9 (SD = 40.1) min/day engaged in ST together. **Proportion of total parent-child MVPA:** • Residential = 35% • Commercial = 24% • Open space = 20% • Educational institutions = 14% • Public facilities = 7% • Mixed/other land uses = 1% • Parents and children spent 2.4 (SD = 4.1) min/day engaged in MVPA together.
Dunton, 2014[29]	USA, Healthy PLACES	135 (50%)	8–14	ActiGraph GT2M/ GlobalSat BT-335, 7 days (average wear time NR)	MVPA (age-specific thresholds ≥ 4 METs)	Parks (within 500 m radial buffer, included national, state, county, city parks and forests)	**MVPA** • Only 27% used a NB park; of those with extended park use (> 15 min), 58% engaged in ≥ 15 min of MVPA within the park space. • Those with extended use engaged in a median of 44.3 min (IQR: 8.5, 163.5) of MVPA per week in the park space. • Park proximity related to use.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Eyre, 2014[30]	England, NR	64 (53%)	7–9	Garmin Forerunner 305, 4 days (including 2 weekend days; average wear time = 388 ± 179 min)	MVPA (≥ 50% heart rate reserve)	School (indoors and outdoors: school field, school playground, school indoors), home, AT (not defined), indoors (house, other building and school), outdoors (green space and non-green space)	**Proportion of total MVPA:** • School = 43% • Playing outside (street/garden) = 23% • Home = 20% • AT = 14% • Time spent in MVPA indoors greater on weekdays vs. weekends (41 ± 30% vs. 17 ± 20%, p = .01). **Proportion (SD) of time per location spent in MVPA:** • Outdoors = 59% (45%) • Indoors = 27% (27%)
							Sex differences • Girls spent less time outdoors on weekdays vs. weekends (32% vs. 54%). • Boys spent more time outdoors on weekdays vs. weekends (41% vs. 33%). • No significant sex differences in percentage of time indoors or in green space.
Jones, 2009[31]	England, SPEEDY	100 (53%)	9–10	ActiGraph GT1M/Garmin Forerunner 205, 4 days (boys: 11.1 ± 2.2 h/day, girls: 10.0 ± 3.2 h/day of wear time)	MVPA (5 min bouts, ≥ 2000 cpm)	Inside (≤ 800 m pedestrian network around home), outside NB (> 800 m network), buildings (domestic residences, shops, indoor sports facilities, covered structure), other built land use, roads and pavement, gardens (private), parks, farmland, grassland, woodland, beaches	**Average total minutes (SD) and proportion of MVPA over 4 days:** • Inside NB = 24.9 (30.1) or 62.5% • Outside NB = 14.9 (25.7) • Buildings = 2.8 (6.0) • Other built land use = 5.5 (10.7) • Roads and pavement/street = 7.5 (11.7) • Gardens = 9.6 (16.5) • Parks = 2.9 (10.0) • Farmland = 5.4 (14.8) • Grassland = 4.7 (12.7) • Woodland = 1.2 (2.8) • Beaches = 0.2 (1.7) • Children who spent more time outside were more active. • Among urban children, gardens (28%) and streets (20%) were most commonly used for MVPA bout time. • Among rural children, farmland (22%) and grassland (18%) most frequently used. • Gardens and street environment supported greatest amount of MVPA.
							Sex differences • Boys had higher proportion of MVPA outside NB vs. girls (p = 0.05), girls had more inside NB.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Lee, 2014[32]	USA, Why and Why Nots of Active Living	112 (51%)	9.5, 7–12	ActiGraph GT1M or GT3X/Garmin Forerunner 203, 7 days (minimum 8 h/day)	MVPA (≥ 4 METs) total continuous	Home-school trips (AT); walkers (walk to/from school at least once a week, live within ½ mile of school and parents reported distance walkable); captive walkers (walk to/from, distance > ½ mile or parents reported distance too far); non-walkers (did not walk to/from school)	**MVPA** • School trips account for an average of 6.9 (10.1) min/day or 11.1% of total daily MVPA. • Among those who walked to school, trip MVPA contributed to 13.7 (11.8) min/day or 21.8% (18.8%) of total MVPA vs. 1.4 (1.9) min/day or 2.4% (3.2%) in those using other forms of travel. • 'Walkers' had 9.0 min/day of trip MVPA (16.1% of total MVPA) vs. 'captive walkers' (longer distance) had 19.9 min/day (29.4% of total MVPA). • All walkers had 12 more min/day vs. non-walkers (13.7 vs. 1.4 min/day, $p < .001$). • Walking to school is a meaningful source of MVPA, especially for those who are less active overall. • Majority of trips were motorized and mixed modes; walking and bicycling accounted for 29.1% and 4.7% of trips, respectively. **Sex differences** • No significant difference by sex.
Mackett, 2007[33]	UK, CAPABLE Study	82 (57%)	8–11	RT3/Garmin Foretrex 201, 4 days (2 week and 2 weekend days)	PA intensity using continuous activity counts (no cut-points used)	Road (e.g., roads, tracks or paths) vs. open space (e.g., public open space: parks, fields, woods)	• Children walked faster, straighter and with more intensity on the road vs. open space.
McMinn, 2014[34]	Scotland, NR	39 (31%)	8.5, 8–9	ActiGraph GT1M/Trackstick Super, 1 journey home from school	MVPA during AT from home to school (> 2296 cpm)	AT (vehicle transport identified as speeds > 25 km/h excluded), location from home to school: green space; other natural; road/track/path; other human-made	**MVPA** • 37.1% of children's time spent actively commuting to school was in MVPA. • AT via road/track/path associated with greater MVPA. • No significant assoc. between green space and MVPA during commute, but travelling via other natural land uses resulted in lower MVPA. **Proportion of total AT time within each separate land-use category spent in MVPA:** • Green space = 36.7% • Other natural = 17.6% • Road/track/path = 41.5% • Other human-made = 35.0%
Moore, 2014[35]	England, NR	28 (61%)	11.8, 11–14	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (average 10.0 ± 2.7 h/day)	MVPA (≥ 2220 cpm, in bouts of ≥ 3 min)	Home, school, street, rural/urban green space defined by researcher using Google Maps	**Minutes (SD) of daily MVPA:** • School = 40.2 (35.1) • Streets = 28.1 (43.8) • Home = 11.8 (18.2) • Rural/urban green = 4.8 (14.5)
O'Connor, 2013[36]	USA, NR	12 (40%)	4.7 (0.8), 3–5	ActiGraph GT3X/QStarz BT 100X, NR	Activity counts/30 seconds, continuous	Home, other home, store, restaurant, church, community center, park, other locations (all used 100 m buffer)	• Church and parks were significant predictors of greater activity accounts vs. child's home. • Children spent significantly more time at home vs. other locations.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Oreskovic, 2012[37]	USA, NR	24 (58%)	11–12	ActiGraph GT1/ Forerunner 201, 7 days including 2 weekend days	MVPA (≥ 1952 cpm, continuous)	Home (25 m buffer), school (within 100 m from school perimeter), car, indoor/other (non-home or school), park/playground (incl. outdoor rec space), street/walking (all coded by GIS specialist)	**Minutes (proportion) of total MVPA:** • Home = 670 (33.5%) • Indoors/other = 114 (5.7%) • School = 169 (8.4%) • Park/playground = 217 (10.8%) • Street/walking = 833 (41.6%) **Seasonal differences** • Proportion of total MVPA higher at home in winter (43.1%), in streets/walking in spring (43.8%) and in parks/playgrounds in summer (57.4%).
Pearce, 2014[38]	UK, PEACH Study	427 (54%)	10.7 (0.5), 10–11	ActiGraph GT1M/ Forerunner 201, 7 days (3:00 p.m.–10:00 p.m. on weekdays)	MVPA (≥ 2296 cpm, continuous)	Indoors vs. outdoors after school	**Minutes (SD) and proportion of total daily after school MVPA:** • Girls outdoors = 4.3 (6.4) min and 19.8% • Boys outdoors = 4.6 (7.1) min and 18.4% • Who the child was with had an impact; indoors = mom/dad, outdoors = friends.
Pizarro, 2017[39]	Portugal, SALTA Project	374 (54%)	11.7 (0.9)	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days	MVPA (≥ 2296 cpm; 5 min bouts)	Leisure, school (polygon using Google Maps), transport (≥ 100 m buffer with average speed ≥ 1.5 km/hr), home (25 m buffer)	**Proportion of total MVPA:** • Transportation (i.e., trips to/from school) = 45.5% • School = 30.5% • Leisure = 21.3% • Home = 2.7% **Proportion of time per domain spent in MVPA:** • Leisure = 7.9% • School = 12.0% • Transport = 18.9% • Home = 4.1% **Sex differences** • For MVPA, the most important contributors were transport domain in girls and leisure domain for boys. • Girls spent significantly more time in transportation (29%) vs. boys (26%). • Girls achieved more of their MVPA time in transportation (54.5% vs. 35.2% in boys), boys achieved more MVPA in school than girls (37% vs. 24.7%).
Quigg, 2010[40]	New Zealand, CALE Study	184 (54%)	7.6, 5–10	ActiGraph GT1M/ GlobalStat DG-100, 7 days (≥ 5 h/day)	PA (accelerometer counts)	Parks/playgrounds (within park boundaries)	**Physical activity** • 1.9% of all PA was located within a city park. **Sex differences** • PA was higher in city parks for boys vs. girls.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Southward, 2012[41]	England, PEACH Study	84	11–12	ActiGraph GT1M/Garmin Foretrex 201, school journey on 4 days	MVPA (≥ 2296 cpm, continuous)	AT: path from home to school and back (within 200 m of home and school)	**Minutes and proportion of total daily MVPA:** • 22.2 min/day or 33.7% (each journey contributed 16%–18% of daily MVPA) • No difference in MVPA between the journey to and from school. **Proportion of AT time spent in MVPA:** • ~50% **Sex differences** • MVPA on journey no different between boys and girls, but journeys contributed a greater proportion to daily MVPA for girls (35.6%) vs. boys (31.3%).
Van Kann, 2016[42]	Netherlands, Active Living Study	257 (53%)	8–11	ActiGraph GT3X/QStarz BT-Q1000XT, 5 days (minimum of 5 min/school yard period)	ST (> 101 cpm), MVPA (> 2295 cpm, continuous)	Schoolyard (10 m Euclidian buffer)	**Minutes (SD) and proportion of total daily ST:** • Schoolyard = 20.2 (12.0) min/day and 4.1% – they spent an average of 54 min/day in school yard. **Minutes (SD) and proportion of total daily MVPA:** • Schoolyard = 8.7 (6.3) min/day and 18.3% **Sex differences** • Boys had more MVPA (10.5 min, 19.2% daily MVPA) vs. girls (7.2 min, 17.6%) in schoolyards. • No significant sex difference for ST.
Wheeler, 2010[43]	UK, PEACH Study	1053 (53%)	10–11	ActiGraph GT1M/Garmin Foretrex 201, 4 days (after school only)	MVPA (≥ 3200 cpm, continuous)	Indoors vs. outdoors not green space vs. outdoors in green space vs. outdoors out of area	**Minutes (SD) and proportion of total daily MVPA:** • Green space = 8.6% boys and 6.1% girls • Outdoors not in green space = 24.5% boys and 26.1% girls • Outdoors out of area = 2.9% boys and 2.8% girls • Indoors = 64.1% boys and 65.0% girls **Proportion of time per location spent in MVPA:** • Outdoors in green space = 24.2% boys and 17.7% girls • Outdoors not green space = 18.5% boys and 16.4% girls • Outdoors out of area = 8.9% boys and 7.4% girls • Indoors = 5.0% boys and 4.0% girls • Youth spent majority of time indoors. • Time in green space more likely to be spent in MVPA vs. outdoor 'other' space. • Green spaces important for supporting more intense PA, but majority of time spent outside of these spaces. **Sex differences** • Odds of engaging in MVPA in green space vs. outdoor non-green space higher in boys vs. girls.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Youth							
Andersen, 2017[44]	Denmark, NR	Baseline 354, post-renewal: 319	13.2 (1.18), 11–16	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (~13 h/day)	ST (≤ 100 cpm), LPA (101–2295 cpm), MVPA (> 2295 cpm, continuous)	In-district time pre-post urban renewal project which included 4 new urban green spaces/ playgrounds and renovation of large public park	**ST** • Adjusted differences in time spent within district between baseline and post-renewal = +13.1 min/day (95% CI: 1.9–28.2, p = 0.043). **LPA** • Adjusted differences in time spent within district between baseline and post-renewal = +7.8 min/day (95% CI: 1.1–14.7, p = 0.012). **MVPA** • Adjusted differences in time spent within district between baseline and post-renewal = +4.5 (95% CI: 1.8–7.2, p < .001).
Burgi, 2015[45]	Switzerland, NR	119 (57%)	12.5 (0.4), 11–14	ActiGraph GT3X/ BT-QStarz Q1000XT, 7 days	MVPA (≥ 2296 cpm, continuous)	Home (30 m buffer), own school (all school property, 10 m buffer), other school, recreation facility (public parks and sports facilities, 10 m buffer), street (10 m buffer), other (others home, shopping, restaurants), outside urban area	**Median weekly minutes (IQR) and proportion of total daily MVPA:** • Home = 34.0 (18.5–59.0) • Own school = 74.7 (51.2–108.3) and 26.8% • Other school = 3.7 (0.3–29.0) • Recreation facility = 4.7 (0.3–19.8) • Street = 94.3 (57.0–143.7) and 34.5% • Other = 25.2 (14.3–39.2) • Outside = 0.0 (0.0–4.2) • School grounds = 33% **Median proportion (IQR) of time per location spent in MVPA:** • Home = 3.0% (1.9%–4.2%) • Own school = 8.6% (5.8%–11.7%) • Other school = 19.2% (8.5%–33.2%) • Recreation facility = 19.4% (6.1%–33.6%) • Street = 18.6% (12.3%–26.9%) • Other = 7.1% (4.9%–10.1%) • Outside = 5.2% (2.3%–12.7%) • The proportion of time spent in MVPA at recreation facilities was greatest, but less frequently visited. **Sex differences** • Boys obtain significantly more MVPA time outside vs. girls. • Boys get significantly more MVPA on other school grounds and at own school vs. girls.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Carlson, 2016[46]	USA, TEAN Study	549 (50%)	14.1 (1.4), 12–16	ActiGraph 7164 or 71256 or GT1M or GT3X/GlobalSat DG-100, 7 days	MVPA (≥ 2296 cpm, continuous)	Home (50 m buffer), near home (1 km street network buffer), school (15 m buffer), near school (1 km street network buffer), other locations	**Minutes (SD) and proportion of total daily MVPA on school days:** • Home = 5.5 (6.6) and 13.1% • Near home = 5.4 (9.2) and 12.9% • School = 23.2 (15.0) and 55.2% • Near school = 2.4 (4.3) and 5.7% • Other locations = 5.5 (9.0) and 13.1% • All locations = 42.0 (22.5) **Minutes (SD) and proportion of total daily MVPA on non-school days:** • Home = 12.0 (14.1) and 37.4% • Near home = 6.8 (11.6) and 21.2% • School = 0.6 (11.6) and 1.8% • Near school = 1.7 (4.9) and 5.3% • Other locations = 11.0 (15.4) and 34.3% • All locations = 32.1 (21.8) **Minutes (SD) and proportion of total daily MVPA (weighted week):** • Home = 7.4 (7.4) and 18.7% • Near home = 5.9 (9.0) and 15.0% • School = 16.7 (10.9) and 42.4% • Near school = 2.2 (3.8) and 5.6% • Other locations = 7.2 (8.6) and 18.3% • All locations = 39.4 (20.1) • Although more MVPA achieved at school, relative to the proportion of time spent at school it is low. • % of location time spent in MVPA lowest at school and highest near home and near school.
							Sex differences • Girls had fewer min/day of MVPA at all locations except near school.
Collins, 2015[47]	England, NR	75 (49%)	13–14	HR monitor/ Garmin Forerunner 305, 4 school days (after-school hours)	MVPA (> 120 bpm, > 140 bpm)	Commute from school to home	**Minutes (SD) and proportion of total daily MVPA:** • Active commuting = 11.7 (13.8) min and 35% (> 120 bpm) • Passive commuting = 3.5 (5.7) min and 18% • Commute distance was significantly lower among active vs. passive commuters (0.95 vs. 3.38 miles). • No significant difference in leisure-time MVPA between active and passive commuters, therefore, active commuting is an important contributor to overall PA levels.
							Sex differences • No significant sex differences in active vs. passive commuters MVPA.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Geyer, 2013[48]	Scotland, GAG Study	27 (52%)	13–15	ActiGraph/ GPS-enabled Blackberry, 6–7 days	ST (< 1100 cpm), LPA (1100–3200 cpm), MVPA (> 3200 cpm, continuous) during leisure time	Green space (natural environments in urban spaces)	**Proportion of total daily MVPA:** • Green space = 8% total PA, 11% of leisure time MVPA • Median of 9 min/day or ~1 hr/week spent in green space. **Proportion of time per location spent in MVPA:** • Green space = 51.5% in LPA + MVPA; 19.8% in MVPA • Non-green space = 18.3%
Klinker, 2014[49]	Denmark, WCMC Study	367 (52%)	13.2 (1.2), 11–16	ActiGraph GT3X/QStarz BT-1000X, 7 days (mean 2.5 days, median 12.7 h/day)	MVPA (≥ 2296 cpm, continuous)	School grounds (address), clubs, sports facilities (if offered activities for 10–16-year-olds; address), playgrounds (address), urban green space (geodata), shopping centers (address), other places, school, recess (using school schedule), physical education (using school schedule), transport, home (10 m buffers)	**Median minutes (IQR) of total daily MVPA (boys):** • Playgrounds = 0.0 (0.0–0.5) • During AT = 10.3 (5.6–15.6) • Physical education = 19.5 (9.8–34.8) • In sports facilities = 0.2 (0.0–4.8) • Urban green space = 1.9 (0.5–4.4) • School grounds = 2.8 (1.5–7.3) • Recess = 8.3 (5.9–12.3) • Passive transport = 0.3 (0.0–4.1) • Home = 4.8 (2.3–10.3) • Shopping center = 0.0 (0.0–0.0) • Other places 5.0 (2.6–11.3) **Median proportion of time per location spent in MVPA (boys):** • Playgrounds = 35.4% • During AT = 34.7% • Physical education = 25.8% • In sports facilities = 24.3% • Urban green space = 23.8% • School grounds = 20.7% • Recess = 15.8% • Passive transport = 15.5% • Home = 3.4% • Shopping center = 6.1% • Other places = 3.2% **Median minutes (IQR) of total daily MVPA (girls):** • Playgrounds = 0.0 (0.0–0.3) • During AT = 9.6 (4.5–16.2) • Physical education = 14.4 (8.0–23.5) • In sports facilities = 0.0 (0.0–0.5) • Urban green space = 1.5 (0.3–3.6) • School grounds = 2.2 (1.3–4.3) • Recess = 6.0 (3.7–8.8) • Passive transport = 0.2 (0.0–3.5) • Home = 6.5 (3.0–12.8) • Shopping center = 0.0 (0.0–0.0) • Other places = 4.1 (2.2–7.8)

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
							Median proportion of time per location spent in MVPA (girls): • Playgrounds = 20.7% • During AT = 31.3% • Home = 3.6% • Urban green space = 17.1% • Physical education class = 16.6% • School grounds = 12.5% • Clubs = 9.5% • Sports facilities = 13.2% • Shopping center = 2.4% • Recess = 10.7% • Passive transport = 9.6% • Other places = 2.6% • Children accumulated more MVPA primarily via school vs. adolescents. **Sex differences** • Boys accumulated more MVPA in leisure, school and transport vs. girls, $p < .05$.
Klinker, 2014[50]	Denmark, WCMC Study	170 (51%)	11–16	ActiGraph GT3X/QStarz BT-1000X, 7 days (≥ 9 h/day)	Outdoor MVPA (≥ 2296 cpm, continuous)	School grounds (10 m buffer), clubs (10 m buffer), sports facilities (10 m buffer), playgrounds (10 m buffer), urban green space (10 m buffer), shopping centers (10 m buffer), other places (10 m buffer), school (10 m buffer), recess (school schedule), physical education (school schedule), transport (active vs. passive), home (10 m buffer)	**Proportion of total daily MVPA:** • Outdoors = 73.8% boys and 65.3% girls **Median minutes (IQR) of total daily outdoor MVPA:** • School grounds = 2.5 (1.2–6.2) • Clubs = 0.0 (0.0–0.2) • Sports facilities = 0.0 (0.0–0.7) • Playgrounds = 0.0 (0.0–0.3) • Urban green space = 1.8 (0.8–8.3) • Shopping centre = 0.0 (0.0–0.0) • Other places = 1.0 (0.4–2.5) • Recess = 5.5 (3.5–8.9) • Physical education = 11.3 (1.8–25.0) • Active transport = 8.3 (3.5–14.6) • Passive transport = 0.4 (0.0–4.2) • Home = 2.3 (0.5–6.8) • Children spent a larger proportion of MVPA outdoors during school hours and recess. • Most daily outdoor MVPA accumulated at school location. **Sex differences** • Girls obtained less of their MVPA outdoors vs. boys.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Lachowycz, 2012[51]	England, PEACH Study	902 (53%)	weekday evenings: 12.0 (0.39), weekends: 12.1 (0.40), 11–12	ActiGraph GT1M/Garmin Foretrex 201, 5 days	Weeknight and weekend day ST (< 100 cpm), LPA (100–2296 cpm), MVPA (≥ 2296 cpm, continuous)	Indoors vs. outdoors, green space, parks (all types, park –formal [organized layout, well-maintained], park-informal [informal recreation], park-natural [provide access to nature including heathland, woodland and wetland], park-sports [area used for organized and competitive sports; e.g., playing fields and tennis courts], park-young persons [designed for use by children and youth including play and game equipment]), private gardens (green space around the home), school grounds (grassland around school), other green space (vegetated areas not otherwise defined including private sports and recreation facilities, cemeteries, golf courses, gardens of publicly accessible buildings), roads/ pavement, green verges (small fragmented vegetation/grass land e.g., centres of roundabouts and strips alongside pavement) , built surfaces	**Minutes (SD) and proportion of total daily ST (3–10 pm of weekday):** • Indoors = 195.7 (90.8) min and 92.5% • Outdoors = 14.5 (28.8) and 7.0% **Minutes (SD) and proportion of total daily outdoor ST (3–10 pm of weekday):** • Green space = 6.0 (16.1) and 41.1% • Parks (all) = 1.1 (6.8) and 7.4% • Park-formal = 0.2 (3.0) and 1.5% • Park-informal = 0.5 (4.9) and 3.2% • Park-natural = 0.1 (2.3) and 0.6% • Park-sports = 0.1 (10.2) and 1.0% • Park-young persons = 0.2 (4.0) and 1.1% • Private gardens = 4.8 (15.1) and 32.9% • School grounds = 0.1 (5.5) and 0.7% • Other green space = 0.01 (0.5) and 0.1% • Roads/pavement = 2.8 (7.2) and 18.9% • Green verges = 0.3 (2.7) and 2.0% • Built surfaces = 5.5 (12.4) and 38.0% **Minutes (SD) and proportion of total daily ST (8 am–10 pm of weekend day):** • Indoors = 363.4 (154.0) and 93.2% • Outdoors = 20.7 (41.3) and 5.3% **Minutes (SD) and proportion of total daily outdoor ST (8 am–10 pm of weekend day):** • Green space = 9.0 (26.9) and 43.7% • Parks (all) = 3.4 (19.1) and 16.4% • Park-formal = 0.5 (8.7) and 2.4% • Park-informal = 1.0 (11.9) and 5.1% • Park-natural = 0.7 (15.2) and 3.6% • Park-sports = 0.1 (3.2) and 0.4% • Park-young persons = 1.0 (19.1) and 5.0% • Private gardens = 5.6 (23.4) and 26.9% • School grounds = 0.1 (2.5) and 0.3% • Other green space = 0.03 (1.3) and 0.1% • Roads/pavement = 3.9 (12.5) and 18.9% • Green verges = 0.6 (7.0) and 3.1% • Built surfaces = 7.1 (14.1) and 34.3%

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
							Minutes (SD) and proportion of total daily LPA (3–10 pm of weekday): • Indoors = 68.2 (38.6) and 87.7% • Outdoors = 9.1 (14.9) and 11.7% **Minutes (SD) and proportion of total daily outdoor LPA (3–10 pm of weekday):** • Green space = 3.5 (7.9) and 38.8% • Parks (all) = 1.2 (7.8) and 12.9% • Park-formal = 0.3 (4.1) and 3.0% • Park-informal = 0.4 (4.1) and 4.4% • Park-natural = 0.1 (1.5) and 0.8% • Park-sports = 0.1 (10.6) and 1.6% • Park-young persons = 0.3 (6.6) and 3.3% • Private gardens = 2.2 (4.2) and 24.5% • School grounds = 0.1 (5.2) and 1.3% • Other green space = 0.01 (0.5) and 0.1% • Roads/pavement = 2.0 (3.7) and 21.6% • Green verges = 0.2 (2.3) and 2.6% • Built surfaces = 3.4 (6.1) and 37.0% **Minutes (SD) and proportion of total daily LPA (8 am–10 pm of weekend day):** • Indoors = 135.5 (70.7) and 89.1% • Outdoors = 13.0 (24.6) and 8.5% **Minutes (SD) and proportion of total daily outdoor LPA (8 am–10 pm of weekend day):** • Green space = 6.1 (15.7) and 46.7% • Parks (all) = 3.5 (16.7) and 26.7% • Park-formal = 0.7 (8.5) and 5.1% • Park-informal = 1.1 (7.7) and 8.3% • Park-natural = 0.6 (8.8) and 4.7% • Park-sports = 0.1 (1.9) and 0.6% • Park-young persons = 1.0 (13.9) and 7.9% • Private gardens = 2.5 (7.7) and 19.2% • School grounds = 0.1 (5.1) and 0.7% • Other green space = 0.01 (0.4) and 0.1% • Roads/pavement = 2.2 (7.6) and 17.1% • Green verges = 0.5 (5.1) and 3.5% • Built surfaces = 4.2 (9.3) and 32.6%
							Minutes (SD) and proportion of total daily MVPA (3–10 pm of weekday): • Indoors = 19.3 (17.2) and 72.6% • Outdoors = 7.0 (1.4) and 26.4% • ~1/2 of outdoor MVPA took place in green space.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
							Minutes (SD) and proportion of total daily outdoor MVPA (3–10 pm of weekday): • Green space = 2.4 (4.8) and 33.6% • Parks (all) = 0.7 (4.7) and 10.1% • Park-formal = 0.2 (3.3) and 2.7% • Park-informal = 0.2 (1.6) and 3.2% • Park-natural = 0.1 (1.1) and 0.8% • Park-sports = 0.1 (7.4) and 1.5% • Park-young persons = 0.1 (3.4) and 2.0% • Private gardens = 1.6 (2.8) and 22.3% • School grounds = 0.1 (3.3) and 1.1% • Other green space = 0.01 (0.4) and 0.1% • Roads/pavement = 1.9 (3.2) and 26.6% • Green verges = 0.2 (1.8) and 2.9% • Built surfaces = 2.6 (4.4) and 36.9% **Minutes (SD) and proportion of total daily MVPA (8 am–10 pm of weekend day):** • Indoors = 33.7 (27.9) and 78.7% • Outdoors = 7.5 (17.2) and 17.6% **Minutes (SD) and proportion of total daily outdoor MVPA (8 am–10 pm of weekend day):** • Green space = 3.5 (9.1) and 46.0% • Parks (all) = 2.2 (10.5) and 29.3% • Park-formal = 0.4 (4.3) and 4.8% • Park-informal = 0.7 (5.0) and 9.9% • Park-natural = 0.5 (6.6) and 6.1% • Park-sports = 0.05 (1.2) and 0.6% • Park-young persons =0.6 (7.6) and 7.8% • Private gardens = 1.2 (3.2) and 16.1% • School grounds = 0.1 (1.8) and 0.5% • Other green space = 0.01 (0.3) and 0.1% • Roads/pavement = 1.6 (6.5) and 20.9% • Green verges = 0.3 (2.7) and 3.8% • Built surfaces = 2.2 (7.1) and 29.3%

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Maddison, 2010[52]	New Zealand, ICAN Study	79 (42%)	14.5 (1.6), 12–17	ActiGraph 7164/Garmin Forerunner 305, 4 days (2 weekday, 2 weekend; ≥ 10 h/day)	ST (< 1.5 METs), LPA (1.5–2.9 METs), MPA (3.0–5.9 METs), VPA (≥ 6.0 METs), MVPA (10 min bouts)	Home (150 m buffer), school (1 km buffer)	**Proportion of time in ST per location:** • School radius (1 km) weekday = 70%, weekend = 69% • Home radius (150 m) weekday = 74%, weekend = 69%
							Proportion of time per location in LPA: • School radius (1 km) weekday = 13%, weekend = 20% • Home radius (150 m) weekday = 12%, weekend = 19%
							Proportion of time per location in MPA: • School radius (1 km) weekday = 15%, weekend = 11% • Home radius (150 m) weekday = 13%, weekend = 11%
							Proportion of time per location in VPA: • School radius (1 km) weekday = 1%, weekend = 0% • Home radius (150 m) weekday = 1%, weekend = 1%
							Proportion of time per location in MVPA bouts: • School radius (1 km) = 71% • Home radius (150 m) = 46% • Less MVPA time spent in home and school radius on weekends vs. weekdays; on weekends MVPA took place outside of home environment. • Weekday MVPA bouts within 1 km of school, 72% took place within school hours. • For weekend MVPA bouts, equal numbers occurring within the school and home environments. • Home and school environments major contributors to MVPA, especially during the week.
Oreskovic, 2015[53]	USA, NR	80 (56%)	12.6 (1.1), 11–14	ActiGraph GT3X/QStarz BT-Q1000XT, 2 weeks	ST (< 100 cpm), MVPA (≥ 2296 cpm, continuous)	Home (40 m buffer), school (40 m buffer), park (incl. green spaces and open land), playground (incl. areas for public rec such as soccer, football, baseball, golf), streets and sidewalks, other	**Median minutes (IQR) of total daily ST:** • School = 87 (63–110) • Home = 50 (40–69) **Mean minutes (SD) of total daily ST:** • Indoor = 95 (29) • Outdoor = 20 (14) • Other = 27 (20) • Streets and sidewalks accounted for greatest amount of daily outdoor ST.
							Median minutes (IQR) of total daily MVPA: • School = 8 (5–12) • Home = 4 (2–8) • Streets and sidewalks = 5 (3–9) • Playgrounds = 3 (1–6) • Parks = 2 (1–4) • Compared to being at home, time spent in school, streets, sidewalks, parks and playgrounds associated with greater MVPA.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Pearce, 2015[54]	Scotland, NR	82 (57%)	12.4 (0.4), 11–13	ActiGraph GT3X/QStarz BT-Q1000eX, 7 days (≥ 9 h/day)	MVPA (> 2296 cpm, continuous)	School (verified using school timetable), indoor vs. outdoor, unstructured vs. structured (identified via diary data)	**Median minutes (IQR) and proportion of total daily weekday MVPA:** • School = 24.2 (18.9–30.7) and 42.1% (29.7%–50.0%) • Unstructured outdoor leisure = 12.2 (5.7–22.5) and 18.2% (11.0%–31.8%) • Unstructured indoor leisure = 14.1 (8.4–25.9) and 24.6% (13.9%–40.4%) • Structured outdoor leisure = 0.0 (0.0–7.1) and 0.0% (0.0%–12.5%) • Structured indoor leisure = 0.0 (0.0–0.9) and 0.0% (0.0%–1.4%) **Median minutes (IQR) and proportion of total daily weekend day MVPA:** • Unstructured outdoor leisure = 16.3 (9.1–35.8) and 39.0% (19.6%–48.8%) • Unstructured indoor = 23.7 (13.8–40.8) and 44.3% (26.0%–66.0%) • Structured outdoor leisure = 0.0 (0.0–23.2) and 0% (0.0%–26.5%) • Structured indoor leisure = 0.0 (0.0–0.0) and 0% (0.0%–0.0%) • Children spent most time and recorded most MVPA at school or in unstructured leisure-time contexts – no recorded structured/organized PA of any kind on weekdays. • Children spent very little time and recorded little MVPA in structured leisure-time contexts.
Pizarro, 2016[55]	Portugal, NR	155 (55%)	15.9 (1.1), 14–18	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (school journey)	MVPA (≥ 2296 cpm, continuous)	AT (to and from school) – Walking: classified if they had a 90th percentile of speed < 10 km/h Bicycling: 90th percentile speed between 10–35 km/h Vehicle: 90th percentile of speed ≥ 35 km/h	**Minutes/trip (SD) and proportion of time in MVPA bouts per mode of AT:** • Walking = 12.0 (5.6) and 78% • Bicycling = 2.2 (2.6) • Vehicle = 1.3 (1.6) • Most frequent mode of travel was walking, followed by vehicle and bicycle. • School-to-home significantly higher min of MVPA vs. home-to-school journey. • Greater distance between home and school associated with lower odds of AT in boys and girls. • AT to and from school "can contribute up to 40% of recommended daily MVPA".

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results	
Rainham, 2012[56]	Canada, NR	316 (47%)	13.2 (0.9), 12–16	ActiGraph GT1M/EM-408 SiRF III, 8 days (> 10 h/day)	MVPA (not defined)	Home, school, commuting, athletic facility, entertainment, green space, military, parking lot, religious, residential, restaurant, retail, services, transportation (all not defined)	**Proportion of total MVPA per location:** **Urban boys:** • Home = 10.8% • School = 22.8% • Commuting = 57.6% • Athletic facility = 0.3% • Entertainment = 0% • Green space = 0.6% • Military = 0.0% • Parking lot = 0.5% • Religious = 1.3% • Residential = 3.2% • Restaurant = 0.5% • Retail = 1.9% • Services = 0.2% • Transportation = 0.3% **Suburban boys:** • Home = 30.1% • School = 22.6% • Commuting = 27.4% • Athletic facility = 1.8% • Entertainment = 0.0% • Green space = 3.9% • Military = 0.0% • Parking lot = 0.0% • Religious = 0.3% • Residential = 9.9% • Restaurant = 0.6% • Retail = 3.0% • Services = 0.2% • Transportation = 0.1% **Rural boys:** • Home = 25.2% • School = 33.1% • Commuting = 27.0% • Athletic facility = 4.0% • Entertainment = 0.0% • Green space = 5.6% • Military = 0.0% • Parking lot = 0.1% • Religious = 0.0% • Residential = 4.4% • Restaurant = 0.2% • Retail = 0.4% • Services = 0.1% • Transportation = 0.0%	**Urban girls:** • Home = 10.6% • School = 23.8% • Commuting = 55.5% • Athletic facility = 2.3% • Entertainment = 0.0% • Green space = 1.3% • Military = 0.2% • Parking lot = 0.2% • Religious =0.4% • Residential = 3.8% • Restaurant = 0.2% • Retail = 1.0% • Services = 0.0% • Transportation = 0.7% **Suburban girls:** • Home = 20.1% • School = 21.7% • Commuting = 42.5% • Athletic facility = 0.6% • Entertainment = 0.0% • Green space = 2.5% • Military = 0.0% • Parking lot = 0.0% • Religious = 0.3% • Residential = 7.5% • Restaurant = 0.2% • Retail = 3.6% • Services = 0.0% • Transportation = 0.9% **Rural girls:** • Home = 24.8% • School = 40.2% • Commuting = 20.7% • Athletic facility = 2.4% • Entertainment = 0.1% • Green space = 4.8% • Military = 0.0% • Parking lot = 0.0% • Religious = 0.2% • Residential = 2.3% • Restaurant = 0.1% • Retail = 4.0% • Services = 0.1% • Transportation = 0.2%

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
							• Urban students achieved more MVPA time in home, school and while commuting vs. suburban and rural students. • For urban students, majority of MVPA occurred while commuting (usually to and from school). • For rural students, majority of MVPA occurred at school.
							Sex differences • No sex differences in urban boys and girls. • Suburban boys spent more MVPA time at home vs. girls (30% vs. 20%). • Suburban girls engaged in more MVPA while commuting vs. boys (42.5% vs. 27.4%). • Rural boys engaged in more MVPA while commuting vs. girls.
Robinson, 2013[57]	USA, NR	31 (71%)	11–14	ActiGraph GT3X, 14 days	MVPA (≥ 2296 cpm, continuous)	NB (youth identified vs. census defined)	**Minutes of total daily MVPA:** • Census-defined NB = 9.5 min vs. Youth-identified NB = 14.7 min, *p* < .0001
Rodriguez, 2012[58]	USA, TAAG study	293 (100%)	15–18	ActiGraph 7164/Garmin Foretrex 201, 6 days	ST (< 100 cpm), LPA (≥ 100 to < 3000 cpm), MVPA (≥ 3000 cpm, continuous)	PA facilities (businesses that support PA including bowling alleys, dance studios, swimming pools, yoga studios, exercise facilities, sports clubs), food outlets, parks, population density (all 50 m buffer)	**ST, LPA and MVPA** In San Diego, presence of each item within 50 m buffer of each GPS/accelerometer point significantly associated with: • Park: 41% higher odds of **LPA vs. ST (95% CI: 1.15–1.74)** • Population density: OR = 1.01 (95% CI: 1.00–1.02) MVPA vs. ST • Schools: OR = 1.69 (95% CI: 1.29–2.20) **MVPA** vs. **ST** • Road length: OR = 0.38 (95% CI: 0.25–0.51) with MVPA vs. ST • Number of food outlets: OR = 0.73 (95% CI: 0.67–0.80) MVPA vs. ST In Minneapolis, presence of each item within 50 m buffer of each GPS/accelerometer point significantly associated with: • Road length OR = 0.43 (95% CI: 0.25–0.74) for LPA vs. ST and MVPA vs. ST • Higher population density: OR = 1.04 (95% CI: 1.02–1.07) of MVPA vs. ST • Presence of parks: OR = 1.86 (95% CI: 1.51–2.31) MVPA vs. ST • Schools: OR = 2.14 (95% CI: 1.30–3.53) with MVPA vs. ST • Higher PA intensity associated with parks, school, high population density and during weekdays and lower in places with more roads.
Voss, 2014[59]	Canada, ASAPJ Study	43 (~37%)	13.8 (0.6)	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (during trip)	MVPA (≥ 2296 cpm, continuous)	AT: transportation to and from school	**Minutes (SD) of total daily MVPA per trip:** • Transportation from home to school = 6.8 (4.0) • Elsewhere to school = 5.5 (2.6) • School to home = 8.4 (5.1) • School to elsewhere = 10.6 (5.5)
Voss, 2015[60]	Canada, ASAPJ Study	42 (36%)	13.8 (0.6)	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days	MVPA (≥ 2296 cpm, continuous)	AT: transportation mode for school trips	**Minutes (SD) of total daily MVPA per trip:** • Walk = 9.1 (5.1) • Transit = 9.5 (5.1) • Car = 4.2 (5.6) • Transit trips significantly longer in distance and duration vs. walk trips, but with similar amounts of MVPA. • Greater walk distance associated with lower walking MVPA.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Adults							
Audrey, 2014[61]	England, Walk to Work Study	103 (57%)	36.3 (11.7)	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (≥ 10 h/day)	MVPA (> 1952 cpm, continuous)	AT: walk to work (based on home and work address and included other destinations if taken as part of journey)	**Minutes and proportion of total daily MVPA per trip:** • 38.0 min and 47.3% • Average PA on walking days substantially higher vs. car days (583.1 ± 182.4 vs. 319.7 ± 148.5, p <.001). • Walking to work associated with higher levels of PA.
Chaix, 2016[62]	France, RECORD GPS Study	227 (32%)	≥ 35	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days	Walking (> 200 steps/10 min, continuous)	AT: trip distance, mode, and characteristics	**Walking:** • 90% of trips less than 0.5 km in length were achieved by walking vs. below 10% for trips > 4 km. • Mid-level distances included a mix of walking, public transport and some personal vehicle use. • Odds of walking > 200 steps/10 min of a trip increased with the number of services accessible and density of green space at the beginning and end of the trip. • Trip-level characteristics stronger than residential characteristics; important to consider outside NB characteristics.
Chaix, 2014[63]	France, RECORD GPS Study	234 (35%)	Median 58 (IR: 41–73)	ActiGraph GT3X/QStarz BT-Q1000XT, 7 days (median 12h, 35 min)	ST (< 150 cpm), MVPA (≥ 2690 cpm, continuous) – vector magnitude	AT (trip = travel from one destination to the next destination)	**Median (interdecile range) proportion of total daily ST:** • Transportation = 13% (5%–23%) • Public transportation trips associated with more ST vs. personal motorized vehicle time. **Median (interdecile range) proportion of total daily steps:** • Transportation = 38% (16%–58%) **Median (interdecile range) proportion of total daily MVPA:** • Transportation = 33% (12%–52%)

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Costa, 2015[64]	UK, Commuting and Health in Cambridge Study	41 (56%)	24–62	Actiheart/ QStarz BT-Q1000X, 7 days	ST (< 1.5 MET), LPA (1.5–3 MET), MPA (3–6 MET), VPA (> 6 MET, continuous)	AT: commuting journeys by mode of transportation (car, bus, car + walk, car + cycle, walk, cycle)	**Median proportion of time per mode spent in ST:** • Car only = 59% • Bus only ~41% • Car + walk ~25% • Car + cycle ~15% • Walk only = 0% • Cycle = 0% **Median proportion of time per mode spent in LPA:** • Car only = 38% • Bus only ~29% • Car + walk ~33% • Car + cycle ~35% • Walk only = 0% • Cycle ~4% • Trips that used a combination of cycle or walking had about 33–35% spent in LPA. **Median proportion of time per mode spent in MVPA:** • Car only = 0% • Bus only ~21% MPA • Car + walk ~21% MPA • Car + cycle ~19% MPA + 2% VPA • Walk only = 100% MPA • Cycle ~56% VPA + 33% MPA • Trips that used a combination of cycle or walking had ~20% spent in MVPA (~8 min).
Dewulf, 2016[65]	Belgium, NR	180 (48%)	59–65	ActiGraph GT3X/QStarz BT-Q1000XT, 1 week (≥ 4 days, ≥ 6 h/day)	ST (0–100 cpm), LPA (101–1951 cpm), MVPA (1952–100 000 cpm, continuous)	Home (50 m buffer), NB (51–1000 m buffer), outside NB (> 1000 m buffer), green areas (including agriculture, grassland, forest, swamp, health land, coastal dune, park, recreation and sport terrains)	**Mean proportion of time per location spent in ST:** • Within NB green area = 48.1% • Within NB non-green area = 63.0% • Higher in non-green areas vs. green areas and in homes. **Mean proportion of time per location spent in LPA:** • Within NB green area = 29.0% • Within NB non-green area = 22.6% • Higher in non-green areas and in homes. **Mean proportion of time per location spent in MVPA:** • Within NB green area = 13.8% • Within NB non-green area = 7.3% • Higher in green areas (vs. non-green areas), greater MVPA outside of NB. **Sex differences** • For men, greater time spent in non-green areas was related to more MVPA, the opposite was true in women.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Dunton, 2013[28]	USA, NR	291 (88%)	39.6 (6), 26–62	ActiGraph GT2M/ GlobalSat BT-335, 7 days	ST (< 100 cpm), MVPA (≥ 2020 cpm, continuous)	Residential, commercial (retail stores, restaurants, personal services, private health club/gym, motels), open space (parks, gardens, wildlife preserves), educational (schools), public facilities (government, health care, religious, libraries, community centres), other (roads, water)	**Proportion of total daily ST (joint parent-child):** • Residential = 75.9% • Commercial = 10.1% • Open space = 7.7% • Educational = 2.1% • Public facilities = 3.4% • Other = 0.7%
							Proportion of total daily MVPA (joint parent-child): • Residential = 34.9% • Commercial = 23.8% • Open space = 19.7% • Educational = 13.7% • Public facilities = 6.7% • Other = 1.2%
Evenson, 2013[66]	USA, SOPARC Study	238 (56%)	40.4, 18–85	ActiGraph GT1M/QStarz BT-1000X, 3 weeks (average 11.5 h/day)	ST (≤ 100 cpm), LPA (101–759 cpm), MPA (2020–5998 cpm), VPA (≥ 5999 cpm), MVPA (≥ 2020 cpm, 10 min bouts)	Parks, AT (to and from parks)	**Proportion of total daily ST:** • Parks = 2.4% • ST higher on days with a park visit. **Proportion of time per location spent in ST:** • Parks = 49.3% • Mean, median and IQR of min/day spent during a park visit = 9.9, 3.8 (0.6–11.0).
							Proportion of total daily LPA: • Parks = 3.1% **Proportion of time per location spent in LPA:** • Parks = 23.1% • Mean, median and IQR of min/day spent during a park visit = 5.1, 1.9 (0.3–5.5).
							Proportion of total daily MPA + VPA: • Parks: MPA = 8.2%; VPA = 9.4% • MVPA higher on days with a park visit. **Proportion of time per location spent in MVPA:** • Parks = 12.0% • Mean, median and IQR of min/day spent during a park visit: VPA = 0.1, 0.0 (0.0–0.0); MPA = 2.2, 0.5 (0.0–2.7), MVPA = 2.3, 0.5 (0.0–2.7). AT to and from a park added an additional 3.7 to 6.6 min of MVPA per visit.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Hillsdon, 2015[67]	England, FAST Study	195 (58%)	18–91	ActiGraph GT1M/QStarz BT-1000X, 7 days (≥ 10 h/day)	Outdoor LMVPA (≥ 500 cpm)	Inside home NB (800 m buffer) vs. outside home NB	**Proportion of total daily outdoor LMVPA:** • Outside the NB: men = 64.7% (95% CI: 57.9–71.4); women = 57.4% (95% CI: 52.2–62.7) • Rural adults spent significantly more LMVPA outside NB vs. urban and town participants. • Those with a car also spent significantly more LMVPA outside NB vs. those without. • Adults spent majority of time indoors. **Sex differences** • Men spent a significantly greater proportion of LMVPA outside of the NB vs. women, $p < .05$.
Holliday, 2017[68]	USA, SOPARC GPS Study	223 (57%)	18–85	ActiGraph GT1M/QStarz BT-1000X, 3 weeks (≥ 4 days, ≥ 10 h/day)	MVPA (used three different cut-points: Matthews' MVPA (≥ 760 cpm, bouts ≥ 10 min); NHANES' MVPA (≥ 2020 cpm, bouts ≥ 10 min); NHANES' VPA (≥ 5999 cpm, bouts ≥ 10 min))	Home (address), roads, parks, commercial (retail locations, strip malls, malls, dense commercial districts, restaurants, gas stations), school (pre-K to university), other (services, offices, golf courses, factories, places of worship, entertainment), fitness (pay gyms, private tennis/soccer facilities, swim clubs, dance/martial arts studios), residential (excluding participant homes), footpath/trail, motorized	**Median (IQR) and proportion of total daily MVPA over 3 weeks:** • Home = 116 (40–242) and 29.4% (Matthews), 6 (0–43) and 20.3% (NHANES) • Road = 25 (0–105) and 15.1% (Matthews), 6 (0–48) and 27.6% (NHANES) • Park = 11 (0–72) and 13.4% (Matthews), 0 (0–12) and 12.5% (NHANES) • Commercial = 14 (0–42) and 8.5% (Matthews), 0 (0–3) and 3.4% (NHANES) • School = 0 (0–32) and 7.6% (Matthews), 0 (0–0) and 9.1% (NHANES) • Other = 0 (0–23) and 5.1% (Matthews), 0 (0–0) and 3.6% (NHANES) • Fitness = 0 (0–0) and 4.2% (Matthews), 0 (0–0) and 7.7% (NHANES) • Residential = 0 (0–17) and 3.5% (Matthews), 0 (0–0) and 2.2% (NHANES) • Footpath/trail = 0 (0–1) and 1.4% (Matthews), 0 (0–0) and 2.9% (NHANES) • Motorized travel = 0 (0–0) and 0.1% (Matthews), 0 (0–0) and 0.2% (NHANES) **Median (IQR) and proportion of total daily VPA (NHANES) over 3 weeks:** • Home = 0 (0–0) and 17.8% • Road = 0 (0–0) and 23.6% • Park = 0 (0–0) and 4.3% • Commercial = 0 (0–0) and 3.9% • School = 0 (0–0), 12.0% • Other = 0 (0–0) and 1.4% • Fitness = 0 (0–0) and 19.3% • Residential = 0 (0–0) and 2.1% • Footpath/trail = 0 (0–0) and 9.0% • Motorized transport = 0 (0–0) and 0.3% • Fitness facilities and schools are important locations for NHANES VPA. • Parks accounted for 4% of park bouted VPA. • NHANES total VPA: together, homes and roads accounted for > 40% of bout-based MVPA across all three PA intensities.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Hurvitz, 2014[69]	USA, TRAC Study	611 (61%)	≥ 18	ActiGraph GT1M/ GlobalSat DG-100, 7 days	ST (≤ 150 cpm), LPA (151–1951 cpm), MPA (1952–5274 cpm, continuous), VPA (≥ 5275 cpm, continuous)	Home (< 125 m), near home (125–1666 m), away (> 1666 m)	**Mean (SD) and proportion of total daily ST:** • Home = 183.3 (90.7) and 36.0% • Near home = 29.9 (25.1) and 5.9% • Away = 125.5 (79.7) and 24.7% • ~55% of sedentary/low physical activity time was spent at home, and 37% spent at away locations. • At home and away locations, most time spent in sedentary/low physical activity (96% and 88%, respectively) vs. only ~65% of time at near locations was spent in sedentary/low physical activity, with 35% spent in MVPA.
							Mean (SD) and proportion of total daily LPA: • Home = 68.6 (34.3) and 13.5% • Near = 11.4 (9.4) and 2.2% • Away = 43.2 (29.1) and 8.5%
							Mean (SD) and proportion of total daily MVPA: • Home = 7.1 (4.9) and 1.4% • Near = 13.2 (9.0) and 2.6% • Away = 13.1 (10.3) and 2.6% • Almost 80% of MVPA occurred in non-home locations (i.e., near and away locations). **Proportion of time per location spent in MVPA:** • Home = 20.7% • Near = 40.0% • Away = 39.3%
							Mean (SD) and proportion of total daily VPA: • Home = 2.0 (0.7) and 0.4% • Near = 6.0 (2.5) and 1.2% • Away = 5.4 (2.5) and 1.1%
Hwang, 2016[70]	USA, NR	106 (76%)	41.7 (10.5), 24–70	ActiGraph GT3X/QStarz TR-Q1000XT, 2 weeks (12–14 valid days)	Walking bouts (> 2000–6166 cpm for at least 7 min)	Inside (1-, 2- and 3-km radii around home) vs. outside NB	**Walking** • More walking occurred outside vs. inside NB. • More walking in "walkable" areas vs. car dependent and 'somewhat' walkable areas.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Jansen, 2016[71]	Netherlands, SPACE Project	308 (55%)	56.4 (6.2), 45–65	ActiGraph GT3X/QStarz BT-Q1000X, 7 days (≥ 10 h/day, ≥ 4 days)	MVPA (≥ 3208 cpm, continuous)	Home (25 m buffer), shopping area (25 m buffer), workplace (50 m buffer), small green area (parks and public gardens), larger green area (recreational, agricultural, forest, natural terrain), sports facilities (require membership or subscription), other residential area (25 m buffer around residences)	**Median minutes (IQR) of total daily MVPA:** • Home = 10.4 (16.8) • Other residential area = 5.0 (14.2) • Residential and shopping area = 0.6 (2.8) • Shopping area = 1.0 (4.1) • Small green area = 1.0 (10.1) • Larger green area = 0.9 (6.6) • Sports facilities = 4.2 (19.6) • Workplaces = 9.9 (19.6) • Transport = 4.6 (11.4) • Other = 1.8 (7.1) **Median proportion (IQR) of time per location spent in MVPA:** • Home = 3.8% (4.1%) • Other residential area = 4.5% (6.3%) • Residential and shopping area = 2.9% (6.6%) • Shopping area = 5.0% (10.6%) • Small green area = 4.5% (10.9%) • Larger green area = 3.6% (8.8%) • Sports facilities = 5.9% (21.6%) • Workplaces = 4.2% (5.2%) • Transport = 5.7% (10.9%) • Other = 4.3% (8.5%)
Jansen, 2017[72]	Netherlands, SPACE Project	279 (54%)	46–65	ActiGraph GT3X/QStarz BT-Q1000X, 7 days (≥ 10 h/day, ≥ 4 days)	ST (< 150 cpm), LPA (150–3208 cpm), MVPA (≥ 3208 cpm, continuous)	Parks (e.g., city parks, children's farm), recreational area (e.g., zoo, playground, picnic places), agricultural green (e.g., grassland, orchard), forest and moorland (e.g., forest, moorland, dunes), blue space (e.g., lakes, rivers, water parks, seas)	**ST** • Highest proportion observed in blue space. • Compared to parks, less ST found in recreational and green space. **LPA** • Parks, recreation areas and agricultural green were found to have the highest (and approx. similar) proportions of time spent in LPA. **MVPA** • Highest levels of MVPA in agricultural green and larger natural environments.
Perez, 2016[73]	USA, Faith in Action	86 (100%)	45.4 (9.3), 18–65	ActiGraph GT3X/QStarz BT-Q1000X, 7 days (≥ 8 h/day, ≥ 2 days)	MVPA (≥ 2020 cpm, continuous)	NB outdoor environment (500 m buffer around home) vs. home (50 m radius)	**Median (IQR) minutes of total daily MVPA:** • NB outdoors = 0.18 (2.1) min/day • More MVPA occurred in the home vs. in NB outdoors.

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TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Rafferty, 2016[74]	UK, NR	26 (65%)	38, 23–65	activPAL/Amod AGL3080, 7 days	MVPA (> 109 steps per minute, continuous)	Work, AT commute (home to work), work excursion (e.g., out for lunch), home, home excursion (at home but outside or going back home from somewhere), other (shopping mall, restaurant, cinema)	**Mean (SD) and proportion of total daily MVPA:** • Commute = 22.0 (14.1) and 68% • Work excursion = 4.1 (5.0) and 12% • At work = 3.5 (3.8) and 11% • Home = 0.3 (0.7) and 1% • Home excursion = 1.3 (2.9) and 4% • Other = 1.5 (2.1) and 4% • 91% of daily MVPA obtained either commuting to work, at work or during work excursions during work time.
Ramulu, 2012[75]	USA, NR	35 (74%)	38, 18–61	Actical/pTrac Pro, 6 days	MVPA (≥ 1535 cpm, continuous)	Home (≤ 536 m buffer) vs. away from home (> 536 m)	**Median minutes (IQR) and proportion (IQR) of total daily MVPA on weekdays:** • Home region = 0 (0–2) min/day and 0.1% (0.0%–0.7%) • Away from home = 19 (9–31) min/day and 3.5% (1.9%–4.6%) **Median minutes (IQR) and proportion (IQR) of total daily MVPA on weekend days:** • Home = 1 (0–4) min/day and 0.3% (0.0%–0.9%) • Away from home = 5 (2–10) min/day and 1.7% (0.7%–3.5%) • Most steps during weekdays taken away from home (median = 4255, IQR: 2921–6444) vs. in home region (median = 848, IQR: 433–1801, $p < .001$). • On weekends, no significant difference in number of steps taken in home region vs. away.
Rodriguez, 2005[76]	USA, NR	35 (60%)	20–61	ActiGraph 7164/Garmin Foretrex 201, 3 days	MVPA (≥ 10 min bouts, threshold not defined)	Indoors (≥ 33% of GPS data located within building footprint), outdoors in NB (1.54 km buffer around home address), outdoors out of NB (all other bouts)	**Proportion of total daily MVPA:** • Outdoors in NB = 35% • Outdoors out of NB = 32% • In-NB bouts were longer and contributed more to total MVPA vs. out of NB bouts.
Stewart, 2016[77]	USA, TRAC Project	671 (63%)	≥ 18	ActiGraph GT1M/ GlobalSat DG-100, 1 week (≥ 8 h/day)	ST (≤ 100 cpm), park PA (> 1000 cpm), MVPA (≥ 1952 cpm, 5 min bouts)	Parks (publicly owned, freely accessible, outdoor spaces intended for leisure or recreation)	**Mean (SD) minutes and proportion (SD) of time per location spent in ST:** • Park visits = 16.8 (32.9) min and 29.9% (31.4%) • Park visitors had less ST and more park-related PA and MVPA vs. non-visitors (even when excluding park visit time). • Park visitors spent an average of 18.4 fewer min/day of ST/day than non-visitors. **Mean (SD) minutes and proportion (SD) of time per location spent in MVPA:** • Park visits = 11.9 (18.4) min and 38.9% (38.6%) (continuous MVPA), 26.6 (29.5) min and 46.7% (44.0%) (park PA bouts includes PA inside and outside of park boundary) • Park visitors achieved 14.3 min/day of park-related PA and 12.2 min/day of MVPA more than non-visitors. • Park visitors had more daily MVPA even when excluding park PA vs. non-visitors.

Continued on the following page

TABLE 2 (continued)
Included study characteristics and summary of findings

Author, year	Country, study	N[a] (% female)	Age[b]	Monitors, wear time	Behaviour	Location[c]	Results
Troped, 2010[78]	USA, NR	148 (53%)	44.0 (13.0), 19–78	ActiGraph 7164/GeoStats GeoLogger, 4 days	MPA (1952–5724 cpm), VPA (≥ 5725 cpm)	Home buffer 50 m, home buffer 1 km, work buffer 50 m, work buffer 1 km	**Mean (SD) minutes and proportion (SD) of time per location spent in MPA:** • Home buffer 50 m = 5.7 (7.9) and 9.7% (23.2%) • Home buffer 1 km = 12.9 (15.5) and 10.4% (14.6%) • Work buffer 50 m = 1.5 (4.0) and 7.8% (22.9%) • Work buffer 1 km = 7.6 (8.8) and 7.5% (9.5%) • Men MPA: home buffer 50 m = 6.1 (7.9) and 8.9% (21.3%), home buffer 1 km = 12.0 (15.5) and 10.9% (14.4%), work buffer 50 m = 1.8 (4.2) and 7.2% (22.1%), work buffer 1 km = 7.5 (7.7) and 8.4% (11.5%). • Women MPA: home buffer 50 m = 5.3 (8.0) and 10.4% (24.9%), home buffer 1 km = 13.7 (15.5) and 9.9% (14.8%), work buffer 50 m = 1.3 (3.8) and 8.5% (24.6%), work buffer 1 km = 7.7 (9.9) and 6.5% (6.6%).
							Mean (SD) minutes and proportion (SD) of time per location spent in VPA: • Home buffer 50 m = 0.3 (1.1) and 0.1% (0.3%) • Home buffer 1 km = 1.1 (3.3) and 1.2% (6.4%) • Work buffer 50 m = 0.1(0.6) and 2.8% (16.7%) • Work buffer 1 km = 0.9 (2.6) and 0.7% (1.8%) • Men VPA: home buffer 50 m = 0.4 (1.4) and 0.1% (0.4%), home buffer 1 km = 1.5 (4.3) and 1.9% (9.1%), work buffer 50 m = 0.2 (0.9) and 5.0% (22.4%), work buffer 1 km = 1.3 (3.2) and 0.9% (1.8%). • Women VPA: home buffer 50 m = 0.2 (0.7) and 0.1% (0.2%), home buffer 1 km = 0.9 (2.1) and 0.5% (1.3%), work buffer 50 m = 0 (0) and 0% (0%), work buffer 1 km = 0.5 (1.6) and 0.4% (1.7%).
							Sex differences • No significant differences between men and women.
Zenk, 2011[79]	USA, DASES Study	120 (75%)	> 18	ActiGraph GT1M/Garmin Foretrex 201, 7 days (≥ 3 days, ≥ 10 h/day)	MVPA (≥ 2200 cpm, continuous)	Fast food outlet density (top 50 national quick service restaurants excluding coffee shops, ice cream places, and juice bars), supermarket availability (chained supermarkets), park land use (municipal park land)	**MVPA** • Percentage of NB area that was park land did not relate to an individual's level of MVPA.

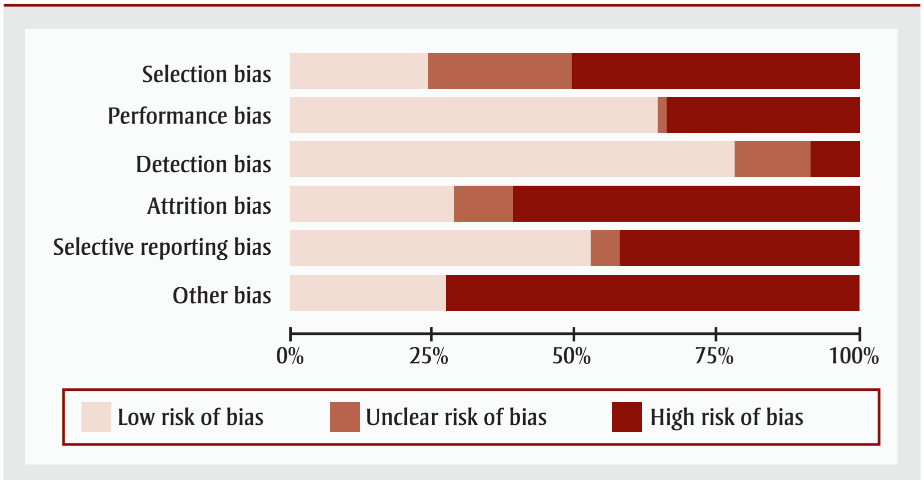
Abbreviations: ASAPJ, Active Streets, Active People Junior Study; assoc., associated; AT, active transportation; bpm, beats per minute; CALE, Children's Activity in their Local Environment; CAPABLE, Children's Activities, Perceptions and Behaviour in the Local Environments; CI, confidence interval; cpm, counts per minute; DASES, Detroit Activity Space Environments Study; F, female; FAST, Forty Area Study; GAG, GPS, Accelerometry and GIS; IQR, interquartile range; km, kilometer; LMVPA, light, moderate and vigorous intensity physical activity; LPA, light intensity physical activity; m, metre; MET, metabolic equivalent; min, minutes; MPA, moderate intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; NB, neighbourhood; NHANES, National Health and Examination Survey; NR, not reported; OR, odds ratio; PA, physical activity; PEACH, Personal and Environmental Associations with Children's Health; RECORD, Residential Environment and Coronary Heart Disease; SALTA, Environmental Support for Leisure and Active Transport; SD, standard deviation; SOPARC, System for Observing Play and Recreation in Communities; SPACE, Spatial Planning and Children's Exercise; SPEEDY, Sport, Physical activity and Eating behaviour Environmental Determinants in Young people; ST, sedentary time; TAAG, Trial of Activity for Adolescent Girls; TEAN, Teen Environment and Neighborhood; TRAC, Travel Assessment and Community; UK, United Kingdom; USA, United States of America; VPA, vigorous intensity physical activity; WCMC, When Cities Move Children.

[a] Number analyzed.

[b] Presented as mean (standard deviation) and/or range.

[c] Buffers are assumed to represent the radius from the centre of the address unless otherwise indicated.

FIGURE 2
Risk of bias summary



Additional studies identified streets/roads as great sources of MVPA among children,[35] largely owing to their use for active transit to-and-from school.[39]

Consistent evidence suggests that the school environment is one of the greatest sources for total MVPA[23,27,30,35,39,42] for children. Specifically, the schoolyard appears to be a large contributor to school-based MVPA, especially among boys.[27,42] The Spatial Planning and Children's Exercise (SPACE) Study in the Netherlands found that children spent a very small proportion of the time (2-3%) inside the school building in MVPA; the schoolyard (especially at recess) was a greater contributor.[27] Similarly, children from the Active Living Study obtained 18% of their daily MVPA in the schoolyard.[42]

While parks and green space were low contributors of total MVPA,[40] time spent within these spaces was often at higher intensities.[23,24,29,43] The Children's Activity in their Local Environment (CALE) Study from New Zealand found that only 2% of recorded PA took place in city parks.[40] Data from the Healthy PLACES study in the US found that only 27% of children used a neighbourhood park and proximity was directly related to use.[29]

Indoor locations appear to be a substantial source of LPA[25] and ST,[22] while outdoor locations contribute more to MVPA.[24,30,43] There is likely a seasonal effect on location of MVPA. Oreskovic et al.[37] found that MVPA was higher in the home environment during winter months and higher in parks/playgrounds during the summer months.

Much of time in the home environment is spent sedentary and appears to be a substantial source of ST.[22-24,28] Dunton et al.[28] found that 76% of parent-child ST was spent in the home. A study of preschoolers found that 45% of time spent in the home environment was spent sedentary.[24] Burgi et al.[23] found that 7- to 9-year-olds spent a median of 60% of their home time sedentary. Results from the Healthy PLACES study also found that among 8- to 14-year-olds, ST often occurred in the home.[22]

Several studies reported on sex differences in locations for MVPA. One study found that boys obtained a higher proportion of their MVPA outside their neighbourhood (> 800 m), while girls obtained a higher proportion inside their neighbourhood.[31] Two studies observed that active transportation is an important location of MVPA, especially among girls. The home-school journey was found to contribute a greater proportion of daily MVPA among girls compared to boys (36% vs. 31%) in one study[41] while another found that girls engaged in more active transportation compared to boys (29% vs. 26%), which in turn contributed to a greater percent of total MVPA (55% vs. 35%).[39] Boys were found to obtain a greater proportion of their daily MVPA at school[39] and in schoolyards compared to girls.[42] Other studies found no sex differences in location of ST, light intensity PA or MVPA.[25,30,32,38,41]

Location-based findings for youth (12-17 years)

The most commonly reported locations in youth were: homes; schools; recreational facilities; active transportation; and, green space. Many focussed exclusively on MVPA within the active transportation environment, specifically the commute to-and-from school.[47,55,59,60] Collins et al.[47] in their study of youth from England found that active commuting contributed to 35% of daily MVPA. Commuting distance appears to be a significant predictor of active transportation, with active commuters often living closer to the destination than passive commuters.[47,55,60]

Roads and sidewalks are major sources of youth MVPA,[45,51,53] largely owing to their use for active transit.[49,56] A Canadian study found that urban youth accumulated the majority (56% for girls, 58% for boys) of their daily MVPA while commuting (largely to-and-from school); this was greater than for suburban and rural students.[56]

Similar to children, the school environment is one of the greatest sources of MVPA among youth;[45,46,49,50,53,54,56] likely reflective of the location where they spend a substantial amount of their day. However, Carlson et al.[46] using data from the US-based TEAN Study, found that although most (55% on school days) MVPA was achieved at school, relative to the proportion of time spent at school, it was a low amount.

Contrary to findings for children, the home environment was found to be a large contributor of MVPA in several studies,[45,46,52] especially on non-school days[46] and in suburban and rural compared to urban youth.[56] A couple of studies, however, noted that the home environment was less of a contributor.[49,53]

Evidence around green space as a contributor of total MVPA is mixed. Results of the GAG Study in Scotland found that green space accounted for only 11% of leisure time MVPA.[48] Whereas, the When Cities Move Children (WCMC) Study in Denmark found urban green space was a major contributor of daily outdoor MVPA.[50] Lachowycz et al.[51] reported that green space and parks were responsible for 46% and 29% of all weekend outdoor MVPA, respectively.

Very few youth studies reported on locations for LPA and ST.[51-53] Similar to findings for children in this regard, indoor locations appear to be greater sources of LPA[51] and ST.[51,53]

Few studies reported on sex analyses. Boys were found to achieve more MVPA outside compared to girls.[45] Studies have found that boys obtain more MVPA compared to girls at school,[45,46,49] in transport[49] and at home,[46] but that girls had more MVPA near school.[46] Rainham et al.[56] found sex differences in suburban and rural, but not urban youth. Suburban boys obtained more of their MVPA at home than suburban girls (30% vs. 20%). While suburban girls spent more of their MVPA time commuting compared to suburban boys (42.5% vs. 27.4%), rural girls spent less of their MVPA time commuting compared to rural boys (20.7% vs. 27.0%).[56] Collins et al.[47] found no sex differences in active commuting.

Location-based findings for adults (≥ 18 years)

The most commonly reported locations in adult studies were: home neighbourhood; home; outside home neighbourhood; parks; green space; active transportation; and, commercial destinations. Evidence suggests that among adults the active transportation environment is one of the greatest sources while the home environment is one of the least common locations of MVPA.

Several studies examined or reported exclusively on time spent in active transportation.[61-64,74] Commuting/active transportation accounted for between 33% and 68% of total daily MVPA.[61,63,74] Chaix et al.[63] found that in general transportation accounted for a median of 13% of ST, but public transportation trips were associated with significantly more ST compared to personalized motor vehicle trips. Costa et al.[64] found that the mode of transportation during a journey was related to the median proportion of time spent in ST, LPA and MVPA. Journey time spent in ST was highest in car- (59%) and bus-only (~41%) journeys, time spent in LPA was greatest among trips that used a combination of car (38%) or car and cycling or walking (~33-35%) or bus-only trips (~29%), and journey time spent in MVPA was greatest in walking- (100%) or cycling-only (~33% MPA + 56% VPA) trips. Approximately 20% of bus-only trip time was spent in MVPA.[64]

Several studies examined time spent in the home environment.[65,68,69,74,75,78] The home environment appears to be associated with ST and LPA,[28,65,69] but not MVPA with most MVPA occurring outside of the home area,[69,74,75] especially on weekdays.[75] In contrast, the US-based System for Observing Play and Recreation in Communities (SOPARC) Study found that homes accounted for 20-29% of bout-based MVPA, whereas roads and fitness facilities were important locations for VPA.[68]

The evidence around parks and green space was mixed, but generally identified that both locations are potential sources of MVPA[65] (though not necessarily substantial amounts[66,71]) among adults, depending on whether they are actually used.[66,77] Data from the SOPARC study found that only 12% of time in parks was spent engaged in MVPA[66] and that this represented ~13% of total daily MVPA.[68]

While few studies commented on the workplace environment, two found that the workplace and workplace neighbourhood were substantial contributors to MVPA, but much of this was likely owed to transportation to-and-from work and daily time spent at work.[71,74] Interestingly, Troped et al.[78] found most MVPA occurred outside of home and work buffers than within them.

Three studies conducted sex-specific analyses. Troped et al.[78] found no significant differences in the location of MVPA by sex. Hillsdon et al.[67] found that men accrued significantly more PA outside of the neighbourhood than women (64.7 % vs. 57.4%). Dewulf and colleagues[65] found that among men, greater time spent in non-green areas was associated with more MVPA; the opposite was true in women.

Discussion

This rapid review examines and synthesizes the available literature around locations of PA and ST in children, youth and adults. Findings provide guidance for the design of future studies by understanding *where* individuals engage in PA and ST and areas of uncertain/weak evidence. Results can be used to support the current knowledge base around correlates and determinants of PA and ST and subsequently inform direction for new interventions by identifying environmental settings of importance.

Only one other review to date has looked at location-based studies. McGrath et al.[8] conducted a systematic review of objectively measured environmental features and MVPA in children and youth. They found that walking on local streets accounted for the greatest proportion of children and youth's daily activity spent outdoors (~40%). They also found that a large proportion of PA occurred in non-green space/other urban areas (26-27%). Similar to our results, they found that streets, roads, car parks, hard surface play areas, pedestrian pathways and shopping areas contributed more to outdoor PA than green spaces, parks and other grassland areas.[8] Our results also underscore the importance of active transportation to-and-from schools and schoolyards as major contributors to daily PA levels in children and youth. Important to note, however, is that McGrath et al.[8] excluded studies which examined citywide data rather than that of neighbourhood areas or data that used school locations as proxies for residential neighbourhoods. Our review builds on this previous work by including: studies regardless of type of location; other intensities (LPA, ST); updated literature; and, adults.

Findings of the present review support and contrast previous systematic reviews looking at the correlates and determinants of PA. The evidence for associations between aspects of the built environment and PA has been mixed, but with the most consistent evidence derived from studies using objectively measured environments and domain-specific PA.[80] In children and youth, evidence suggests a positive association exists between access to recreation facilities, playgrounds/parks, measures of walkability (including sidewalks) and PA.[80,81] Findings from our review suggest that schoolyards and active transportation are substantial contributors to child/youth daily PA rather than parks, especially on weekdays. Similar to our findings, systematic review evidence suggests that distance to school is negatively associated with PA in children.[81]

In adults, systematic review evidence suggests that in general, access to recreation facilities is positively associated with PA.[80,82,83] Only one[68] of the location studies used in our review commented specifically on indoor recreation facilities (e.g., fitness centres, pools). There is mixed evidence on the association between sidewalks and PA.[82,83] Among adults, factors in the built environment are likely relevant to different domains of PA. For example, sidewalks may be integral to the active transportation environment or to the workplace environment. Similar to our findings, evidence also suggests that the transportation environment is a correlate and determinant of total PA in adults.[80]

Much less previous work has examined the associations between factors in the built environment and ST.[9,84,85] In children, contrary to popular assumption, a higher playground density and availability of sports equipment in the school has been shown to be associated with greater ST,[85] whereas increasing the length of breaks at school and providing safe road crossings are associated with lower ST.[85] The studies in our review highlight the impact of the school environment on ST. For instance, most ST is recorded in the home and school environments,[23] emphasizing the importance of activity breaks in these environments and providing an opportunity for active transportation to-and-from school for regular MVPA. In adults, evidence suggests that proximity or density to green spaces is negatively associated with objectively measured sitting time.[84] Only one study in the present review looked at a measure of area 'greenness' and found that ST was higher in non-green areas compared to greener areas.[65] Mixed findings have been found around the association with neighbourhood walkability, walking/cycling infrastructure and recreation facilities and ST.[9,84] While the presence of active transportation supportive environments (e.g., lockers, bike storage, shower facilities) in the workplace have been shown to be positively associated with total objectively measured ST, they are also associated with greater levels of PA.[84] This finding suggests and supports the idea that interventions designed to increase PA may not always result in significant reductions of ST.[86]

This review serves to provide direction for future location-based studies. Many of the studies did not employ a full-day perspective and instead reported on results related to specific locations. For example, many focussed exclusively on time spent in travel to-and-from school or work. In recognition of the importance of movement across the 24-hour spectrum, future studies should report on locations across all intensities of movement including LPA and ST. Future studies would also benefit from reporting results by sex to understand if girls/women and boys/men spend their time in different locations at different intensities.

Strengths and limitations

The strengths of this review include a comprehensive search strategy developed with two research librarians, an *a priori* established protocol and the assessment of risk of bias. The review also took a life-course approach by looking at the findings separately in children, youth and adults and reporting on sex differences where available. Unfortunately, none of the included studies reported on findings specifically in older adults. Given that many included this population in their overall sample, we encourage future researchers to report on this segment of the adult population separately.

One of the major limitations of the review is the heterogeneity of the studies and their reporting. There was little standardization of the nomenclature used to describe the locations and many studies did not report measures of variance, preventing the conduct of a meta-analysis; future studies would benefit from reporting both on daily minutes and proportion per location. We were also not able to distinguish whether home environment behaviours occurred inside or outside of the home. Nor were we able to discern the location characteristics (e.g., road, path, and sidewalk) for many studies that focussed on active transportation. As this is an important domain of PA, we felt it was important to include these studies under a general "active transportation" location. Other studies reported movement behaviours in locations often associated with active transportation (e.g., roads), but the purpose/domain of this activity was not distinguishable. There will always be a limitation with being too specific in these efforts as active transportation takes place over a heterogeneous set of street geographies. As an example, it might start on a quiet residential street, continue on a shared-use walk/bike path, move to a painted bike lane and finish on a dedicated bike lane. In this example, only 3 out of 4 components of the journey occurred on a "road", and even then the types of roads differ. In our opinion, the key point is that PA occurred in the "travel" environment. Many of the studies were based on small and biased samples; there is a need for larger representative samples. Using GPS overlaid onto GIS helps to increase the accuracy of identifying locations of movement, but it is important to understand that the quality of GIS data can be variable and can ultimately introduce a source of measurement bias.[87] Findings from the literature have also identified that 12-14 days of monitoring are needed to provide reliable estimates of PA, and that time in the home or commercial environments require substantial monitoring times (> 19 days).[88,89] The majority of the included studies assessed movement over a 7-day period and many only required 4 days of valid data. Therefore, the findings may not be reliable. Future studies should consider the evidence around monitoring time requirements for reliable estimates. There was also substantial heterogeneity in the measures of activity and ST including the different devices, wear time requirements and cut-points used to define intensity. Finally, while GPS devices improve our understanding of the location of PA and ST, they also have their own limitations: there is the potential for large data loss due to signal drop outs, inadequate battery power and wear time adherence.[16] Many of the studies experienced substantial data loss.

Conclusion

In conclusion, this review provides a summary of the evidence around the locations where children, youth and adults obtain their ST, LPA and MVPA. There is limited evidence around the location of LPA and ST compared to MVPA. Evidence suggests that the active transportation environment is a potentially important contributor of MVPA across an individual's lifespan. There is a need for future location-based studies to report on locations of all intensity of movement using a whole-day approach in larger more representative samples.

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Conflicts of interest

We declare that we have no conflicts of interest related to this work.

Authors' contributions and statement

SAP was responsible for the conceptualization, design, acquisition, analysis, interpretation of the data, and drafting and revising of the paper. GPB, DPR and WT were responsible for the conceptualization, interpretation of the data, and revising of the paper.

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Original quantitative research

The association between physical fitness and health in a nationally representative sample of Canadian children and youth aged 6 to 17 years

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Abstract

Introduction: This study explored the relationship between physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children and youth aged 6–17 years.

Methods: We conducted a secondary data analysis of Canadian Health Measures Survey (Cycles 1 and 2; 2007-2011) data. The physical fitness measures included cardiorespiratory fitness (CRF; modified Canadian Aerobic Fitness Test), strength (handgrip strength), flexibility (sit-and-reach), and muscular endurance (partial curl-ups). The physical health indicators included directly measured biomarkers (total and HDL [high-density lipoprotein] cholesterol, C-reactive protein, glucose, and HbA1c [glycohaemoglobin]) and measures of adiposity, resting heart rate, and blood pressure. Psychosocial health was assessed using the Strengths and Difficulties Questionnaire. Multiple linear regressions were used to determine the association between variables, stratified by age groups and sex.

Results: 3,800 (48.9% female) children and youth were retained for this analysis. CRF displayed significant favourable associations with most physical health indicators in male and female participants. There were less significant favourable associations with flexibility and muscular endurance compared with CRF across age and sex groups. Strength was associated with higher adiposity in males and females, and lower heart rate in male children ($\beta = -1.9$; 95% CI: -2.9, -1.0) and female youth ($\beta = -2.0$; 95% CI: -2.7, -1.2). There were few significant favourable associations between measures of physical fitness and psychosocial health in this sample of children and youth.

Conclusion: These findings suggest that physical fitness, and especially CRF, is a significant indicator of physical health among Canadian children and youth aged 6–17 years.

Keywords: *cardiorespiratory, psychosocial, strength, biomarkers, youth*

Highlights

- Physical fitness, especially cardiorespiratory fitness, is associated with favourable indicators of physical health among Canadian children aged 6 to 11 and youth aged 12 to 17 years.
- Associations between physical fitness and psychosocial health, as measured by the Strengths and Difficulties Questionnaire, are generally null and may require further research.
- Physical fitness assessments are feasible measures that could help improve the monitoring of paediatric health status.

Introduction

Physical fitness is a construct that includes cardiorespiratory fitness (CRF), muscular endurance and strength, flexibility, agility, and in some circumstances, body composition.[1] Physical fitness may reflect an individual's capability to perform daily physical activity or physical exercise, providing a potential indication of physical health status.[1–4] Studies indicate that some components of physical fitness, such as CRF, in late adolescence may predict future comorbidity, cardiovascular diseases, and all-cause mortality in adulthood.[5–7] Combined, these studies demonstrate the utility of physical fitness as an indicator to help better understand health among school-aged children and youth. However, in recent years, the national surveillance and regular monitoring of physical fitness among children and youth has not been prioritized in Canada.

In 2012, the Institute of Medicine (IOM) produced a comprehensive report on the role of physical fitness in describing youth health, with a focus on recommending health-related fitness measures that could be implemented in national youth fitness surveys conducted in the educational environment.[1] One area of future development identified by the IOM report was for national surveys to include measures of physical fitness along with other health measures to further confirm whether relationships between specific fitness test items and health outcomes exist (recommendation

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10-4, p. 237).[1] However, this continues to be a gap in the literature with very few studies reporting these associations in large, representative samples of children and youth. Specifically, we were unable to identify Canadian studies that investigated associations between physical fitness and health outcomes in population representative samples of children and youth.

Similarly, the relationships between components of physical fitness and psychosocial health indicators among children and youth remain poorly understood. This is an important issue given that, in Ontario, emergency department visits and hospitalizations related to mental health increased by 32.5% and 53.7% respectively between 2006 and 2011.[8] If relationships are demonstrated between physical fitness and psychosocial health, this could provide new intervention targets to help improve psychosocial health in Canadian children and youth. Thus, the purpose of this study was to assess the associations between components of physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children aged 6–11 years and youth aged 12–17 years.

Methods

Participants

The present analyses used data from 6- to 17-year-olds who took part in cycle 1 (2007–09) and 8- to 17-year-olds who participated in cycle 2 (2009–11) of the Canadian Health Measures Survey (CHMS).[9] For children younger than 12 years old the majority of questionnaires were completed through proxy interviews with the child's parent/guardian.[10,11] The CHMS is a repeated cross-sectional survey that collects data from nationally representative samples of 3–79 year-olds living in private households. The survey represents approximately 96% of Canadians, with those from the three territories, Aboriginal settlements, members of the Canadian Forces, institutionalized individuals, and those from certain remote areas not represented in the survey. The overall response rate for both cycles was 53.5% of selected households, with survey weights adjusted for non-response bias.[12]

A total of 3,800 (48.9% female) children and youth aged 6–17 years, across both CHMS cycles, were included in the present analyses. The CHMS includes an interviewer-administered questionnaire at the respondent's home followed by a visit to a mobile examination centre (within the subsequent six weeks) for a series of physical measurements. Further details about the CHMS data collection procedures, screening guidelines, and eligibility criteria are available elsewhere.[10,11]

Ethics approval for the CHMS was obtained by Statistics Canada from Health Canada's Research Ethics Board.[13] Children aged 6–13 years provided written informed assent, and their parent/guardian provided written informed consent. Youth aged 14–17 years provided written informed consent.

Physical fitness measures

Physical fitness was measured by health measures specialists following the Canadian Physical Activity, Fitness, and Lifestyle Approach (CPAFLA) protocols.[14] CRF was assessed using the modified Canadian Aerobic Fitness Test (mCAFT).[14] The mCAFT is a progressive submaximal step test where participants follow an age- and sex-dependent starting cadence, with the pace increasing at every 3-minute interval. Participants were asked to follow the cadence of an audio recording, and the test was completed once participants reached 85% of their age-predicted maximal heart rate (220 – age). CRF ($\dot{V}O_{2peak}$) was calculated using the Weller et al equation:[15,16]

$\dot{V}O_{2peak} = 17.2 + 1.29 \times \dot{V}O_{2peak}* - 0.09 \times$ body mass in kg $- 0.18 \times$ age in years, where * represents the oxygen cost of stepping at the final stage.

Grip strength was measured (in kilograms [kg]) using a Smedley III dynamometer (Takei Scientific Instruments, Japan), with each hand being measured, alternately, twice. The grip strength score combined the best score from each hand. *Muscular endurance* was assessed using the number of partial curl-up repetitions performed in one minute following the pace of a metronome set to 50 beats per minute, with 25 repetitions being the maximum score. *Flexibility* was assessed with the sit-and-reach test using a flexometer (Fit Systems Inc, Calgary, Canada) where participants were asked to sit on the floor with their legs extended in front of them, and to stretch as far forward towards their toes without bending the knees. The best score from two attempts was recorded to the nearest 0.1 cm.[14] All physical fitness measures were conducted in the mobile examination centre.

Physical health indicators

A total of 12 physical health indicators were included in this analysis. Body composition assessments were measured following the CPAFLA protocol.[14] Height was measured using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA), and weight was measured using a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada). Body mass index (BMI) was calculated from the measured height and weight values. Waist circumference was measured at the midpoint between the lowest floating rib and the top of the iliac crest, following the World Health Organization protocol.[17] The sum of skinfolds was calculated from subcutaneous fat measurements taken from five sites using Harpenden skinfold calipers (Baty International, UK): triceps, biceps, subscapular, iliac crest, and medial calf.[14]

Resting heart rate and systolic and diastolic blood pressure were measured following the CHMS protocol.[18,19] The protocol included six measurements at 1-minute intervals following 5-minutes of quiet rest using an automated oscillometer (BpTRU™ BPM-300, BpTRU™ Medical Devices Ltd., Coquitlam, British Columbia). Final measurements were calculated from the mean score of the last five measurements.

Non-fasted blood samples were collected by certified phlebotomists and analyzed at the Health Canada laboratory following standardized procedures.[20] Lipid profiles (total cholesterol and high-density lipoprotein (HDL)/total cholesterol ratio) and C-reactive protein were measured in serum; glycohaemoglobin (HbA1c) in whole blood; and glucose in plasma samples. All measures were taken in a mobile examination centre. Further details about bio-specimen sampling, storage and analysis can be found elsewhere.[20]

Psychosocial health indicators

Psychosocial health was assessed with the parent reported Strength and Difficulties Questionnaire (SDQ).[21,22] The SDQ consists of 25 items that make up five subscales including emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and pro-social behaviour. The total difficulties score combines four subscales, excluding pro-social behaviour, the only positive subscale. For low-risk population-based studies, it is recommended to combine the emotional symptoms and peer-relationship problems into one internalizing subscale, and the conduct problems and hyperactivity/inattention subscales into one externalizing subscale. This converts the questionnaire from five subscales to three. [23]

Maturity offset

Maturity offset was estimated using sex-specific multiple regression equations that were originally calculated using prospective data from 152 Canadian children and youth aged 8–16 years, followed from 1991 to 1997.[24]

Statistical analysis

Analyses were conducted using SAS Enterprise Guide 5.1 (SAS Institute Inc., Cary, NC, USA) using survey weights. To account for the complex survey design the bootstrap technique was used to calculate 95% confidence intervals, with the degrees of freedom set to 24.[25,26] Statistical significance was set at $p < 0.01$.

The physical fitness variables (CRF, grip strength, partial curl-ups, sit-and-reach) were converted to age- and sex-standardized z-scores to help with interpretation and to normalize the variables. Multiple linear regression analyses were adjusted for parent self-reported household income and highest level of parental education (both measured during the home visit using a standard questionnaire) for all ages. We also adjusted the analysis for maturity offset only in youth aged 12 to 17 years. Throughout, we use the term "favourable" to help describe values that represent better health. For instance, negative beta values indicate better health for all variables, except for HDL cholesterol and prosocial behaviours where positive beta values indicate better health. We use "unfavourable" to describe beta values that indicate worse health.

Results

Descriptive characteristics of the sample stratified by age groups and sex are displayed in Table 1. Compared with females, males had higher CRF, strength, and muscular endurance scores (youth only); females had higher flexibility scores. For males and females, children (aged 6–11 years) had significantly higher CRF scores than their youth (aged 12–17 years) counterparts. Female children had significantly higher resting blood pressure when compared with male children. There were also significant differences between male and female children across some of the psychosocial health scores (externalizing, prosocial behaviours, and the total difficulties score). In youth, these sex differences were no longer significant.

Among males (Table 2), CRF was significantly associated with 9 out of 12 physical health indicators among youth, and 6 out of 12 physical health associations were significant among children. Specifically, in male children each standard deviation increase in male CRF was associated with a reduction of 2.8 cm in waist circumference, 12.1 mm in sum of skinfold thickness, 1.1 kg/m^2 in BMI, 1.4 mmHg in systolic blood pressure, 1.1 mmHg in diastolic blood pressure, and 2.7 bpm in resting heart rate. In male youth, each standard deviation increase in CRF was associated with a reduction of 5.8 cm in waist circumference, 14.1 mm in sum of skinfold thickness, 2.1 kg/m^2 in BMI, 1.1 mmHg in systolic blood pressure, 1.0 mmHg in diastolic blood pressure, 3.1 bpm in resting heart rate, 0.2 mmol/L in total cholesterol, 0.2 in total cholesterol/HDL ratio, and 0.4 nmol/L in C-reactive protein. Grip strength among males was unfavourably associated with waist circumference in children and BMI in children and youth, but favourably associated with resting heart rate only in children. Muscular endurance was significantly associated with 4 out of 12 physical health indicators for youth, and 6 out of 12 for children, although the effect sizes were not as large when compared with CRF. Flexibility was only favourably associated with 4 out of 12 health indicators in male children, and 2 out of 12 in male youth.

Among females (Table 3), CRF was the physical fitness measure that had the most significant favourable associations with physical health. In female children, CRF was favourably associated with 8 out of 12 health indicators, and 9 out of 12 health indicators for youth. In female children, one standard deviation increase in CRF was associated with a reduction of 4.3 cm in waist circumference, 12.6 mm in sum of skinfold thickness, 1.4 kg/m^2 in BMI, 1.3 mmHg in systolic blood pressure, 3.6 bpm in resting heart rate, 0.1 in total cholesterol/HDL ratio, 0.4 nmol/L in C-reactive protein, and a 0.0 mmol/L increase in HDL cholesterol. In female youth, each standard deviation increase in CRF was associated with a reduction of 4.5 cm in waist circumference, 13.6 mm in sum of skinfold thickness, 1.9 kg/m^2 in BMI, 1.6 mmHg in systolic blood pressure, 1.1 mmHg in diastolic blood pressure, 3.4 bpm in resting heart rate, 0.2 in total cholesterol/HDL ratio, and 0.1 mmol/L increase in HDL cholesterol. Grip strength was unfavourably associated with adiposity measures in female children (waist circumference, sum of five skinfolds, and BMI). Among female youth, grip strength was unfavourably associated with BMI, but there were significant favourable associations with resting heart rate. Muscular endurance was favourably associated with adiposity measures in female children, while in female youth, muscular endurance was significantly associated with 2 out of 12 health indicators. Flexibility among females was only favourably associated with 1 out of 12 indicators of health. Among female youth, muscular endurance was favourably associated with internalizing, externalizing, and total difficulties score, and CRF was also favourably associated with internalizing. No other associations were found between physical fitness measures and psychosocial health indicators.

Discussion

To our knowledge, this study is the first to explore the associations between physical fitness and indicators of physical and psychosocial health in a large representative sample of Canadian children and youth aged 6–17 years. We identified strong favourable associations between physical health and CRF among males and females. We also identified some strong favourable associations between physical health and muscular endurance and flexibility, and mixed favourable and unfavourable associations with grip strength. Most measures of fitness were not significantly associated with measures of psychosocial health, except for significant favourable associations with muscular endurance and CRF in female youth. These results highlight the importance of physical fitness, especially CRF, as an indicator that is significantly and favourably associated with several physical health indicators in paediatric populations.

TABLE 1
Participant descriptive statistics by sex for Canadian children (aged 6-11 years) and youth (aged 12-17 years)

	Total (n = 3800)		Males (n = 1943)		Females (n = 1857)	
	Children (n = 2157) Mean or % (95% CI)	Youth (n = 1643) Mean or % (95% CI)	Children (n = 1086) Mean or % (95% CI)	Youth (n = 857) Mean or % (95% CI)	Children (n =1071) Mean or % (95% CI)	Youth (n = 786) Mean or % (95% CI)
Mean age (years)	8.6 (8.5–8.7)	14.5 (14.4–14.6)	8.5 (8.3–8.7)	14.4 (14.2–14.7)	8.7 (8.5–8.8)	14.6 (14.4–14.8)
Parental education (%)						
Less than college	17.7 (14.6–20.8)	21.5 (17.6–25.4)	17.7 (13.8–21.7)	21.3 (16.6–26.0)	17.7 (14.2–21.2)	21.7 (16.3–27.0)
College	39.5 (33.9–45.1)	38.6 (32.5–44.8)	41.0 (33.1–48.8)	37.2 (30.8–43.6)	38.0 (32.9–43.1)	40.2 (33.1–47.3)
University	42.8 (35.8–49.7)	39.9 (32.6–47.2)	41.3 (32.6–50.0)	41.5 (33.6–49.4)	44.3 (38.0–50.6)	38.1 (29.4–46.9)
Household income (%)						
Less than $40 000	19.2 (15.5–23.0)	16.5 (13.3–19.6)	18.9 (13.3–24.6)	17.4 (13.3–21.6)	19.6 (16.1–23.0)	15.4 (11.7–19.2)
$40 000 to $79 999	33.7 (30.1–37.2)	32.4 (28.0–36.9)	32.0 (27.9–36.2)	33.5 (27.1–39.8)	35.4 (30.4–40.3)	31.3 (25.7–36.9)
$80 000 or more	47.1 (42.4–51.8)	51.1 (45.6–56.5)	49.1 (42.8–55.3)	49.1 (42.1–56.1)	45.1 (39.7–50.5)	53.3 (46.4–60.1)
Maturation						
Maturity offset (years)	n/a	1.5 (1.4–1.6)	n/a	1.1 (0.9–1.3)	n/a	2.1 (2.0–2.2)
Physical fitness measures						
$\dot{V}O_{2peak}$ score (mL/kg/min)	51.9 (51.6–52.2)	49.0 (48.6–49.5)	53.8 (53.2–54.3)	52.1 (51.5–52.8)	50.2 (49.9–50.6)	45.7 (45.0–46.3)
Grip strength (kg)	26.2 (25.3–27.0)	57.0 (55.2–58.8)	27.0 (25.9–28.2)	65.2 (62.7–67.7)	25.2 (24.3–26.2)	47.9 (46.5–49.2)
Muscular endurance (reps)	10.2 (9.3–11.0)	19.4 (18.7–20.2)	9.8 (8.7–10.9)	21.0 (20.3–21.8)	10.5 (9.4–11.7)	17.6 (16.6–18.6)
Flexibility (cm)	26.2 (25.6–26.7)	25.3 (24.4–26.3)	24.0 (23.3–24.6)	21.9 (20.4–23.4)	28.4 (27.7–29.1)	29.2 (27.9–30.5)
Physical health indicators						
Waist circumference (cm)	60.9 (60.3–61.5)	74.1 (72.8–75.5)	61.8 (61.0–62.6)	75.2 (73.5–76.8)	59.9 (59.2–60.6)	73.0 (71.4–74.5)
Sum of 5 skinfolds (mm)	51.6 (49.7–53.4)	59.9 (57.7–62.1)	50.2 (47.8–52.7)	49.1 (46.8–51.5)	53.0 (51.0–55.0)	71.9 (68.6–75.1)
BMI (kg/m^2)	17.9 (17.7–18.1)	22.0 (21.4–22.5)	18.2 (17.9–18.4)	21.9 (21.3–22.6)	17.7 (17.5–17.9)	22.1 (21.4–22.7)
Systolic blood pressure (mmHg)	93.9 (93.4–94.4)	98.1 (97.2–99.1)	93.5 (92.8–94.3)	99.5 (98.3–100.8)	94.3 (93.6–94.9)	96.7 (95.6–97.5)
Diastolic blood pressure (mmHg)	61.0 (60.4–61.5)	62.0 (61.0–62.9)	60.7 (59.9–61.6)	61.8 (60.6–63.0)	61.2 (60.7–61.8)	62.2 (61.2–63.1)
Resting heart rate (bpm)	80.2 (79.1–81.3)	74.8 (73.7–75.9)	78.1 (76.5–79.8)	73.5 (71.9–75.1)	82.4 (81.4–83.5)	76.3 (75.0–77.5)
Total cholesterol (mmol/L)	4.2 (4.2–4.3)	4.1 (4.0–4.1)	4.2 (4.1–4.3)	4.0 (3.9–4.1)	4.2 (4.2–4.3)	4.2 (4.1–4.2)
HDL cholesterol (mmol/L)	1.4 (1.4–1.4)	1.3 (1.3–1.3)	1.4 (1.4–1.5)	1.3 (1.2–1.3)	1.4 (1.4–1.4)	1.4 (1.3–1.4)
Total cholesterol/HDL ratio	3.1 (3.0–3.2)	3.2 (3.2–3.3)	3.1 (3.0–3.1)	3.3 (3.2–3.4)	3.2 (3.1–3.2)	3.1 (3.1–3.2)
C-reactive protein (nmol/L)	1.3 (1.1–1.6)	1.3 (1.1–1.5)	1.5 (1.1–1.9)	1.1 (0.9–1.3)	1.2 (1.0–1.3)	1.7 (1.3–2.0)
Glucose (mmol/L)	4.6 (4.6–4.7)	4.7 (4.6–4.7)	4.6 (4.6–4.7)	4.7 (4.7–4.8)	4.6 (4.5–4.7)	4.6 (4.6–4.7)
HbA1c (%)	5.5 (5.4–5.5)	5.4 (5.4–5.5)	5.5 (5.4–5.6)	5.4 (5.4–5.5)	5.4 (5.3–5.5)	5.4 (5.3–5.5)
Psychosocial health indicators						
Internalizing	2.8 (2.6–3.0)	2.7 (2.5–3.0)	2.9 (2.6–3.3)	2.6 (2.4–2.8)	2.7 (2.5–2.9)	2.9 (2.5–3.3)
Externalizing	4.2 (4.0–4.4)	3.3 (3.0–3.6)	4.9 (4.5–5.3)	3.6 (3.2–4.0)	3.4 (3.1–3.7)	2.9 (2.5–3.4)
Prosocial behaviour	9.1 (9.0–9.2)	9.0 (8.9–9.2)	8.8 (8.6–9.0)	8.9 (8.6–9.1)	9.5 (9.4–9.5)	9.3 (9.1–9.4)
Total difficulties score	7.0 (6.6–7.4)	6.0 (5.6–6.5)	7.8 (7.1–8.6)	6.2 (5.7–6.7)	6.1 (5.8–6.5)	5.8 (5.1–6.6)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein.

Although CRF, muscular endurance, and flexibility demonstrated consistent and favourable associations with indicators of physical health, this was not the case for grip strength. Rather, grip strength was associated with a greater waist circumference, sum of skinfold thickness, and body mass index, consistent with other studies.[27,28] Indeed, musculoskeletal fitness measures other than grip strength, such as those where participants are asked to propel their body through space (e.g., vertical jump, standing broad jump), might be better indicators of health in paediatric populations.[4] Previous studies have identified favourable associations between measures of muscular endurance and health,[29,30] which corresponds with our partial curl-up results. Flexibility in our study displayed favourable associations with indicators of physical health in males but not females. However, Mikkelsson et al. determined that sit-and-reach flexibility in youth was a significant predictor of future health-related

TABLE 2
Associations between physical fitness *z*-scores and physical health and psychosocial health indicators among male children aged 6-11 years (n = 1086) and youth aged 12-17 years (n = 857)

	CRF *z*-score		Grip strength *z*-score		Muscular endurance *z*-score		Flexibility *z*-score	
	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)
Physical health indicators								
Waist circumference (cm)	−2.8 (−3.7, −1.9)*	−5.8 (−6.8, −4.9)*	3.0 (1.8, 4.1)*	1.8 (0.2, 3.4)	−1.4 (−2.4, −0.5)*	−2.1 (−3.2, −1.0)*	−1.4 (−2.2, −0.7)*	−1.6 (−2.9, −0.3)
Sum of 5 skinfolds (mm)	−12.1 (−15.8, −8.4)*	−14.1 (−17.2, −11.0)*	2.9 (−0.8, 6.6)	0.6 (−2.5, 3.8)	−5.8 (−8.3, −3.4)*	−4.4 (−7.2, −1.7)*	−4.4 (−6.4, −2.3)*	−3.1 (−5.3, −0.8)*
BMI (kg/m²)	−1.1 (−1.4, −0.8)*	−2.1 (−2.5, −1.7)*	1.0 (0.5, 1.4)*	0.9 (0.4, 1.4)*	−0.6 (−1.0, −0.3)*	−0.9 (−1.3, −0.4)*	−0.3 (−0.6, −0.1)	−0.4 (−0.8, 0.1)
SBP (mmHg)	−1.4 (−2.3, −0.6)*	−1.1 (−2.0, −0.3)*	1.2 (0.3, 2.1)	1.4 (0.2, 2.6)	−0.1 (−0.9, 0.7)	0.1 (−0.7, 0.9)	−0.9 (−1.4, −0.3)*	0.0 (−0.7, 0.7)
DBP (mmHg)	−1.1 (−1.7, −0.5)*	−1.0 (−1.6, −0.4)*	0.8 (−0.1, 1.6)	−0.1 (−1.0, 0.7)	0.1 (−0.7, 0.8)	−0.2 (−0.9, 0.6)	−0.6 (−1.2, 0.0)	−0.0 (−0.6, 0.6)
Resting heart rate (bpm)	−2.7 (−4.7, −0.7)*	−3.1 (−4.4, −1.9)*	−1.9 (−2.9, −1.0)*	−0.6 (−2.1, 1.0)	−2.0 (−3.3, −0.6)*	−0.4 (−1.5, 0.6)	−1.3 (−2.5, −0.1)	−2.0 (−3.2, −0.7)*
Total cholesterol (mmol/L)	−0.1 (−0.2, −0.0)	−0.2 (−0.2, −0.1)*	−0.0 (−0.1, 0.1)	−0.1 (−0.1, −0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)
HDL cholesterol (mmol/L)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, −0.0)	0.0 (0.0, 0.1)*	0.0 (0.0, 0.1)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)
Total cholesterol/HDL ratio	−0.1 (−0.2, 0.0)	−0.2 (−0.3, −0.1)*	0.0 (−0.0, 0.1)	0.1 (−0.1, 0.2)	−0.1 (−0.2, −0.0)*	−0.1 (−0.2, −0.0)*	−0.1 (−0.1, 0.0)	−0.1 (−0.2, −0.0)
C-reactive protein (nmol/L)	−0.4 (−0.9, 0.0)	−0.4 (−0.6, −0.1)*	0.1 (−0.2, 0.5)	−0.1 (−0.2, 0.0)	−0.4 (−0.8, −0.0)	−0.2 (−0.4, −0.0)	−0.5 (−0.8, −0.2)*	−0.2 (−0.4, 0.0)
Glucose (mmol/L)	−0.0 (−0.1, 0.1)	−0.0 (−0.1, −0.0)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.1, 0.1)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)
HbA1c (%)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)
Psychosocial health indicators								
Internalizing	−0.3 (−0.6, −0.0)	−0.3 (−0.6, −0.0)	−0.1 (−0.3, 0.2)	−0.2 (−0.5, 0.1)	−0.5 (−0.9, −0.1)	−0.4 (−0.6, −0.2)*	−0.3 (−0.6, −0.1)	−0.1 (−0.5, 0.3)
Externalizing	−0.1 (−0.5, 0.4)	0.0 (−0.3, 0.3)	−0.1 (−0.5, 0.2)	0.2 (−0.2, 0.5)	−0.4 (−0.8, −0.0)	0.1 (−0.2, 0.4)	−0.3 (−0.7, 0.1)	0.2 (−0.4, 0.7)
Prosocial behaviours	−0.0 (−0.2, 0.1)	0.1 (−0.1, 0.2)	0.0 (−0.1, 0.2)	−0.1 (−0.2, 0.1)	0.2 (−0.0, 0.3)	0.0 (−0.1, 0.2)	−0.0 (−0.2, 0.1)	−0.0 (−0.1, 0.1)
Total difficulties score	−0.4 (−1.1, 0.3)	−0.3 (−0.8, 0.2)	−0.2 (−0.8, 0.4)	−0.0 (−0.6, 0.6)	−1.0 (−1.7, −0.2)	−0.3 (−0.7, 0.1)	−0.7 (−1.2, −0.2)	0.0 (−0.9, 1.0)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: β, unstandardized beta coefficient; BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein; SBP, systolic blood pressure.
Note: All data are adjusted for highest parental education, household income and, in youth only, maturity offset.
* $p < 0.01$.

fitness in adulthood among males, providing some indication that flexibility could be a potentially important health-related fitness trait in pediatric male populations.[31]

Results from this study suggest that CRF is the health-related fitness component most strongly associated with physical health among children and youth, as this measure demonstrated the greatest number of significant favourable associations with physical health when compared with other physical fitness measures, and the effect sizes were considerably larger. This is consistent with other studies. For instance, among middle aged adults, a 2-mmHg reduction in systolic blood pressure was associated with a 10% lower risk of stroke mortality and a 7% lower risk of mortality from ischemic heart disease.[32] In the present cross-sectional study, we showed that one standard deviation increase in CRF was associated with a 1.1–1.4 mmHg and a 1.3–1.6 mmHg reduction in systolic blood pressure in males and females, respectively. Although these associations do not meet the 2-mmHg standard for clinical meaningfulness among adults, it is likely that these associations are meaningful in paediatric populations.

The present study also shows significant favourable associations between CRF and adiposity (waist circumference, sum of 5 skinfolds, and BMI) where better CRF scores are strongly associated with lower adiposity levels. This finding is consistent with results from a large systematic review.[3] Due to the feasibility of conducting fitness measures in the field, these findings support a growing body of evidence that highlights the possibility of monitoring physical fitness levels to help better understand the health status of paediatric populations.[1,31,33]

In addition to physical health, the present study highlights null associations between physical fitness and psychosocial health, as measured by the SDQ, except for muscular endurance in female and male youth, and CRF in female youth. Although a study reported significant associations between physical activity levels and psychosocial health,[34] the findings reported in this study are original and call for further research in the area. It is likely that a more complex analysis, such as structural equation modelling, could help better describe the association between components of physical fitness, physical activity, and

TABLE 3
Associations between physical fitness *z*-scores and physical health and psychosocial health indicators among female children aged 6-11 years (n = 1071) and youth aged 12-17 years (n = 786)

	CRF *z*-score		Grip strength *z*-score		Muscular endurance *z*-score		Flexibility *z*-score	
	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)	Children β (95% CI)	Youth β (95% CI)
Physical health indicators								
Waist circumference (cm)	−4.3 (−5.5, −3.2)*	−4.5 (−5.5, −3.6)*	2.9 (2.0, 3.8)*	2.1 (0.2, 3.9)	−1.8 (−2.8, −0.8)*	−1.8 (−2.8, −0.8)*	−0.6 (−1.4, 0.1)	−1.2 (−2.2, −0.1)
Sum of 5 skinfolds (mm)	−12.6 (−15.9, −9.2)*	−13.6 (−16.3, −10.8)*	4.4 (2.3, 6.5)*	2.6 (−2.6, 7.8)	−5.6 (−8.1, −3.1)*	−4.1 (−7.2, −0.9)	−3.9 (−6.4, −1.3)*	−0.5 (−3.9, 3.0)
BMI (kg/m²)	−1.4 (−1.8, −1.1)*	−1.9 (−2.2, −1.6)*	1.1 (0.8, 1.4)*	1.0 (0.3, 1.7)*	−0.7 (−1.0, −0.3)*	−0.6 (−1.1, −0.1)	0.0 (−0.3, 0.3)	−0.0 (−0.5, 0.5)
SBP (mmHg)	−1.3 (−1.9, −0.6)*	−1.6 (−2.4, −0.9)*	1.0 (0.2, 1.7)	0.1 (−0.8, 1.0)	−0.5 (−1.0, 0.1)	−1.0 (−1.9, −0.1)	0.0 (−0.7, 0.7)	0.1 (−0.9, 1.0)
DBP (mmHg)	−0.5 (−0.9, 0.0)	−1.1 (−1.8, −0.3)*	0.5 (−0.1, 1.2)	−0.2 (−1.1, 0.6)	0.0 (−0.5, 0.6)	−0.9 (−1.6, −0.3)*	0.1 (−0.6, 0.8)	−0.1 (−0.9, 0.8)
Resting heart rate (bpm)	−3.6 (−4.5, −2.7)*	−3.4 (−4.5, −2.3)*	−1.6 (−2.6, −0.6)	−2.0 (−2.7, −1.2)*	−1.0 (−1.9, −0.0)	−0.8 (−2.1, 0.6)	−0.4 (−1.7, 0.9)	−2.0 (−3.2, −0.8)*
Total cholesterol (mmol/L)	−0.0 (−0.1, 0.0)	−0.1 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.1, 0.1)	0.0 (−0.1, 0.1)	0.1 (−0.0, 0.2)
HDL cholesterol (mmol/L)	0.0 (0.0, 0.1)*	0.1 (0.0, 0.1)*	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)
Total cholesterol/HDL ratio	−0.1 (−0.2, −0.0)*	−0.2 (−0.2, −0.1)*	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.1)	−0.1 (−0.1, 0.0)	−0.1 (−0.1, 0.0)	−0.0 (−0.1, 0.0)	−0.0 (−0.1, 0.1)
C-reactive protein (nmol/L)	−0.4 (−0.5, −0.2)*	−0.6 (−1.2, −0.1)	−0.1 (−0.3, 0.1)	−0.0 (−0.3, 0.3)	−0.2 (−0.3, 0.0)	−0.3 (−0.7, 0.1)	−0.1 (−0.3, 0.1)	0.1 (−0.2, 0.4)
Glucose (mmol/L)	−0.1 (−0.2, −0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	0.0 (−0.0, 0.0)	0.0 (−0.0, 0.1)	−0.0 (−0.1, 0.0)	0.0 (−0.1, 0.1)	0.0 (−0.0, 0.1)
HbA1c (%)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)	−0.0 (−0.0, 0.0)	0.0 (−0.0, 0.0)
Psychosocial health indicators								
Internalizing	−0.1 (−0.4, 0.1)	−0.5 (−0.9, −0.2)*	−0.1 (−0.3, 0.1)	−0.3 (−0.8, 0.1)	−0.2 (−0.5, 0.0)	−0.5 (−0.8, −0.2)*	−0.1 (−0.3, 0.0)	−0.4 (−0.8, 0.0)
Externalizing	−0.0 (−0.5, 0.5)	−0.1 (−0.5, 0.2)	0.1 (−0.1, 0.3)	0.3 (−0.1, 0.7)	−0.0 (−0.3, 0.3)	−0.7 (−1.2, −0.3)*	−0.1 (−0.4, 0.2)	−0.3 (−0.7, 0.2)
Prosocial behaviours	−0.0 (−0.1, 0.1)	0.1 (−0.1, 0.3)	0.0 (−0.1, 0.1)	0.0 (−0.1, 0.2)	−0.1 (−0.1, 0.0)	0.2 (0.0, 0.3)	0.0 (−0.1, 0.1)	−0.0 (−0.1, 0.1)
Total difficulties score	−0.1 (−0.8, 0.5)	−0.7 (−1.3, −0.1)	−0.0 (−0.4, 0.3)	−0.0 (−0.9, 0.8)	−0.3 (−0.7, 0.2)	−1.2 (−1.9, −0.5)*	−0.2 (−0.5, 0.1)	−0.7 (−1.4, 0.1)

Source: 2007-to-2009 and 2009-to-2011 (Cycles 1 and 2) Canadian Health Measures Survey, combined.
Abbreviations: β, unstandardized beta coefficient; BMI, body mass index; CI, confidence interval; CRF, cardiorespiratory fitness; DBP, diastolic blood pressure; HbA1c, glycohaemoglobin; HDL, high-density lipoprotein; SBP, systolic blood pressure.
Note: All data are adjusted for highest parental education, household income and, in youth only, maturity offset.
* $p < 0.01$.

psychosocial health among children and youth.

Strengths and limitations

This study represents a robust assessment of the associations between physical fitness and indicators of physical and psychosocial health in a nationally representative sample of Canadian children and youth aged 6–17 years. Strengths include the large sample size, many diverse and direct measures of physical health indicators and physical fitness, and the use of the validated SDQ to measure psychosocial health. We also used survey weights and the bootstrap technique to account for non-response bias and the complex study design. Nevertheless, this study is not without limitations. For example, the cross-sectional design does not allow for causal inferences. The partial curl-up assessment suffered from a ceiling effect as a result of the maximum amount of repetitions being attained in one minute (25 repetitions). There was also a floor effect for the partial curl-up assessment where some participants were unable to perform one repetition. The results may have also been influenced by residual confounding, although we stratified by sex and age groups and controlled for potential confounders including maturity offset, highest parental education, and household income.

Conclusion

Physical fitness, and especially CRF, is a significant indicator of physical health and could help complement other measures to improve the understanding of pediatric population health in Canadians. Our findings suggest that physical fitness measures do not generally provide a good indication of psychosocial health, as measured by the SDQ, among school-aged children and youth. More research is needed in this area, especially research that examines the associations between physical fitness and psychosocial health.

Conflicts of interest

The authors have no conflicts of interest to disclose.

Authors' contributions and statement

JJL, RL, and MST conceived the study design and research objectives. JJL and

RL ran the statistical analysis. JJL drafted the manuscript. All authors reviewed and approved the final manuscript.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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At-a-glance

Supervised Injection Services: a community-based response to the opioid crisis in the City of Ottawa, Canada

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Abstract

In response to the current opioid crisis in Canada, establishing safe injection services (SIS) in high risk communities has become more prevalent. In November 2017, The Trailer opened in Ottawa, Canada and tracks client use, overdose treatment and overdoses reversed. We analyzed data collected between November 2017 and August 2018. During peak hours, demand for services consistently exceeded The Trailer's capacity. Overdoses treated and reversed in this facility increased substantially during this period. Results suggest The Trailer provided an important though not optimal (due to space restrictions) harm reduction service to this high-risk community.

Keywords: *supervised injection sites, supervised injection services, supervised consumption sites, harm reduction, addiction, opioids, naloxone*

Highlights

- The Trailer (supervised injection service) was established as a response to the opioid crisis in Ottawa, Canada.
- The Trailer offers a 24-hour service to clients.
- Overdose reversals during the tracking period increased significantly.
- The demand for services has consistently exceeded capacity.

Introduction

Canada is currently in the midst of an opioid crisis.[1] From 2016 to 2017 apparent opioid-related deaths increased by 34% in Canada from 2978 to 3987.[2] This increase is largely attributed to the growing toxicity of the illegal drug supply.[2,3] Supervised injection services (SIS) represent one type of harm reduction method designed to mitigate the effects of opioid use.

According to recent systematic reviews,[4,5] community-based SIS have been found to reduce overdose mortality and morbidity among persons using SIS, increase harm reduction behaviours (decreased sharing and reuse of syringes), and increase initiation of substance use disorder treatment services. The SIS model has also been found to be cost-effective and to contribute to reducing pressure on community services, such as emergency medical services (EMS).[4,6] The establishment and operation of community-based SIS in Canada, however, remain a controversial harm reduction method.[7,8,9]

In November 2017, following a severe spike in deaths related to injection of opioids in the city of Ottawa, Canada, "The Trailer" was established; a SIS managed by Ottawa Inner City Health, Inc. (OICHI) and sanctioned by the Government of Canada. The Trailer is located in a high drug use area of Ottawa, with a catchment area that includes both shelters and treatment services for persons who use drugs in the community. This at-a-glance provides an overview of the clients and overdose treatments at The Trailer.[10]

Methods

The Trailer is responsible for tracking services and providing quarterly results to the Ontario Provincial Government. The Trailer is also required to provide an Annual Report to Health Canada. Most results reported here are based on tracking results for November 2017 through August 2018 (August 2018 results are not available in the Annual Report).

The Trailer's clients work with staff to establish an easy to remember unique identifier that is designed to maintain their anonymity, while also allowing their use of the SIS to be tracked.

The Trailer tracks several key data markers, including individual visits, types of drugs used (self-reported only), number of injections performed, overdoses, as well as observable health concerns (e.g., abscesses; wounds).

For overdoses, the type of treatment used is tracked. For clients showing signs of overdose and are breathing, oxygen/rescue breathing, and stimulation are used ("oxygen treatment"). If oxygen treatment only is used, then the overdose treatment is captured in this category. If the client is not breathing or is not responding to oxygen or stimulation, then naloxone is administered ("naloxone treatment").

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The experience of The Trailer is that many clients inject multiple (2-3 times) times per visit. While the number of injections is tracked, we have calculated the rate of overdose per 1000 visits, rather than per 1000 injections, as has been the approach in the past where most overdose events were linked to single injections.[11,12] This approach takes into consideration changing drug injection methods over time and therefore gives a better indication of overdose burden.

Results

Client profile

As of October 19, 2018, The Trailer had registered 1049 clients since its inception in November 2017 (OICHI personal communication, 2018). This number does not include clients who have died since November 2017 (six known deaths). Between November 2017 and August 2018, The Trailer provided services to an average of 226 different clients per month.[10] The OCIHI reported that their client base was relatively stable with an approximate 13% turnover per month.

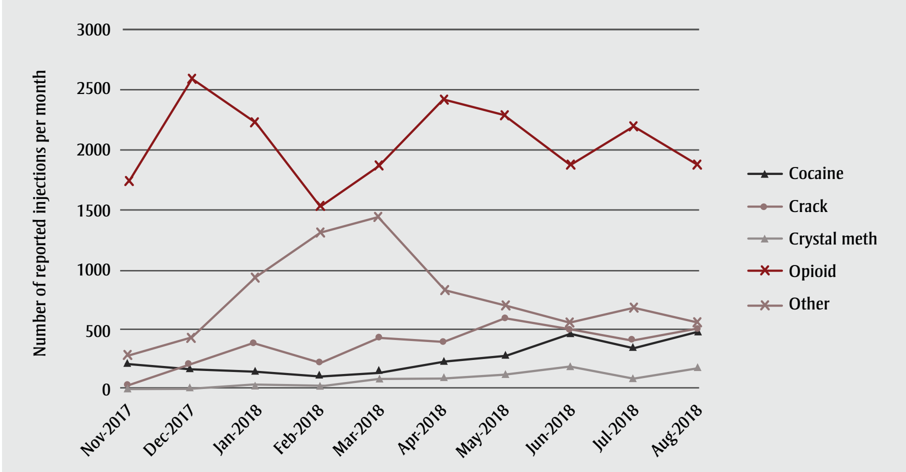
Approximately three-quarters of clients identified as male and most (60%) were between 25 and 45 years old. 12% of clients reported they were between 18 to 25 years old.

Opiates were by far the most common drug reported to be injected in The Trailer (Figure 1), though the reported use of opiates dropped from around 75% of all injections at the beginning of the tracking period to just over half by the end of the tracking period. The percentage who reported injecting cocaine or crack both increased slightly over time.

Use of Supervised Injection Services

The Trailer provides a 24-hour service to clients. Table 1 provides the total number of individual visits per month to The Trailer and the average number of visits per day between November 2017 and August 2018. Originally expected to accommodate 60 to 80 visits per day, The Trailer actually averaged 121 visits per day. Demand was highest in the late afternoon and evening, and almost always exceeded injection booth availability. Therefore, during peak hours clients were required to wait outside for space to open inside the facility.

FIGURE 1
Injectable drugs reported used at The Trailer by month, November 2017–August 2018, Ottawa, Ontario, Canada



Data source: Ottawa Inner City Health, Inc. (OICHI), *Report to Health Can SIS, November 2017-September 2018*.[10]

Table 1 also provides the number of overdose treatments per month provided (either oxygen or naloxone) inside the facility. The number of overdoses that resulted in EMS calls were not included in these estimates. Approximately 0–2 overdoses per month resulted in EMS calls.

For most months, the type of treatment used was nearly equal with an overall monthly average of 29 oxygen and 28 naloxone treatments. Figure 2 provides the rate of overdose reversals per 1000 visits to The Trailer for each month for naloxone treatment, for oxygen treatment, and for both treatments combined. All trends are statistically significant. For naloxone treatment alone, the statistically significant ($p < .05$) linear trend indicates an increase of 5 naloxone reversals per month over the time period. OICHI reported (personal communication, 2018) that the overdose reversals during the tracking period (naloxone only) represented 112 unique clients.

Discussion

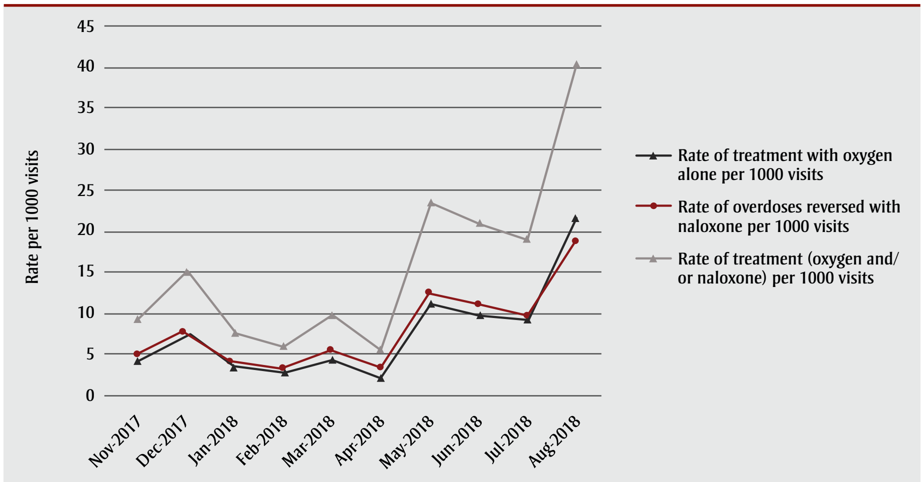
The opioid crisis, fuelled by unpredictable and unprecedented toxic supplies of illegal street drugs, has led to an urgent need for supervised injection services. Location, accessibility and attitudes toward clients, however, can be critical to the success or failure of a SIS.[7,13] The Trailer has been able to meet the needs of many of its clients because it is located within the community in which it serves, is open 24-7, and has adopted a model that cultivates a safe space for its clients free of shame, thereby earning the trust necessary to

TABLE 1
Number of Trailer visits and number of overdose treatments by month, November 2017–August 2018, Ottawa, Ontario, Canada

Visits/ treatments	Nov. 2017	Dec. 2017	Jan. 2018	Feb. 2018	March 2018	April 2018	May 2018	June 2018	July 2018	Aug 2018
Visits per month	3061	3171	4070	3435	3621	4129	3146	3626	3730	4192
Average number of visits per day	127.5[a]	102.3	131.3	122.8	116.8	138.0	101.5	120.9	120.3	135.2
Overdoses treated with oxygen alone	13	24	15	10	16	9	35	36	35	90
Overdoses reversed with naloxone	15	24	16	11	20	14	39	40	36	79

Data source: Ottawa Inner City Health, Inc. (OICHI), *Report to Health Can SIS, November 2017-September 2018*.[10]
[a] Based on 24 days; The Trailer opened on November 7, 2017.

FIGURE 2
Rates of overdose reversals by naloxone, treatment with oxygen alone and treatment with oxygen and/or naloxone, November 2017–August 2018, Ottawa, Ontario, Canada



Data source: Ottawa Inner City Health, Inc. (OICHI), Report to Health Can SIS, November 2017-September 2018.[10]
Note: The treatment with naloxone may be preceded by a treatment with oxygen that was insufficient to treat the overdose.

introduce needed health and addiction services.[4,13,14] However, service needs at The Trailer during peak hours consistently exceeded capacity, which put clients who found it difficult to wait at risk of harm or death if they injected unsupervised. Although plans for a permanent site are on hold, a new trailer (The Trailer 1.5) opened in December 2018, which increased the number of injection booths from 8 to 12.

Safe injection services (SIS) help to ensure that, instead of potentially dying alone either at home or in public places, those who inject illegal drugs have a safe space in which unintended overdoses can be reversed. In some respect, a community SIS can be seen as the proverbial "canary in the coal mine". It is an on the ground service that can signal the introduction of a toxic or "bad batch" of illegal street drugs in an area. Consequently, it is a spike in overdose reversals that alerts the community, instead of a spike in overdose deaths.

The growing toxicity of illegal drugs, driven by the introduction of ever-changing fentanyl analogues,[3,15] has complicated the way services are provided at The Trailer. For example, The Trailer staff has had to contend with increases in the number of overdoses treated. In addition, the spectrometer located at Ottawa's Sandy Hill Centre has identified the presence of synthetic opioids in non-opiate drugs, such as crack cocaine and methamphetamines.[3] Consequently, the OICHI is now championing expanding their services to also provide a safe space for those who ingest drugs through inhalation (safe consumption services).[10]

Strengths and limitations

The Trailer's commitment to anonymity for its clients makes it very challenging to characterize this population in any detail. Locating The Trailer in a high drug use area, however, suggests that clients are likely similar to those who have utilized successful SIS in the past (e.g., long-term users; marginalized; lower contact with the health care system).[16,17] It was also not possible to assess the actual composition of drugs used, their impact on overdose events or the pattern of overdoses.

However, we were able to provide estimates of overdose burden, choosing to calculate overdose rates per 1000 visits. The changes in drug injection patterns, in our view, suggest that our approach provided a more comparable estimate with overdose burden estimates of the past, particularly for heroin where overdoses typically occur after one injection.[11,12] Although successful treatment with naloxone is often considered the formal definition of an "overdose reversed," the burden associated with oxygen treatment has also been reported. It is not possible to determine how many of these cases would have resulted in an overdose requiring naloxone in the absence of oxygen treatment.

Finally, we were unable to determine whether clients used The Trailer for all their injections. Past studies have demonstrated that use of an established SIS is far from 100%.[16,18] This is likely the case for The Trailer's clients, thereby leaving them at risk when they must wait for an injection booth and/or when they choose to inject in higher risk situations.

Conclusion

The number of opioid overdoses avoided or reversed due to oxygen or naloxone treatment has greatly increased over the short period since The Trailer was established. There is evidence that The Trailer during this period was unable to fully meet the needs of clients in the community.[10] Whether the new temporary trailer with an additional 4 booths can meet demand remains to be seen.

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Conflicts of interest

The first author (SDV) is a peer worker at The Trailer. The second author (MdG) was Acting Editor-in-Chief of this issue of the HPCDP Journal, but recused herself from taking any editorial decisions on this manuscript.

Authors' contributions and statement

SDV, MdG and MTD conceived and outlined the paper and conducted the analyses. SDV, MdG and HM wrote the paper. All authors critically reviewed and provided revisions to all aspects of the paper.

Ethics approval: analyses were based on aggregate, publicly available data, and as such, REB approval was not required.

The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Release notice

Collaborating to advance economics of noncommunicable diseases

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In July 2018, the *Pan American Journal of Public Health* published a thematic issue on the Economics of Noncommunicable Diseases (NCDs). Integrating economic tools and methods to build evidence for multisectoral NCD efforts is a focus of collaboration between the Pan American Health Organization (PAHO) and the Public Health Agency of Canada (PHAC). This ongoing effort, profiled in the issue, aims to encourage interdisciplinary research to bridge NCD evidence gaps.

Dr. Theresa Tam, Chief Public Health Officer of Canada, provided an editorial comment in the issue. She stresses the benefits of using the analytical language of economics when communicating with experts outside the health sector and calls for increased collaboration. She acknowledges that harnessing economics will require better integration of economic data into surveillance platforms and adaptation of economic methods for public health applications.

Two articles by PHAC researchers discuss the economic rationale, methods and evidence towards an investment case for obesity prevention and control in the Region of Americas. Many evidence gaps exist. The authors found limited Region-specific studies on consumer behaviour, on comprehensive NCD burden or on the economic evaluation of interventions. They outline how a comprehensive investment case for obesity would rely on a social cost-benefit analysis framework where monetized social benefits of a healthier population are measured against the cost of interventions. The investment case should also include other criteria such as equity, feasibility and synergy among a proposed suite of interventions.

Two other articles in the issue discuss causal pathways from socioeconomic status to health and from trade to health. Also, three Regional studies are presented: one on unhealthy diet and physical activity patterns, another on tobacco taxation, and the third on affordability and taxation for beer and sugar-sweetened beverages.

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With thanks to our 2018 peer reviewers

We are grateful to the following people for their significant contribution to *Health Promotion and Chronic Disease Prevention in Canada* as peer reviewers in 2018. Their expertise ensures the quality of our journal and promotes the sharing of new knowledge among peers in Canada and internationally.

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Other PHAC publications

Researchers from the Public Health Agency of Canada also contribute to work published in other journals. Look for the following articles published in 2018:

Smolina K, Crabtree A, Chong M, […] **Mill C,** et al. Patterns and history of prescription drug use among opioid-related drug overdose cases in British Columbia, Canada, 2015-2016. Drug and Alcohol Dependence. 2019;194:151-8. doi: 10.1016/j.drugalcdep.2018.09.019

Tam T. Building collaborations to integrate economics into noncommunicable disease action. Rev Panam Salud Publica. 2018;42:e36. doi: 10.26633/RPSP.2018.36.

Young I, Thaivalappil A, **Waddell L**, Meldrum R, **Greig J**. Psychosocial and organizational determinants of safe food handling at retail and food service establishments: a systematic review and meta-analysis. Int J Environ Health Res. 2018;1-16. doi: 10.1080/09603123.2018.1544611.

Zakaria D, **Shaw A**. Trends in mammography, hormone replacement therapy, and breast cancer incidence and mortality in Canadian women. Cancer Causes Control. 2019. doi: 10.1007/s10552-019-1127-3.