Contribution of walking to school to individual and population moderate-vigorous intensity physical activity: systematic review and meta-analysis

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Running Head: MVPA during walking to school

Abstract

1   **Purpose**. This study estimated the contribution of walking to/from school to

2   objectively measured daily moderate-vigorous intensity physical activity (MVPA) in

3   individuals and populations. **Methods.** MEDLINE, PsycINFO and SPORTDiscus

4   were systematically searched up to February 2015. Two reviewers independently

5   screened titles/abstracts/full-text articles, and assessed study quality. **Results.** Of

6   2430 records, 116 were eligible for full-text screening. Twelve studies met the

7   inclusion criteria of reporting objectively obtained measures of MVPA (total and

8   while walking to/from school) in children and adolescents. The weighted mean

9   MVPA accumulated in walking to and from school was 17 minutes per day in primary

10   school pupils (9 samples, n=3422) and 13 minutes per day in high school pupils (4

11   samples, n=2600). Pooled analysis suggested that walking to and from school

12   contributed 23% and 36% of MVPA on schooldays in primary school age children

13   and high school pupils, respectively. All included studies were of high

14   methodological quality. **Conclusions.** Walking to and from school makes a

15   meaningful contribution to individual schoolday MVPA for active commuters in

16   western countries. Since schooldays represent only around half of all days, and

17   prevalence of walking to school is low in many countries, the contribution of walking

18   to school to population MVPA is probably low.

19

20

Introduction

21

22 Recent reviews have suggested that active commuting (walking, cycling) to school

23 has a number of health and non-health benefits, including potentially reduced

24 adiposity, and environmental gains arising from reduced car use (15, 26,40,42).

25 Active commuting to school is an important element of physical activity and health

26 policy in many parts of the world. Active commuting to school is widely considered

27 as an important contributor to the achievement of daily moderate-vigorous intensity

28 physical activity (MVPA) recommendations (5,50), but there has been a marked

29 decline in the prevalence of active commuting to school internationally (11,12,49).

30

31 A great deal of research and policy effort has focused on interventions to increase the

32 prevalence of active commuting to school, with the implicit assumption that such

33 interventions will produce a meaningful increase in population MVPA. Assessing the

34 extent to which future research and policy should focus on active commuting to

35 school depends on an improved –more quantitative-understanding of the contribution

36 which it actually makes to MVPA. The MVPA accumulated during active commuting

37 is usually seen by researchers and policymakers in terms of the individual child who

38 is commuting actively, and with a focus on schooldays. A population perspective of

39 the contribution of active commuting to school to MVPA would place less emphasis

40 on individual active commuters and schooldays, by considering both the fact that not

41 all days are schooldays (18), and the prevalence of active commuting, which is very

42 low in many countries (49).

43

44 Recent reviews and original studies on the topic of active commuting to school have

45 asked research questions about secular trends in, and prevalence of, active commuting

46   (11,12,31,41,42,49) ; the main determinants and correlates of active commuting

47   (12,27,47); the efficacy of interventions to promote active commuting (29), and the

48   health effects of active commuting (8,15,24,26, 34,40,41).These reviews have

49   generally made the implicit or explicit assumption that active commuting to school

50   makes a meaningful contribution to individual and/or population MVPA. To date, no

51   systematic review has asked a research question about the amount of MVPA which is

52   actually being accumulated by children and adolescents in active commuting to

53   school, and the extent to which MVPA accumulated during the active commute

54   contributes to population MVPA. The primary aims of the present study were

55   therefore to systematically review and critically appraise the evidence on the amount

56   of MVPA being accumulated while walking to/ from school, and to examine the

57   contribution of MVPA while walking to school to overall MVPA on schooldays in

58   those individuals. The secondary aim was to consider the contribution of walking to

59   and from school to population MVPA, by allowing for days on which children and

60   adolescents do not attend school, and the prevalence of active commuting in the

61   population (18).

62

63   **Methods**

64   **Literature searching and study inclusion criteria**

65   The literature search was conducted in February 2015 using the three most relevant

66   electronic databases: MEDLINE; PsycINFO and SPORTDiscus. The search strategy

67   was based on the following components: population (children and adolescents);

68   exposure (active commuting to and from school via walking); and outcome

69   (objectively measured MVPA). While we originally considered the inclusion of data

70   from children and adolescents who cycled to/from school the focus of the present

71   review was walking to/from school, because in all eligible studies the prevalence of

72   cycling to school was negligible and it was possible to extract data only from those

73   who walked to/from school. In any case, accelerometry as used in most previous

74   studies is unsuitable for measurement of MVPA during cycling (46). Studies

75   published from 2004 were eligible for inclusion so that any evidence would be

76   generalizable given recent rapid secular trends in active commuting (49). The search

77   strategy in MEDLINE is given in **Table 1,** and was adapted as required for the other

78   two databases. Full literature search details are available from the corresponding

79   author on request. Reference lists of eligible studies were also examined for

80   potentially eligible studies.

81

82   To be eligible for inclusion in the review, papers had to: report information on school-

83   age children and adolescents (4 – 19 years of age); use objective methods for

84   measuring MVPA (heart rate monitoring; accelerometry; combined heart rate

85   monitoring-accelerometry; direct observation); report MVPA while walking to/from

86   school, with any accelerometry cut-point or other objective method, be original

87   research, published in a peer reviewed journal; be observational in design, though

88   intervention studies were considered for inclusion if pre-intervention data and/or

89   control group data were given separately; be published in the English language. There

90   is no ideal (or even consensus) definition of active commuting to and from school,

91   and so studies were not excluded on the basis of how they defined or operationalised

92   active commuting. In most studies active commuting was operationalised as the time

93   periods before and after school (typically the 1 hour before school and 1 hour after

94   school), and so these will include some MVPA spent in domains other than active

95   commuting. In all eligible studies the data extracted for the present review was

96   considered to represent the estimated MVPA accumulated during the walk to and

97   from school (and the MVPA on schooldays) among those who regularly walked

98   to/from school. There is also no certainty (or even consensus) over which

99   accelerometer data reduction decisions are ideal for minimising biases in MVPA

100   estimates (9,13,17,21,37), and so studies were not excluded on the basis of the data

101   reduction decisions they made.

102

103   Two authors independently considered the titles/abstracts of all papers identified by

104   the search, referring to a third author for discussion and mediation where required.

105   Two authors also examined the papers identified for full-text screening, and referred

106   to a third author where necessary for discussion/mediation.

107

108   **Data extraction**

109   Three authors examined every eligible study and used a standard data extraction form

110   in order to populate the evidence tables. The extracted items were: first author,

111   publication year, country, objective measurement type, cut point for MVPA, sample

112   size, mean age, summary MVPA data (minutes/day) walking to and from school and

113   daily MVPA during schooldays for those who walked to and from school. Eligible

114   studies included only participants who walked to school regularly and/or provided

115   data for such individuals-for the present study data were extracted only from children

116   and adolescent study participants who regularly walked to/from school.

117

118   **Data analysis and synthesis**

119   The eligible studies fell logically into two categories: studies of primary school pupils

120   (elementary and middle school); studies of high school pupils, and so data were

121   synthesised for these two age groups separately.

122

123   **Contribution of active commuting to *individual* MVPA for those who walk to**

124   **school**

125   In some studies the MVPA content of commuting time was expressed as a percentage,

126   and so absolute MVPA (minutes) was recalculated based on data on the percentage of

127   time spent in MVPA and commuting time provided by each eligible study. For each

128   individual study the proportional contribution of walking to and from school to total

129   daily MVPA was calculated. An overall pooled estimate was calculated for primary

130   school pupils and high school pupils by averaging the proportional contributions from

131   each study. A weighting factor based on study sample size was used to weight

132   proportional contributions in the pooled estimate.

133

134   **Contribution of walking to/from school to *population* MVPA, allowing for non-**

135   **school days and prevalence of active commuting**

136

137   Since children and adolescents who walk to/from school can only do so on school

138   days, and since not all children and adolescents walk to/from school, the contribution

139   which walking to school makes to the overall population MVPA cannot be

140   determined by considering active commuters and schooldays alone (18). In order to

141   estimate the contribution of walking to/from school to *population* total MVPA, data

142   on the proportion of days per year when children and adolescents attend school were

143   used, along with data on the population prevalence of walking to school. Data on the

144   number of schooldays attended per year vary both within-nations and between-

145   nations. For the economically developed nations from which eligible studies were

146   found in the present review, around half of all days per year are school days (33). To

147   estimate the contribution of walking to/from school MVPA to total population

148   MVPA, the schoolday commuting data can therefore be reduced by around half for

149   those in the population who walk to/from school (18).

150

151   The contribution which walking to and from school makes to population MVPA will

152   also depend on the population prevalence of active commuting-for children who do

153   not walk to/from school the contribution which this behavior makes is negligible. The

154   impact of the prevalence of walking to/from school on population MVPA was

155   illustrated with two examples, taken from nations with studies eligible in the review

156   and of interest because of the contrast they provide in the prevalence of walking

157   to/from school: Scotland, where current prevalence of regular walking to school is

158   around 50% (36); the USA, where prevalence of walking to school in children is

159   <15% (11).

160

161   **Assessment of quality of the eligible studies**

162   Studies identified as eligible were assessed independently for quality by three authors,

163   resolving any disagreements by discussion. The Tooth et al (48) tool for assessing the

164   quality of observational studies was considered initially-it consists of over 30 items,

165   and some items of particular importance to the quality of accelerometry studies are

166   not included. The Tooth et al tool has been used previously, with substantial

167   modification, in recent systematic reviews of physical activity studies with an 11-item

168   (19), or 8-item (45) checklist. In the present study the Tooth et al tool (48) was

169   modified for use as a 15-item checklist, scored out of 6, as shown in **Table 2**. Each

170   eligible study therefore received a score out of 6, with higher scores reflecting higher

171   study quality.

172

173   **Results**

174   **Study selection and characteristics of eligible studies**

175   The study flow diagram is provided in **Figure 1**. Of 2430 records identified in the

176   initial review of the three databases, 116 were identified for full text screening. Of

177   these, 12 records were eligible for inclusion, reporting on 13 samples. Reasons for

178   exclusion are reported in Figure 1.

179   All studies used the ActiGraph, though with a variety of different models as well as

180   different approaches to data collection and reduction.

181   Nine samples involved primary school pupils, with a total sample size of 3422

182   children, in Denmark (1 study), England (4 studies), Scotland (1 study), and USA (3

183   studies). Study characteristics are summarized in **Table 3**. Four eligible samples

184   involved high school pupils (**Table 4**), with a total sample size of 2600 adolescents, in

185   three nations: Denmark (1 study); England (1 study); USA (2 studies).

186

187   **Results on walking to and from school in primary school pupils**

188   The mean daily MVPA accumulated during the walk to and from school in these

189   studies ranged from a low of 4 minutes/day in one study to 24 minutes/day in another

190   (**Table 3**). The weighted mean MVPA across the nine studies was 17 minutes per

191   school day.

192   **Figure 2A** displays the proportional contribution of walking to and from school to

193   total daily MVPA for each study. For those children who walked regularly to/from

194   school, pooled analysis showed that the commute represented 23% of daily MVPA on

195   schooldays.

196

197   **Results on walking to and from school in high school pupils**

198   The mean daily MVPA accumulated while walking to and from school ranged from a

199   low of 9 minutes/day in one study to a high of 18 minutes/day in another (Table 4).

200   Weighted mean MVPA in walking to and from school across the four studies was 13

201   minutes per day.

202   Proportion of walking to and from school to total daily MVPA for individual studies

203   is summarized in **Figure 2B**. For those adolescents who walked to and from school

204   regularly, pooled analysis showed that the contribution of the commute represented

205   36% of total daily MVPA on schooldays.

206

207   **Study quality assessment**

208   On quality assessment (Tables 2 and 3), all eligible studies scored at least 5/6.

209

210

211   **Discussion**

212   **Main findings and implications**

213 The present study suggests that walking to and from school contributes about one

214 quarter of *individual* total daily MVPA *on schooldays* for active commuters to

215 primary school (contributing up to around a third of the recommended MVPA of 60

216 minutes/day on schooldays), and around one-third of total *school day* MVPA for

217 active commuters to high school (contributing up to around a fifth of the

218 recommended MVPA of 60 minutes/day on schooldays) in western countries. These

219 findings illustrate the importance of active commuting to MVPA, for those

220 individuals who commute actively, on schooldays.

221

222 For an understanding of the importance of active commuting to *population* MVPA the

223 number of school days actually attended per year matters (18), as does active

224 commuting prevalence. As an example, the only eligible study from Scotland (29)

225 reported that primary school age children who walked to and from school

226 accumulated around 16 minutes MVPA per school day while doing so, the equivalent

227 of around 8 minutes MVPA per day when averaged over a whole year for individuals

228 who commute actively. Since the population prevalence of regular walking to school

229 in Scottish primary school children is currently around 50% (36), this means that the 8

230 minutes/day MVPA contribution to overall population MVPA (ie when those who do

231 not walk to and from school are included) is reduced further.

232

233 In the USA, with a prevalence of walking to and from school of around 13% in 5-11

234 year olds (11), and mean MVPA during walking to school of around 4-14 minutes per

235 school day (Tables 3 and 4), the current contribution of walking to and from school to

236 *population* MVPA will be very low. In accelerometry studies of nationally

237 representative samples of US children, mean daily MVPA estimates vary from a low

238   of 75-95 minutes (3, 50), to a high of around 180 minutes (32). If these estimates are

239   accurate, the present study suggests that nearly all population MVPA must be

240   accumulated in domains other than active commuting to school (at home; in active

241   and outdoor play; in school based physical activity-recess and physical education; in

242   organized sport).

243

244   Walking to/from school may be associated with higher overall physical activity and

245   may provide health and non-health benefits (15,40,43), but the present study suggests

246   that it makes only a small contribution to *population* MVPA , probably a combination

247   of low prevalence of active commuting to school, limited MVPA during the commute,

248   short commuting distances (18, 22, 27,35,42), and the fact that so many days are not

249   schooldays (12,18). If walking to school is going to make a much greater contribution

250   to population MVPA in future, the prevalence, duration, and MVPA content of

251   walking to school must all be increased substantially. A discussion of policy and

252   strategy options and arguments for improving surveillance of active commuting to

253   school, and for increasing the prevalence and MVPA content of active commuting to

254   school, would go beyond the scope of the present study, but these issues are dealt with

255   elsewhere (31,42,49, 51,52). Researchers and policymakers should also consider

256   whether focusing on domains of physical activity other than active commuting to

257   school might be more effective in the promotion of population MVPA (18).

258

259

260   **Comparisons with other studies**

261   Since previous systematic reviews on active commuting to school have asked research

262   questions distinct from the present study, there are no directly comparable reviews.

263   Janssen (18) recently examined the relative public health gain in Canada, of targeting

264   different physical activity domains (active commuting vs. physical education, active

265   play, school recess, and organised sport). He concluded that successful promotion of

266   active commuting to school might make only a relatively small contribution, in part

267   because school days represent only around half of all days, and in part because walks

268   to school were typically short.

269

270   **Review and evidence strengths and weaknesses**

271   The present study represents a high-level of evidence. The study had an *a priori*

272   protocol and followed PRISMA guidelines in conduct and reporting (30). The

273   evidence considered by the present review had a number of strengths too. In

274   particular, eligible studies were all rated as being of high or very high quality. The

275   studies included were in some cases based in large, nationally representative, surveys

276   or cohorts, a strength in terms of generalizability.

277

278   The present study also had a number of weaknesses. First, studies eligible for

279   inclusion had to be published in peer reviewed journals in English language, and this

280   may have excluded relevant evidence. Literature searching was restricted by starting

281   the search for papers published from 2004: this may be seen as a weakness, but was

282   intended as a strength, to focus the review on more recent, and more generalizable

283   evidence given rapid secular declines in active commuting to school. The present

284   study used a 15-item quality assessment measure, but collapsing this to 6 items for

285   scoring purposes might have reduced the ability to discriminate between studies on

286   the grounds of quality.

287

288   Various limitations probably led to overestimates of the estimated MVPA content of

289   the walk to/from school. In most eligible studies the walk to and from school was

290   operationalized as specified periods before and after school (typically in the hour

291   before school and the hour after school), so MVPA accumulated will be greater than

292   the MVPA during the walk *per se*, by including some MVPA in domains other than

293   active commuting (e.g. play, sport). Walking to and from school might provide

294   opportunities for active play which would not be available when commuting

295   passively, though these opportunities may not always be realised (44). Removal of the

296   accelerometer by study participants before the end of the day may have biased eligible

297   studies towards an overestimate of the contribution of the commute to schoolday

298   MVPA in some cases. The use of low accelerometer cutpoints may also have inflated

299   the absolute amount of MVPA during the commute.

300

301   The present study did not consider light intensity physical activity during walking to

302   and from school, but there is an emerging body of evidence that light intensity

303   physical activity may have a number of health benefits for children and adolescents

304   (4,14,23,25).It is unlikely that all walking to school is MVPA, and indeed several

305   studies of the energy cost of walking in children and adults give mean values for

306   walking of less than three times resting energy expenditure, and so categorise walking

307   as a light intensity activity (1,2).

308

309   One major gap in the eligible evidence reviewed by the present study was the absence

310   of data from low-middle income and non-western countries. The decision to restrict

311   the search to studies in the English language may have contributed to this. Developing

312   countries around the world are undergoing a 'physical activity transition '(20,31) and

313   recent international surveillance of active commuting to school (49) has suggested

314   that the secular decline in active commuting to school seen in high-income countries

315   may also be occurring in low-middle income countries. In many countries a minority

316   of children will be commuting actively to school, and prevalence of active commuting

317   will be declining (15,41,49). In a recent study of children in rural South Africa,

318   walking long distances to school was the norm, but the speed of walking was low and

319   so the MVPA accumulated during the walk to/from school was limited (10). It is not

320   clear whether these findings from South Africa apply to other low and middle-income

321   countries.

322

323   Conclusions

324   The present study suggests that walking to and from school may make a meaningful

325   contribution to individual schoolday MVPA in western countries for those individuals

326   who commute actively. If walking to school is going to make a more substantial

327   contribution to *population* MVPA, then the prevalence will have to be increased

328   markedly. The extent to which walking to school is contributing to individual or

329   population MVPA among children and adolescents in low and middle-income

330   countries is less clear.

References Cited

1. Adolph AL, Puyau MR, Vohra FA, Nicklas TA, Zakeri IF, Butte NF. Validation of uniaxial and triaxial accelerometers for the assessment of physical activity in preschool children. J Phys Act & Health 2012; 9: 944-953.

2. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ et al Compendium of physical activities and update of activity codes and MET intensities. Med Sci Sports Exerc 2000; 32:s498-s504.

3. Belcher BR, Berrigan D, Dodd KW, Emken BA, Chan CP, Spruit-Metz D. Physical activity in US youth: effect of race/ethnicity, age, gender, and weight status. Med Sci Sports Exerc 2010; 42: 2211-2221.

4. Carson V, Ridgers, ND, Howard, BJ, Winkler EAH, Healy GN, Owen N, Salmon J. (2013). Light-intensity physical activity and cardiometabolic biomarkers in US adolescents. PLoS ONE 2013; 8(8).

5. Chillon P, Ortega FB, Ruiz JR, Veidebaum T, Oja L, Maestu J, Sjostrom,M. Active commuting to school in children and adolescents: An opportunity to increase physical activity and fitness. Scand J Publ Health 2010; 38, 873–879.

6. Cooper AR, Jago R., Southward E, Page AS. Active travel and physical activity across the school transition. Med Sci Sports Exerc 2012; 44: 1890–1897.

7. Cooper AR, Page AS, Wheeler BW., Griew P, Davis L , Hillsdon M, Jago R. Mapping the walk to school using accelerometry combined with a global positioning system. Am J Prev Med 2010; 38: 178–183.

8. Cooper AR, Andersen LB, Wedderkopp N., Page AS, Froberg K. Physical activity levels of children who walk, cycle, or are driven to school. Am J Prev Med. 2005; 29: 179–184.

9. Corder, K., Brage, S., Ramachandran, A., Snehalatha, C., Wareham, N. & Ekelund, U. Comparison of two Actigraph models for assessing free-living physical activity in Indian adolescents, *J Sports Sci 2007;* 25: 1607-1611.

10. Craig EM, Bland RM, Reilly JJ. Objectively measured physical activity levels of children and adolescents in rural South Africa: high volume of physical activity at low intensity. Applied Physiol Nutr Metab 2013; 38:81-4.

11. Dentro KN, Beals K, Crouter SE, Eisenmann JC, Mackenzie TL, Pate RR, Saelens BE, Sisson SB, Spruit-Metz D, Sothern M, Katzmarzyk PT. Results for the US 2014 Report Card on Physical Activity for Children and Youth. J Phys Act & Health 2014 11 (suppl 1): s105-112.

12. Dessing D, de Vries SI, Graham J, Pierik FH. Active transport between home and school assessed with GPS: cross-sectional study amongst Dutch elementary school children. BMC Public Health 2014; 14: 227.

13. Dorsey K, Herrin J, Krumholz ZH, Irwin M. The utility of shorter epochs in direct motion monitoring. Res Q Exerc Sport 2009; 80: 460-468.

14. Dowd KP, Harrington DM, Hannigan A, Donnelly AE. Light intensity physical activity is associated with adiposity in adolescent females. Med Sci Sports Exerc 2014; 46: 2295-2300.

15. Faulkner GE, Buliung RN, Flora PK, Fusco C.Active school transport, physical activity levels and body weight of children and youth: a systematic review. Prev Med 2009; 48:3-8.

16. Freedson PS, Sirard J, Debold EP. Calibration of the CSA Inc accelerometer. Med Sci Sports Exerc 1997; 29: 45.

17. Hislop J, Bulley C, Mercer T, Reilly JJ. Comparison of accelerometer cutpoints for physical activity and sedentary behavior in pre-school children: a validation study. Pediatr Exerc Sci 2012; 24: 563-576.

18. Janssen I. Active play: an important physical activity strategy in the fight against childhood obesity. Can J Publ Health 2014; 105: e22-27.

19. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. Am J Prev Med 2013; 44:651-658.

20. Katzmarzyk PT. Increasing global research capacity in physical activity for children and youth. Res Exerc Epidemiol 2014; 16: 71-75.

21. Kim Y, Beets MW, Pate RR, Blair SN. The effect of reintegrating Actigraph accelerometer cutpoints in pre-school children: comparison using different epoch lengths. J Sci Med Sport 2013; 16: 129-134.

22. Klinker CD, Schipperijn J, Christian H, Kerr J, Ersbøll AK, Troelsen, J. Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. Int J Behav Nutr Phys Act. 2014; 11:8.

23. Kwon S, Janz KF, Burns TL & Levy SM . Association between light-intensity physical activity and adiposity in childhood. Pediatr Exerc Sci, 2011; 23:218-229.

24. Larouche R., Faulkner GEJ, Fortier M., Tremblay M. Active transportation and adolescents' health. Am J Prev Med 2014; 46: 507–515.

25. Leary SD, Ness AR, Smith GD, Mattocks C, Deere K, Blair SN, Riddoch C. Physical activity and blood pressure in childhood. Hypertension 2008; 31: 92-98.

26. Lee MC, Orenstein MR, Richardson MJ. Systematic review of active commuting to school and childrens physical activity and weight. J Phys Act Health 2008; 5:930-49.

27. Lee C, Li L. Demographic, physical activity, and route characteristics related to school transportation: an exploratory study. Am J Health Promot 2014; 28: 77–88.

28. Mendoza JA, Watson K, Nguyen N, Cerin E, Baranowski T, Nicklas TA. Active commuting to school and association with physical activity and adiposity among US youth. J Phys Act Health. 2011; 8: 488-495.

29. McMinn D, Rowe D. A, Murtagh S, Nelson NM. The effect of a school-based active commuting intervention on children's commuting physical activity and daily physical activity. Prev Med 2012; 54: 316–318.

30. Moher D, Liberati A, Tetzlaff J, Altman DG, the PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. Br Med J 2009; 339:b2535.

31. Muthuri SK, Wachira LJM, LeBlanc AG, Francis CE, Sampson M, Onywera VO, Tremblay MS. Temporal trends and correlates of physical activity, sedentary behaviour, and physical fitness among school-aged children and youth in sub-Saharan Africa: a systematic review. Int J Env Res Pub Health 2014; 11: 3327-3359.

32. Nader PR, Bradley RG, Houts RM, McRitchie SL, O'Brien M. Moderate-vigorous physical activity from ages 9-15 years. JAMA 2008; 300: 295-305.

33. OECD Education at a glance 2013. OECD Indicators, OECD Publishing 2013.

34. Owen CG, Nightingale CM, Rudnicka AR, van Sluijs EMF. Travel to school and physical activity levels in 9–10 year-old UK children of different ethnic origin. PLoS ONE. 2012: e30932.

.

35. Panter J, Jones A, Van Sluijs EMF, Griffin S. Associations between active commuting and physical activity. Pediatr Exerc Sci 2011; 23, 72-86.

36. Reilly JJ, Dick S, McNeill G, Tremblay MS. Results from the Scottish Report Card on Physical Activity for Children and Youth. J Phys Act & Health 2014; 11 (suppl 1), s93-s97.

37. Reilly JJ, V Penpraze, J Hislop, G Davies, S Grant, JY Paton. Objective measurement of physical activity and sedentary behaviour: review with new data Arch Dis Child 2008; 93:614-619.

38. Saksvig BI, Catellier DJ, Pfeiffer K, Schmitz KH, Conway T, Going S, Ward D, Strikmiller P. & Treuth MS. Travel by walking before and after school and physical activity among adolescent girls. Arch Pediatr Adolesc Med 2007: 161: 153-158.

39. Saksvig BI, Webber LS, Elder JP, Ward D, Evenson KR, Dowda M, Chae SE, Treuth, MS. A cross-sectional and longitudinal study of travel by walking before and after school among eighth-grade girls. J Adolesc Health. 2012; 51: 608–614.

40. Schoeppe S, Duncan MJ, Badland H, Oliver M, Curtis C. Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: a systematic review. J Sci Med Sport 2013; 16:312-9.

41. Sirard JR, Riner WF, McIver KL, Pate RR. Physical activity and active commuting to elementary school, Med Sci Sports Exerc. 2005; 37: 2062–2069.

42. Sirard J, Slater ME. Walking and bicycling to school: a review. Am J Lifestyle Med 2008; 2:372-96.

43. Stanley RM, Maher C, Dollman J. Modelling the contribution of walking between home and school to daily physical activity in primary age children. BMC Publ Health 2015; 15: 445.

44. Southward EF, Page AS, Wheeler BW, Cooper AR. Contribution of the school journey to daily physical activity in children aged 11-12 years. Am J Prev Med 2012; 43: 201-204.

45. Tanaka C, Reilly JJ, Huang W. Longitudinal changes in objectively measured sedentary behaviour and their relationship with adiposity in children and adolescents: systematic review and evidence appraisal. Obes Rev 2014; 15: 791–803.

46. Tarp J, Anderson LB, Østergaard L. Quantification of Underestimation of Physical Activity During Cycling to School When Using Accelerometry. J Phys Act Health, 2015, 12, 701 -707.

47. Timperio A, Ball K, Salmon J, Roberts R, Giles-Corti B., Simmons D, Baur LA, Crawford D. Personal, family, social, and environmental correlates of active commuting to school. Am J Prev Med 2006; 30:45-51.

48. Tooth I, Ware R., Bain C., Purdie D M, Dobson, A. Quality of reporting of observational longitudinal research. Am J Epidemiol 2005; 161:240-248.

49. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV et al .Physical activity of children: a global matrix of grades comparing 15 countries. J Phys Act & Health 2014; 11 (suppl 1): s113-s125.

50. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the US measured by accelerometer. Med Sci Sports Exerc 2008; 40: 181-188

51.   Tudor-Locke C, Ainsworth BE, Popkin BM, 2001. Active commuting to school: an overlooked source of childrens' physical activity ? Sport Med 2001; 31:309-13.

52. Voss E, Waters M, Fraser A, McKay H. School travel by public transport: rethinking active transport. Prev Med Rep 2015; 2:65-70.

Table 1 Search Strategy in MEDLINE

exp child/

exp adolescent/

child*.tw.

adolesc*.tw.

(boy* or girl*).tw.

teen*.tw.

youth*.tw.

(pupil* or student* or schoolchild*).tw.

(young adj2 (person* or people)).tw.

p?diatr*.tw.

school*.tw.

1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11

exp Walking/ or exp Bicycling/

*Travel/

(active adj2 (commut* or transport* or travel* or lifestyle* or life-style* or living)).tw.

(walk* or cycl*).tw.

13 or 14 or 15 or 16

exp Motor Activity/

exp Exercise/

*physical endurance/ or exp physical fitness/

*Sports/

21 or 18 or 19 or 20

(physical* adj2 activ*).tw.

exercis*.tw.

"physical fitness".tw.

"physical endurance".tw.

(physical activity adj2 (level* or intensit* or energy expenditure)).tw.

"MVPA".tw.

moderate-to-vigorous.tw.

"moderate to vigorous".tw.

22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30

objectiv* measur*.tw.

exp actigraphy/ or *monitoring, ambulatory/

exp Accelerometry/

32 or 33 or 34

("GPS" or global positioning system or "GIS" or global information

system).tw.

acceleromet*.tw.

(activpal or activgraph or activity monitor*).tw.

heart rate monitor*.tw.

35 or 36 or 37 or 38 or 39

12 and 17 and 31 and 40

limit 41 to english language

limit 42 to yr="2004 -Current"

TABLE 2 Study Quality Assessment Criteria

Criterion	Definition	Mark Allocation
Sample recruitment	Sample: How were they recruited e.g. poster Time: When was the study conducted Place: Where did the recruitment take place	1 point for listing 3 criteria
Sample description (n, age, gender)	Number of participants recruited Mean age of participants % Gender male and female	1 point for listing all 3 criteria
Attrition	Number of participants recruited and the number actually measured	1 point for listing both criteria
Data collection and reduction	Type of device; epoch; no of days of active commuting specified as minimum; duration of monitoring time; monitor placement; data reduction decisions	1 point for listing 3 criteria
MVPA definition given	MVPA defined and accelerometry cut-off or other method given	1 point for listing both criteria
Results	Adequate description of numbers actually analysed, with summary MVPA data	1 point for listing both criteria

TABLE 3 Contribution of Walking to and from School to Daily MVPA in Primary School Studies

Study, Year, Setting	Accelerometer, MVPA cut-off Point	Sample Size; Mean age (SD)	Total mean schoolday MVPA [minutes/day]	Mean MVPA Walking to/from school [minutes/day]	Quality Rating
McMinn et al 2012, Scotland (29)	ActiGraph GT1M, Freedson cutpoint[d]	166; 8.6y (0.5)	90 (SD 27)	16 (SD 8)	5
Owen et al 2012, England (34)	ActiGraph GT1M, $\geq$2000 cpm	1393; 9.9y (0.4)	74 (95% CI 71-76)	22 (95% CI 21-23)	6
Panter et al 2011, England (35)	ActiGraph GT1M, $\geq$2000 cpm	723; 10.2y (0.3)	74 (SD 23)	15 (SD 7)	6
Lee and Li 2014, USA (27)	ActiGraph GT1M and GT3X, Freedson cutpoint [d]	109; 9.5y(not given)	63 (SD 11)	7 (SD 10)	5
Cooper et al 2005, Denmark (8)	ActiGraph 7164, cut-point unclear	328; 11y (0.4)	193 (SD 59)	7 (SD not given)	5
Cooper et al 2012[a], England (6)	ActiGraph GT1M, $\geq$2295 cpm	500; 11y (0.4)	62 (SD 22)	14 (SD not given)	6
Cooper et al 2010, England (7)	ActiGraph GT1M, $\geq$3200 cpm	70; 11y (0.3)	43 (SD 18)	11[b] (SD 5)	6
Sirard et al 2005, USA (41)	ActiGraph, model not given, $\geq$1017	21; 10y(0.6)	102 (SD not given)	24 (SD not given)	6

Saksvig et al 2007[c], USA (38)	cmp ActiGraph 7164, ≥1500 counts per 30 seconds	112; 6th grade	29 (SD 2)	11 (SD 1)	6

[a] Primary school age sample from Cooper et al 2012 (6). [b]Paper provided MVPA during route to school only, so has been doubled. [c] Study of girls only. [d]

Freedson MVPA cutpoint (16) equivalent to 906cpm and 1018cpm for 9 and 10y olds respectively, using the following equation

METS = 2.757 + (0.0015 x counts/min) – (0.08957 x age (yr)) – (0.000038 x counts/min x age (yr))

 In all cases daily MVPA data refer to schooldays only among children who walked to school regularly. MVPA: moderate-to-vigorous physical activity, cpm:

counts per minute

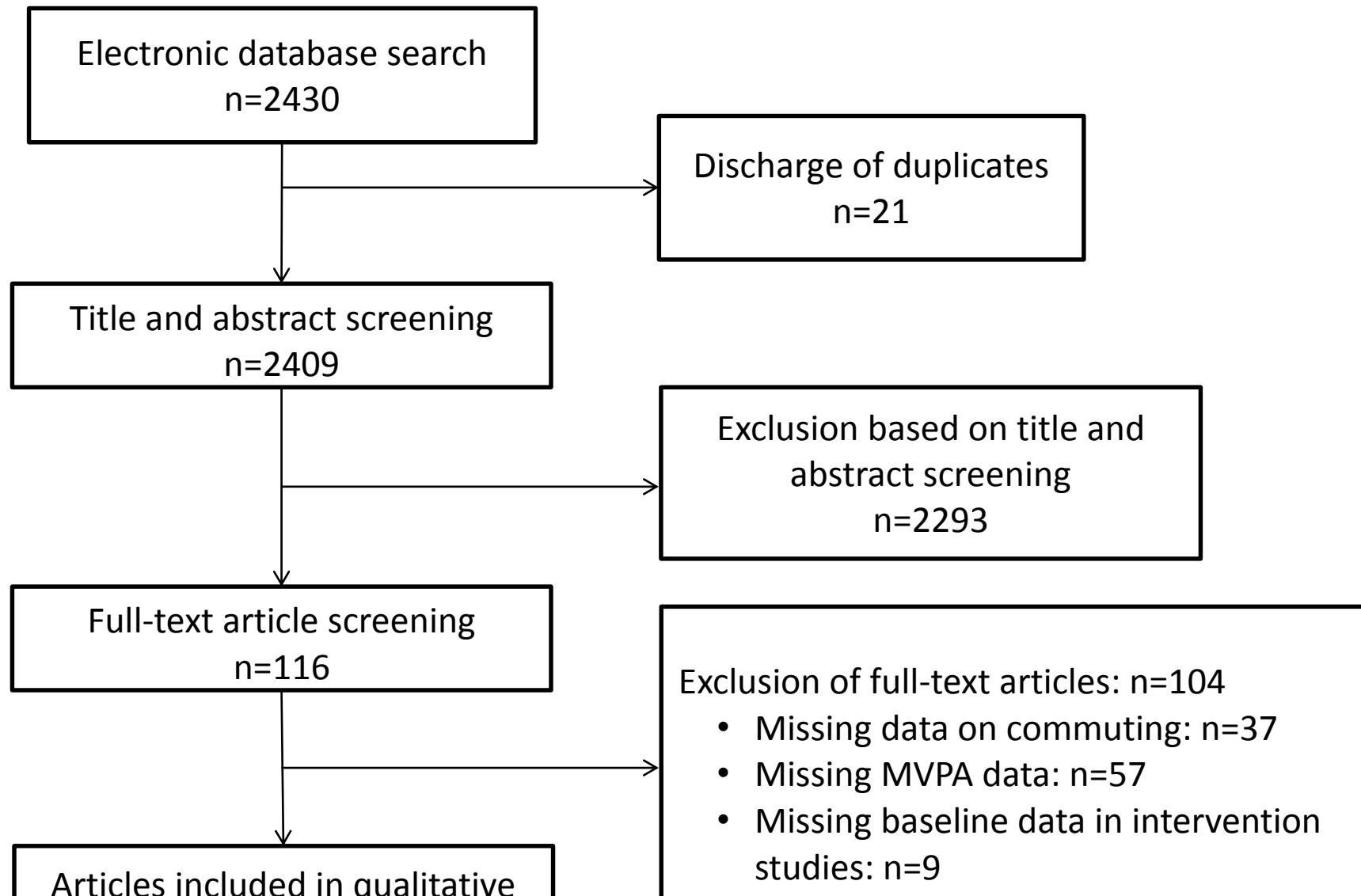**TABLE 4 Contribution of Walking to and From School to Daily MVPA in High School Studies**

Study, Year, Setting	Method and Cut Point	Sample Size; Mean (SD) age	Mean total schoolday MVPA [minutes/day]	Mean MVPA Walking to/from school [minutes/day]	Quality Rating
Mendoza et al 2011, USA (28)	ActiGraph 7164, Freedson cutpoint [a]	789; 14.4y (SE 0.1)	30 (SE 2)	9 (SE 1)	6
Klinker et al 2014, Denmark (22)	ActiGraph GT3X,$\geq$ 2296 cpm	367; 13.2y (0.2)	Median 64 (IQR 42-97)	Median 10 (IQR 5-16)	5
Cooper et al 2012[b], England (6)	ActiGraph GT1M, > 2295 cpm	500; 12y (0.4)	63 (SD 23)	18 (SD not given)	6
Saksvig et al 2012, USA (39)	ActiGraph 7164, $\geq$ 3000 cpm	944; 14y(SD not given)	26 (SD 2)	14 (SD 1)	6

[a]Freedson MVPA cut-point (16) equivalent to 1546cpm in 14y olds , using the following equation

METS = 2.757 + (0.0015 x counts/min) – (0.08957 x age (yr)) – (0.000038 x counts/min x age (yr))

[b]Secondary school data from Cooper et al 2012 (6).

Daily MVPA estimates are schoolday MVPA in study participants who walked to school regularly. MVPA: moderate-to-vigorous physical activity, cpm:
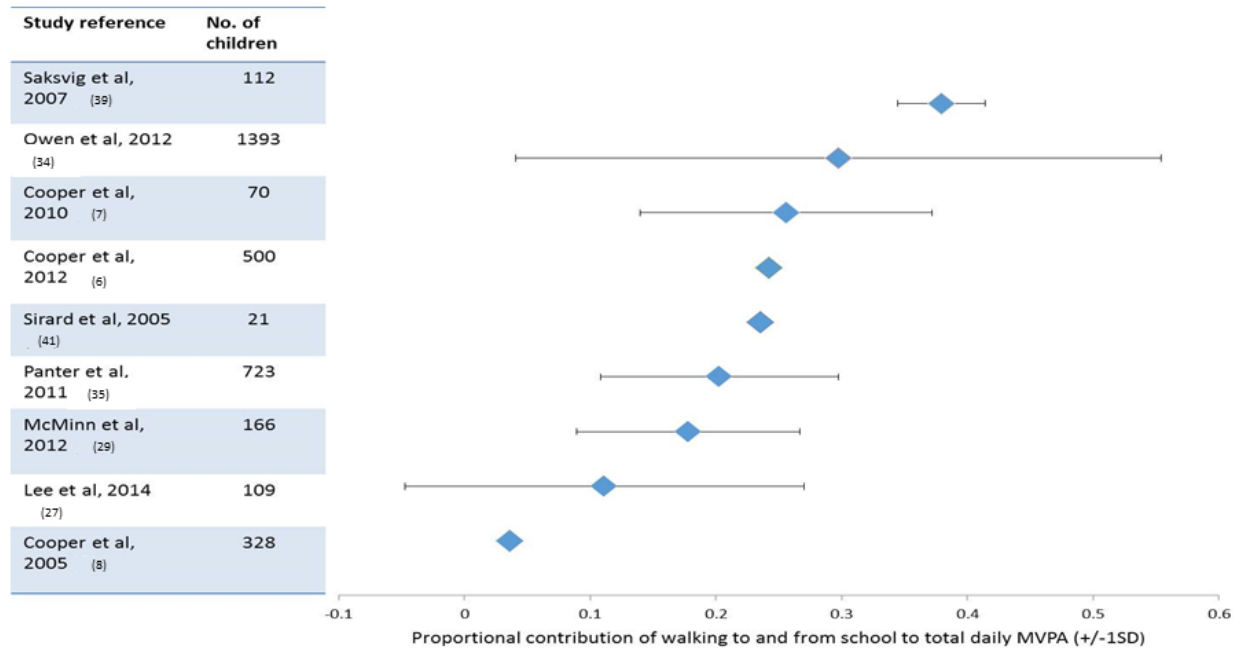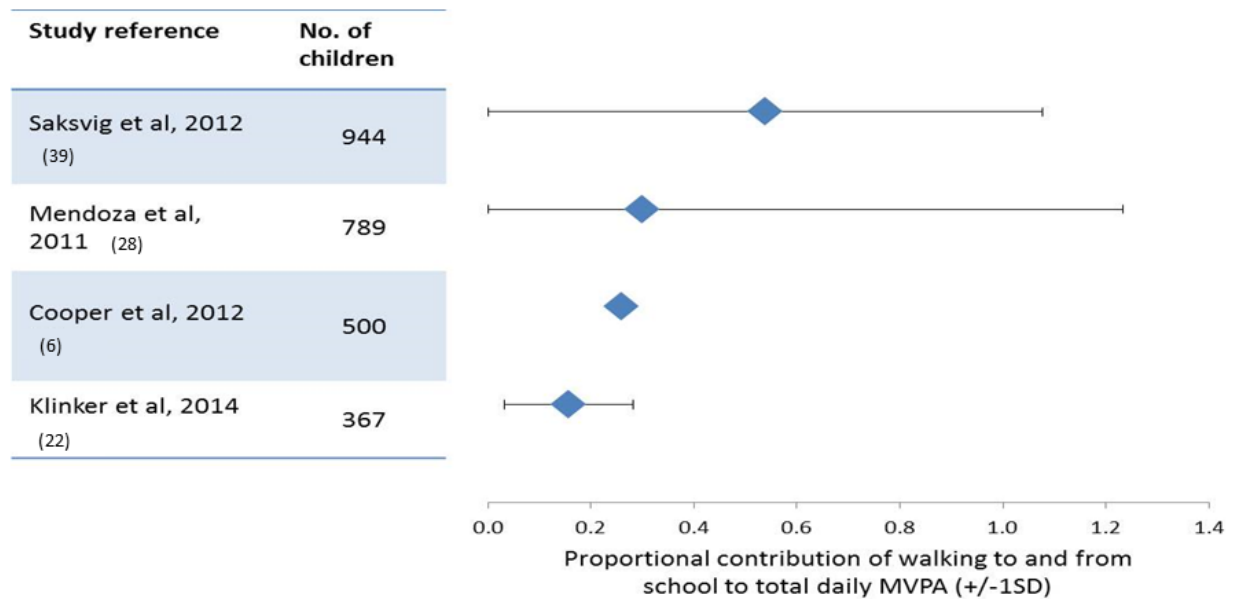
counts per minutes

Electronic database search
n=2430

Discharge of duplicates
n=21

Title and abstract screening
n=2409

Exclusion based on title and
abstract screening
n=2293

Full-text article screening
n=116

Exclusion of full-text articles: n=104
- Missing data on commuting: n=37
- Missing MVPA data: n=57
- Missing baseline data in intervention
  studies: n=9

Articles included in qualitative

A

B

Figure 2 Proportional contribution (mean, SD) of daily walking to and from school to total moderate-to-vigorous physical activity (MVPA) on schooldays. A: Primary school pupils, B: High school pupils.