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Article Title: Tracking the Commute Home From School Utilising GPS and Heart Rate Monitoring: Establishing the Contribution to Free-Living Physical Activity

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ABSTRACT

Background: Active school commuting is widely regarded as a key opportunity for youth to participate in physical activity (PA). However, the accurate measurement of the commute journey home from school and its contribution to total free-living moderate-to-vigorous PA (MVPA) is relatively unexplored. ***Methods***: 75 adolescents (38 males, 37 females) wore an integrated GPS and heart rate device during after-school hours for four consecutive weekdays. ***Results***: Active commuters were significantly more active (11.72 minutes MVPA) than passive commuters (3.5 minutes MVPA) during their commute home from school (p=0.001). The commute journey home of walkers and cyclists on average contributed 35% of their total free-living PA. However, there was no significant difference in the overall free-living PA levels of passive and active commuters (p>0.05). 92.7% of youth living within 1.5 miles of the school actively commuted, compared to 16.7% of youth who lived further away. Socio-economic differences in commuting patterns were also evident. ***Conclusions***: The findings highlighted the significant proportion of total free-living PA that was attributed to active commuting home from school. The study demonstrates the usefulness of utilising GPS and heart rate data to accurately track young people's after-school PA. Demographic influences and implications for future research are discussed.

Key words: youth, global positioning system, active commuting, free-living physical activity.

INTRODUCTION

The commute patterns of young people travelling to school have been extensively explored in previous literature, with an array of studies supporting the contribution of active commuting to overall PA levels[1,2] and health.[3,4] Given the opportunity that active school commuting provides in terms of regular and habitual PA in youth,[5] it is unsurprising that school commuting patterns have been broadly targeted by a number of PA promoting intervention studies.[6,7] Such widespread interest in school commuting patterns has been fuelled by internationally declining rates of youth actively commuting to school.[2,8] The proportion of youth in the UK actively commuting to and from school has significantly declined over the past three decades,[9] with the West Midlands (Central England) in particular having the lowest proportion of youth cycling to and from school compared to other regions in England.[10]

Whilst young people's school commuting patterns have been widely researched, it has been reported that inconsistencies and inaccuracies in the measurement of commute type and commute journey are a major limitation in many previous studies.[3] This is predominantly a methodological issue, as the vast majority of previous studies measured commute type and commute journeys using subjective methods, whilst others utilised traditional objective motion sensors. Both of these traditional methods lack the ability to precisely measure integral commute information such as the exact route travelled, the precise commute time (excluding and accounting for potential stop-offs) and the independent contribution of the commute journey to daily PA.

It has been outlined in a review by Lee et al[8] that despite significant research interest, it is difficult to determine whether active commuting leads to increased PA or whether active youth are simply more likely to actively commute to and from school. Lubans et al[3] concluded that a future strategy for improving such methodological issues in measuring commuting patterns could utilise new systems such as global positioning system (GPS) devices. A study by Cooper et al[11] measured children’s commute to school over a two day period using GPS combined with accelerometers; the findings of this study supported the utilisation of these tools in objectively tracking children’s movement. It also indicated the need for future studies to explore the potentially crucial after-school time period in which young people travel home from school.[11] The current study utilises GPS to track adolescents’ commuting patterns when travelling home from school over a four day period. The study aims to accurately measure the precise contribution of the commute journey to overall free-living (after school) PA levels in a sample of youth from Central England. Furthermore, it aims to explore disparities in commuting patterns between youth according to gender and socio-economic background.

METHODS

Participants

The study was conducted in Central England, and all participants were 13-14 year-olds from a convenience sample of five secondary schools. A total of 125 participants were invited to participate in the study and written informed consent was obtained from a parent or legal guardian of 112 adolescents. A final sample of 75 adolescents (38 males, 37 females) provided sufficient data to be included within the study. The schools were identified based on their demographic characteristics, with socio-economic status, ethnic minority representation and geographical location determined by census data and each schools’ latest Ofsted report. The majority of participants (51%) were from suburban, higher than average socio-economic status (SES) backgrounds, although subsamples of rural (24%) and lower SES (25%) youth were also represented within the sample. The overwhelming majority of participants were white Caucasian. Statistics regarding the percentage of children eligible for free-school meals were used to determine socio-economic status, in accordance to the schools' latest Ofsted report. The data collection was conducted during the warmer months of the school year (in the late spring and summer term). Institutional ethical approval was granted for this study.

Measures

A Garmin Forerunner 305 (Garmin Ltd., Olathe, KS, USA) GPS device was utilised to track young people's commute journey home from school and free-time during the remainder of the day, over four consecutive weekdays. The GPS device was worn as a wrist watch and provided an objective measure of a range of PA and commute journey information, such as location, speed, distance travelled, elevation, pace, and calories expended. This device was synchronised and wirelessly connected with a heart rate monitor, to provide an additional indication of PA intensity. Previous literature has supported the feasibility and validity of this method in measuring young people's PA.[12-14] To ensure that battery life was sufficient to record daily free-living PA, data points were recorded at inconsistent intervals, whenever there was a significant change in the participants' movements (i.e., speed, direction, elevation, distance) or heart rate. In accordance with previous studies utilising GPS to measure commute journey,[11,15] the majority of participants also completed a daily subjective activity diary that was an adapted version of the Heyward[16] activity log. This provided a participant-reported account of their free-living activities, including the commute journey home from school. Previous research supports the use of activity diaries as a measure of PA in adolescents,[17] and it was used here for triangulation purposes. It was also utilised to establish participant activities when they were not wearing the GPS device and when there was signal drop-out, as recommended in previous studies.[18] Body Mass Index (BMI) measurements were recorded (without shoes or excess clothing) and in accordance with International Obesity Task Force (IOTF) criteria, age and gender-specific

BMI cut-off points were used to establish obesity classification.[19] Height was measured to the nearest 0.5 centimetre using a Seca portable height measure (Seca Ltd., Hamburg, Germany) and mass was measured to the nearest 100 grams using Seca scales (Seca Ltd., Hamburg, Germany).

Procedure

The adolescent's activities for this study were recorded during their free-time after school, including their commute home at the end of the school day. Following detailed written and verbal instructions, each participant wore the GPS and heart rate monitor during after-school hours for four consecutive weekdays. Adolescents were required to return the devices to the researcher on a daily basis (each morning when arriving at school). This allowed the researcher sufficient time to upload all of the participants' GPS data, clear the memory and fully recharge the GPS units,[20] before returning them to the students later in the school day. As the adolescents were not required to recharge the devices themselves, this minimised participant burden whilst also allowing the researcher to conduct daily checks to ensure that the research procedure was being adhered to (i.e., participants were wearing the device, completing the activity diary and the GPS devices were in working order).

Once collected, the data was manually cleaned before the participants' commute journey was extracted, so that it could be accurately and independently analysed. Commute journey data were classified as the data points from when the participant left the school building (at the end of the school day) until the first data point whereby the participant had reached their home. In order to accurately represent the commute journey home, stop-offs (e.g. at a friend's house) were not included in the recording of commute journey information, as these could be lengthy and skew commute information such as commute time or MVPA. For each of the participants' commute journeys, the researcher recorded whether the journey was direct or indirect. The GPS data is automatically merged with the heart rate data (with each data point collected, recording both participant location and heart rate). The locational data was then cross-checked with the self-reported activity diaries. As conducted in previous literature[15], data recorded for the remainder of the free-time (between the arrival home and bedtime) were also independently analysed using analysis of variance (ANOVA) to explore potential gender and SES differences in youth. Comparisons were then analysed between the adolescents' commute PA levels and overall free-living PA levels, to establish potential associations between commute activeness and overall activeness.

Statistical analysis

Descriptive statistics and analysis of variance (ANOVA) were utilised to establish the presence of any statistically significant differences in the commute patterns of youth when comparing genders, type of commute, and SES. A priori power analysis using G*Power 3.1 (with an alpha error probability power of .05, power of 0.85 and effect size of F=0.4) indicated that a sample size of 75 participants was sufficient to identify within the ANOVA, statistically significant differences in the MVPA levels of active and passive commuters. In all statistical analyses, a two-tailed significance value of $p < 0.05$ was adopted. PA data were log10 transformed to establish a normal distribution. For clarity, as there were no differences in analyses when using transformed or untransformed data, untransformed values are presented within the study's results, as conducted in previous literature.[21] Pearson correlations were performed to establish relationships between commute activity levels and PA during the remainder of young people's free-time. The geographical information software (GIS) used to interpret the location data was the Garmin training centre and Garmin Connect programs (Garmin Ltd., Olathe, KS, USA). SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

To ensure that the current study findings are comparable with previous literature, two MVPA cut-off points were utilised to account for 140 bpm and 120 bpm MVPA thresholds.[12,15,22,23] This increased the transparency of the PA intensity findings. For inclusion in the data analyses, adolescents had to provide a minimum of 3 hours of combined GPS and heart rate data for at least one day.[21] As there was a strong likelihood of varying participant compliance and subsequently differing numbers of days completed by each participant, the mean daily PA data was stacked and weighted in accordance with the number of days that each participant provided at least 3 hours of full data. The percentage of youth that provided sufficient combined heart rate and GPS data on 3 weekdays (41.3%), was higher than the percentage of youth that provided 1 (26.7%), 2 (16%) or 4 (16%) days of data. As conducted in previous research utilising GPS and heart rate monitoring,[15] all statistical analyses conducted on the free-living and commute PA data were based on the weighted statistics. The weighting of statistical data is fully discussed elsewhere[24] and ensures that the findings provide a fairer reflection on the average daily commute and free-living PA levels of participants.

RESULTS

Whilst all 75 adolescents provided GPS data of their commute home from school, 13 adolescents did not provide heart rate data during their commute journey. The majority of adolescents walked home from school (57.4%) and others travelled via bicycle (4%), bus (17.3%), or car (21.3%). As in previous research,[25] participants were categorised as either active (walkers and cyclists) or passive commuters (bus and car users). Only a minority of youth significantly deviated from a direct route home from the school gates, with 95% travelling directly home and 3% visiting a recreational facility such as a public park or playground en-route to their home.

Comparing Active and Passive Commuters

A two-way ANOVA revealed a highly significant difference in the PA levels of active and passive commuters during their journey home from school ($F_{(3,61)}$=12.667, *p*=0.001). Active commuters on average participated in 11.72 (± 13.82) minutes of MVPA during their journey home, whilst passive commuters only participated in 3.5 (± 5.66) minutes. Although there were significant differences between commute modes, no gender differences were evident (*p*>0.05). Also, when conducting the same analysis with the higher MVPA threshold of 140 bpm, the findings were similar, with a highly significant difference in commute MVPA between active and passive commuters ($F_{(3,61)}$=8.770, *p*=0.004).

A two -way ANOVA revealed no significant difference in the BMI scores of active and passive commuters or males and females (*p*>0.05). However, on average, passive commuters (3.38±1.77 miles) lived significantly further from school ($F_{(3,61)}$=60.376, *p*<0.001) compared to active commuters (0.95±0.85 miles). Descriptive statistics for the analyses above are presented in Table 1.

When comparing the overall daily MVPA of youth, there was no significant difference in the overall free-living PA levels of active and passive commuters regardless of whether the 120 bpm or 140 bpm threshold was used (both, *p*>0.05). Furthermore, when utilising the 120 bpm cut-off point, 23.7% of active commuters and 29.2% of passive commuters achieved the recommended 60 minutes MVPA guidelines. However, when applying the 140 bpm threshold, only one adolescent from the whole sample participated in over 60 minutes of MVPA.

When focusing on the young people's free-living PA excluding the commute journey home, a two-way ANOVA revealed no significant difference in the MVPA levels of active and passive commuters, regardless of MVPA cut-off point (*p*>0.05). This is highlighted in the descriptive statistics in Table 1. A Pearson correlation also revealed no significant relationship between the number of minutes in MVPA during the commute and the number of minutes in MVPA during the remainder of the day (r=0.012, $p>0.05$). This provides further evidence that active commuters are generally no more active than passive commuters during the rest of their free-time.

Figure 1 illustrates the difference in total daily MVPA between active and passive commuters whilst also indicating the proportion of MVPA contributed by the commute journey (for the 120 bpm MVPA threshold). As illustrated, the contribution of the commute journey to total MVPA is significantly influenced by the mode of the commute. This is highlighted by comparing the average contribution of commute MVPA (>120 bpm) to overall daily MVPA in walkers (34.23%±30.53%), cyclists (56.56%±45.08%), bus users (29.08%±50.72%) and car users (9.51%±18.25%).

There was a significant difference in the composition of active and passive commuters' total daily MVPA ($F_{(3,61)}=6.242$, $p=0.015$) when applying the 120 bpm threshold. As illustrated in Figure 1 and Table 1, a significantly higher proportion of active commuters' total MVPA consisted of MVPA during the commute journey (35.24%), compared to passive commuters (18.32%). Furthermore, a Pearson correlation revealed a significant positive relationship between number of minutes in MVPA during the commute and the number of minutes in total free-living daily MVPA in active commuters (r=0.263, $p=0.039$), but not passive commuters ($p>0.05$). This underlines the valuable contribution of young people's active commuting home from school, and its overall contribution to total MVPA. A strong positive relationship was apparent (r=0.968, $p<0.001$) when correlating overall free-living MVPA with MVPA during the remainder of the day (excluding the commute journey MVPA). This emphasises the importance of additional PA during young people's free-time in contributing to overall daily PA level.

92.7% of youth who lived within 1.5 miles of the school actively commuted home, whilst only 16.7% of youth who lived further than 1.5 miles actively commuted home from school. Only one adolescent (a cyclist) commuted a distance greater than 2.2 miles. These results underline the significant impact that commute distance has on young people's commute choice. These calculations were based on the approximate measurement of commute distance calculated by a GIS. As illustrated in Figure 2, when correlating the GIS approximated distance with the GPS measured distance, there was a highly significant positive relationship (r=0.919, $p<0.001$).

Comparing high and low socio-economic status (SES) youth

A two-way ANOVA revealed a significant interaction in the commute MVPA levels of youth between gender and SES ($F_{(3,61)}=6.752$, $p=0.018$). Males (21.36±12mins) participated in substantially more commute MVPA (>120 bpm) than females (10.46±10.49mins) in low SES youth, whilst in high SES youth, females (7.57±10.70mins) were slightly more active during their commute compared to males (5.39±11.21mins). These descriptive statistics also demonstrate the significant difference in the commute MVPA of high and low SES youth ($F_{(3,61)}=14.030$, $p<0.001$). 60% of low SES females actively commuted home from school compared to 88.9% of low SES males. Whilst there was a substantial gender difference in the commute activity level of low SES youth, there was, however, no significant difference in the distance that low SES males (0.99 miles) and females (0.93 miles) travelled home from school ($p>0.05$).

Whilst there was no significant difference in commute distance between genders, a significant difference in the commute distance of low and high SES youth was evident ($F_{(3,74)}=5.838$, $p<0.018$) with low SES youth commuting a significantly shorter distance (0.95 miles) compared to high SES youth (2.14 miles). When controlling for commute distance, a two-way analysis of covariance (ANCOVA) revealed that the difference in commuting MVPA due to SES was still statistically significant ($F_{(3,61)}$=9.768, p=0.003). 57.1% of high SES youth actively commuted home from school, compared to 73.7% of low SES youth. When applying the higher 140 bpm MVPA threshold, the findings replicated those at the lower MVPA threshold (>120 bpm).

DISCUSSION

Previous literature has questioned whether active school commuting makes youth more active or whether active youth are simply more likely to actively commute.[8] The current study provides no evidence to support a proposition that young people's commute mode is predominantly determined by their overall activity level,[26] with a slightly higher percentage of passive commuters (29.2%) attaining the recommended guidelines of 60 minutes of daily MVPA, compared to active commuters (23.7%). Furthermore, there was no significant correlation between commute activity level and PA for the remainder of the day, and no significant differences were evident in either overall daily free-living MVPA or remaining free-living MVPA (excluding the commute journey) between active and passive commuters (p>0.05). These findings support a longitudinal study by Carver et al[27] that found no association between active transport and daily MVPA for mid-adolescent aged youth. Despite the lack of association between commute mode and overall daily free-living MVPA, a substantial proportion of active commuters' total free-living MVPA was contributed by their commute journey home from school. This underlines the important contribution that active commuting made to the total daily PA levels of walkers and cyclists.

Although the findings of the current study concur with that of Carver et al,[27] they do not support several previous studies which outlined a strong positive association between active commuting and youth PA levels throughout the whole day and during leisure time.[1,28-

[30] The contrast between the findings of the current study and previous literature may be due to methodological differences. The current study focused on measuring young people's commute journey home from school and the remainder of the evening for each testing day. Bearing in mind that youth are also required to commute to school in the morning, the daily amount of PA contributed by active commuting may potentially be double the values reported in the current study. Subsequently, the study findings need to be interpreted with this point in mind. Furthermore, whilst the vast majority of previous literature has focused on the morning commute journey to school,[2] the afternoon journey may have a greater impact on young people's free-living PA during after-school hours. Thus, the findings of the current study raise the question of whether youth who actively commuted home from school compensated for their active commute during the rest of the day. Whilst previous research has explored the potential stimulatory or compensatory effects of school-based recess and physical education lessons on total PA in youth,[31,32] further investigations into the potential effects of active commuting would be intriguing. Whilst the current study findings do not provide conclusive evidence, descriptive statistics indicated that passive commuters (42.39 minutes MVPA) were more active during the remainder of the day compared to active commuters (31.44 minutes MVPA).

Rather than young people's general 'activeness' being the primary influence on their choice of commute type, as highlighted in previous literature,[33,34] the predominant influence appears to be the distance between the school and the home. Passive commuters travelled significantly further compared to active commuters, with 92.7% of youth who lived within 1.5 miles of the school actively commuting home, and no adolescents walking further than 2.2 miles. Only 16.7% of youth who lived further than 1.5 miles actively commuted home from school. These results support the findings of Nelson et al[35] who also found that the vast majority of adolescent walkers lived within 1.5 miles, and cyclists within 2.5 miles of the school. It can be implied from such findings that commute distance is a major barrier to youth who live 1.5 miles or more from the school. In light of these outcomes, trends indicating that young people are now living further away from schools compared to previous generations are very concerning,[36] with literature citing urban planning and school relocations as major obstacles to the promotion of active commuting.[37]

In order for future researchers and policy makers to overcome the substantial barrier of commute distance, the promotion of cycling may provide a more viable and time efficient form of active commuting for youth who live greater than 1.5 miles. The current study highlights the substantial MVPA contribution of cycling home from school (28.11±23.96mins MVPA), providing support for a range of research studies, interventions and policies[38-41] that promote cycling as an active and healthy mode of transport. Such schemes and studies recognise the importance of enhancing the built environment to promote cycling through the provision of safe and cycle friendly environments.

Previous literature has indicated that males are more likely than females to actively commute to and from school.[42,43,2] However, the current study revealed no gender differences in the commute mode of youth. Nevertheless, a gender difference was evident within the commuting patterns of low SES youth, with 60% of females and 88.9% of males from low SES backgrounds actively commuting home from school. This gender difference within low SES youth cannot be attributed to commute distance disparities, as the average commute distance of low SES males (0.99 miles) and females (0.93 miles) were equivalent. Other social and environmental factors may underlie this gender commute pattern imbalance. Safety concerns, with parents being more protective of girls than boys[44,2] is one such factor.

Consistent with previous research,[45,2] low SES youth were significantly more active during their commute home from school (15.69mins MVPA) compared to high SES youth (6.44mins MVPA). A study by Zhu and Lee[46] indicated that youth from a low SES or ethnic minority background had shorter school commute distances but greater perceived safety risks and poor street environments. Whilst acknowledging the disparity in subgroup sample size, the current study also found that low SES youth lived significantly closer to the school (0.95 miles) compared to high SES youth (2.14 miles). However, even when the statistical analysis was adjusted to control for commute distance, a significant difference in the commute MVPA levels of high and low SES youth was still evident. Future studies could use a mixed-methods approach to further explore environmental and social perceptions whilst utilising GPS to track the commute journey of youth.

Whilst the current study provided a detailed insight into young people's commute journey home from school and its contribution to overall free-living MVPA, there are some limitations to the study. Firstly, the limited battery-life and memory capacity of the GPS devices makes full day's testing of youth PA patterns problematic. Subsequently, young people's free-time from the end of the school day until their bed-time was specifically targeted. This allowed for the detailed measurement of youth PA during the commute home and remainder of the day, but does not account for other potentially crucial PA opportunities throughout the adolescents' school day (e.g. commute to school, Physical Education lessons and recess times).[47] Therefore, conducting studies utilising GPS to encompass all of the PA opportunities in young people's average weekday is a key recommendation for future research. Such studies would advance current understanding of young people's movement patterns and PA opportunities during a 'normal' day within their own natural built environment.

The measurement of the commute journey home from school using GPS on a large scale is complex.[11] Research employing larger samples of equal numbers of low and high SES groups should be considered in future work. Future studies, employing a larger and more representative sample size would potentially help in consolidating the preliminary conclusions from this study. The current study is limited by its cross–sectional design, hindering the study's ability to establish causal effects. Furthermore, its use of standardised cut-off points to establish MVPA thresholds, do not differentiate between the varying fitness levels of each participant. Future studies could account for individual differences by measuring resting heart rate to determine heart rate reserve, whilst some studies using GPS have supported the utilisation of accelerometers in measuring MVPA in youth.[11,14,21] Despite such limitations, the current study provides further support to the appropriateness of utilising GPS devices in providing accurate and objective measures of young people's PA. The findings provide support for the importance of active commuting to the overall free-living PA of youth. Demographic and environmental influences have also been acknowledged.

CONCLUSION

The current study provides a detailed insight into the commute patterns of young people when travelling home from school, and highlights the substantial contribution of active commuting to overall free-living MVPA in walkers and cyclists. The study provides a valuable insight into the utilisation of GPS technology in tracking young people's commuting patterns and provides intriguing comparisons between youth from different demographic backgrounds. It also addresses calls from previous research to utilise GPS technology in the measurement of active school commuting patterns[3] and to focus on young people's PA patterns during the time period after-school.[48,11] The findings highlight commute distance as a major determinant for commute mode in youth, although the high proportion of youth who lived within 1.5 miles of the school and actively commuted was encouraging. Future research and intervention studies may wish to focus on the promotion of cycling as a means of encouraging youth who live further than 1.5 miles away from the school to actively commute. Environmental and social determinants should also be further explored and both transport and health policies should differentiate between the needs of youth from different demographic backgrounds.

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REFERENCES

1. Faulkner GEJ, 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 (1): 3-8.
2. Davison KK, Werder JL, Lawson CT. Children's active commuting to school: Current knowledge and future directions. *Prev Chronic Dis*. 2008; 5(3): 100.
3. Lubans DR, Boreham CA, Kelly P, Foster CE. The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. *Int J Behav Nutr Phys Act*. 2011; 8:5.
4. Hamer M, Chida Y. Active commuting and cardiovascular risk: A meta-analytic review. *Prev Med.* 2008; 46(1): 9-13.
5. Tudor-Locke C, Ainsworth BE, Popkin BM. Active commuting to school: An overlooked source of childrens' physical activity? *Sports Med.*2001; 31(5): 309-313.
6. Heelan KA, Abbey BM, Donnelly JE, Mayo MS, Welk GJ. Evaluation of a walking school bus for promoting physical activity in youth. *J Phys Act Health.* 2009; 6: 560-567.
7. Boarnet MG, Day K, Anderson C, McMillan T, Alfonzo M. California's safe routes to school program: impacts on walking, bicycling, and pedestrian safety. *J Am Plann Assoc.* 2005; 71(3): 301-17.
8. Lee MC, Orenstein MR, Richardson MJ. Systematic review of active commuting to school and children's physical activity and weight. *J Phys Act Health.*2008; 5: 930-949.
9. Stratton G, Fairclough SJ, Ridgers, ND. Physical activity levels during the school day. In: Smith AL, Biddle SJH, ed. Youth physical activity and sedentary behaviour: Challenges and solutions. Champaign, Ill: Human Kinetics; 2008.

10. Department for Transport. NTS9908 - Trips to and from school by main mode - region and area type: Great Britain, 2009/2010. *National Travel Survey Statistics*, 2012.
11. 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(2): 178-183.
12. Fjortoft I, Lofman O, Thoren, KH. Schoolyard physical activity in 14-year-old adolescents assessed by mobile GPS and heart rate monitoring analysed by GIS. *Scan J Public Health*. 2010; 38: 28-38.
13. Duncan JS, Badland HM, Schofield G. Combining GPS with heart rate monitoring to measure physical activity in children: A feasibility study. *J Sci Med Sport*. 2009; 12: 583-585.
14. Jones AP, Coombes EG, Griffin SJ, van Sluijs EMF. Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems. *Int J Behav Nutr Phys Act*. 2009; 6: 42.
15. Collins P, Al-Nakeeb Y, Nevill A, Lyons M. The impact of the built environment on young people's physical activity patterns: A suburban-rural comparison using GPS. *Int J Environ Res Public Health.* 2012; 9; 3030-3050.
16. Heyward VH. *Advanced Fitness Assessment and Exercise Prescription.* 6th Ed. Champaign, Ill: Human Kinetics; 2010.
17. Greene JC, Caracelli VJ, Graham WF. Toward a conceptual framework for mixed-method evaluation designs. *Educ Eval Pol Anal.* 1989; 11: 255-274.
18. Maddison R, Jiang Y, Hoorn SV, Exeter D, Mhurchu CN, Dorey E. Describing patterns of physical activity in adolescents using global positioning systems and accelerometry. *Pediatr Exerc Sci.* 2010; 22: 392-407.

19. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing the standard definition for child overweight and obesity worldwide: International survey. *Br Med J.* 2000; 320: 1240-1243.
20. Maddison R, Mhurchu CN. Global positioning system: a new opportunity in physical activity measurement. *Int J Behav Nutr Phys Act*. 2009; 6: 73.
21. Cooper AR, Page AS, Wheeler, BW, Griew P, Jago R. Patterns of GPS measured time outdoors after school and objective physical activity in English children: The PEACH project. *Int J Behav Nutr Phys Act*. 2010; 7: 31.
22. Sleap M, Tolfrey K. Do 9- to 12 yr-old children meet existing physical activity recommendations for health? *Med Sci Sports Exerc.* 2001; 33(4): 591–596.
23. Durrant RH, Baranowski T, Davis H, Rhodes T, Thompson WO, Greaves KA, Puhl J. Reliability of indicators of heart rate monitoring in children. *Med Sci Sports Exerc.* 1993; 25(3): 389-395.
24. Little RJA, Rubin DB. *Statistical Analysis with Missing Data*. 2nd Ed. New Jersey, Wiley Press; 2002.
25. Andersen LB, Lawlor DA, Cooper AR, Froberg K, Anderssen SA. Physical fitness in relation to transport to school in adolescents: the Danish youth and sports study. *Scand J Med Sci Sports*. 2009; 19(3): 406–411.
26. Department of Health, Physical Activity, Health Improvement and Protection. *Start active, stay active: a report on physical activity from the four home countries' Chief Medical Officers.* London, Department of Health; 2011.
27. Carver A, Timperio AF, Hesketh KD, Ridgers ND, Salmon JL, Crawford DA. How is active transport associated with children's and adolescents' physical activity over time? *Int J Behav Nutr Phys Act*. 2011; 8:126.

28. Alexander LM, Inchley J, Todd J, Currie D, Cooper AR, Currie C. The broader impact of walking to school among adolescents: seven day accelerometry based study. *Br Med J.* 2005; 331: 1061- 1062.
29. Cooper AR, Page AS, Foster LJ, Qahwaji D. Commuting to school: are children who walk more physically active? *Am J Prev Med*. 2003; 25: 273-276.
30. Santos MP, Oliveira J, Ribeiro JC, Mota J. Active travel to school, BMI and participation in organised and non-organised physical activity among Portuguese adolescents. *Prev Med.* 2009; 49: 497-499.
31. Dale D, Corbin CB, Dale KS. Restricting opportunities to be active during school time: do children compensate by increasing physical activity levels after school? *Res. Q. Exerc. Sport*. 2000; 71: 240–248.
32. Alderman BL, Benham-Deal T, Beighle A, Erwin HE, Olson RL. Physical education's contribution to daily physical activity among middle school youth. *Ped Exerc Sci.* 2012; 24: 634-648.
33. McDonald NC. Active transportation to school: trends among U.S. schoolchildren, 1969–2001. *Am J Prev Med.* 2007; 32: 509–516.
34. Babey SH, Hastert TA, Huang W, Brown R. Sociodemographic, family, and environmental factors associated with active commuting to school among US adolescents. *J Public Health Policy*. 2009; 30: S203-220.
35. Nelson NM, Foley E, O'Gorman DJ, Moyna NM, Woods CB. Active commuting to school: How far is too far? *Int J Behav Nutr Phys Act*. 2008; 5: 1.
36. Ham SA, Martin S, Kohl III HW. Changes in the percentage of students who walk, or bike to school – United States, 1969-2001. *J Phys Act Health.* 2008; 5: 205-215.
37. Badland H, Schofield G. The built environment and transport-related physical activity: What we do and do not know. *J Phys Act Health.* 2005; 2: 435-444.

38. Dill J. Bicycling for transportation and health: The role of infrastructure. *J Public Health Policy*. 2009; 30: S95-S110.
39. Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: Lessons from Netherlands and Germany. *Am J Public Health*. 2003; 93: 1509-1516.
40. Nelson AC, Allen D. If you build them, commuters will use them. *Transportation Res Rec.* 1997; 1578: 79-83.
41. Shephard RJ. Is active commuting the answer to population health? *Sports Med.* 2008; 38(9): 751-758.
42. Silva KS, Nahas MV, Borgatto AF, Oliveira ES, Del Duca GF, Lopes AS. Factors associated with active commuting to school and to work among Brazilian Adolescents. *J Phys Act Health.* 2011; 8: 926-933.
43. Van Dyck D, De Bourdeaudhuij I, Cardon G, Deforche B. Criterion distances and correlates of active transportation to school in Belgian older adolescents. *Int J Behav Nutr Phys Act.* 2010; 7: 87.
44. Mackett R, Brown B, Gong Y, Kitazawa K, Paskins J. Children's independent movement in the local environment. *Built Environ.* 2007; 33(4): 454–468.
45. McDonald NC. Critical factors for active transportation to school among low-income and minority students. *Am J Prev Med.* 2008; 34(4): 341-344.
46. Zhu X, Lee C. Walkability and safety around elementary school: Economic and ethnic disparities. *Am J Prev Med*. 2008; 34(4): 282-290.
47. Demetriou Y, Honer O. Physical activity interventions in the school setting: A systematic review. *Psych Sport Exerc.* 2012; 13:186-196.
48. Tudor-Locke C, Lee SM, Morgan CF, Beighle A, Pangrazi R. Children's pedometer-determined physical activity during the segmented school day. *Med Sci Sports Exerc.* 2006; 38(10): 1732–1738.

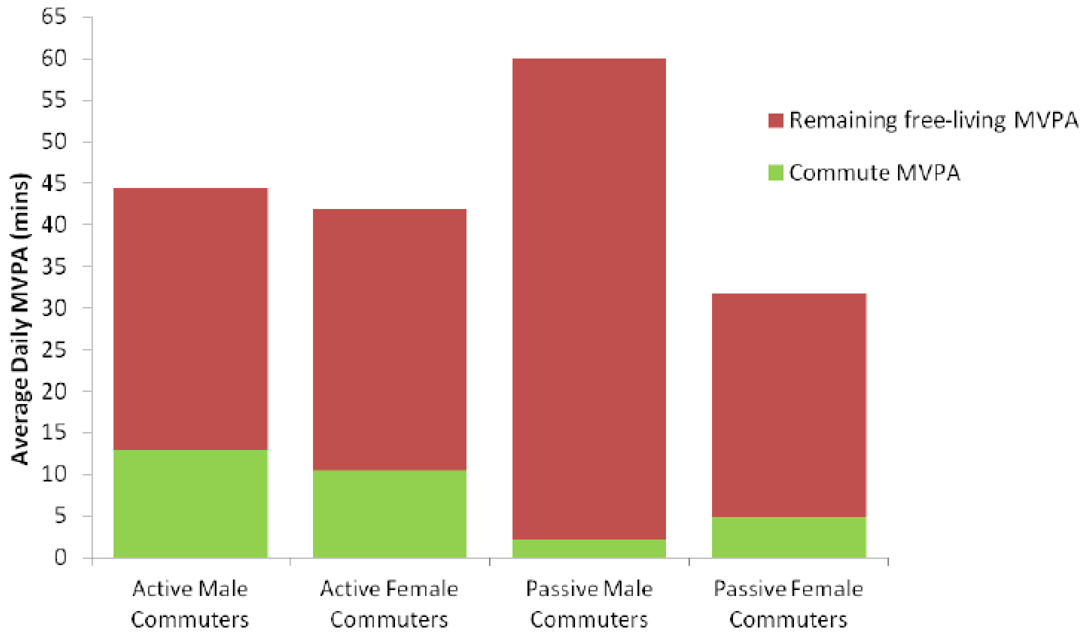

Figure 1. Average daily free-living MVPA (>120bpm) and the contribution of the commute journey.

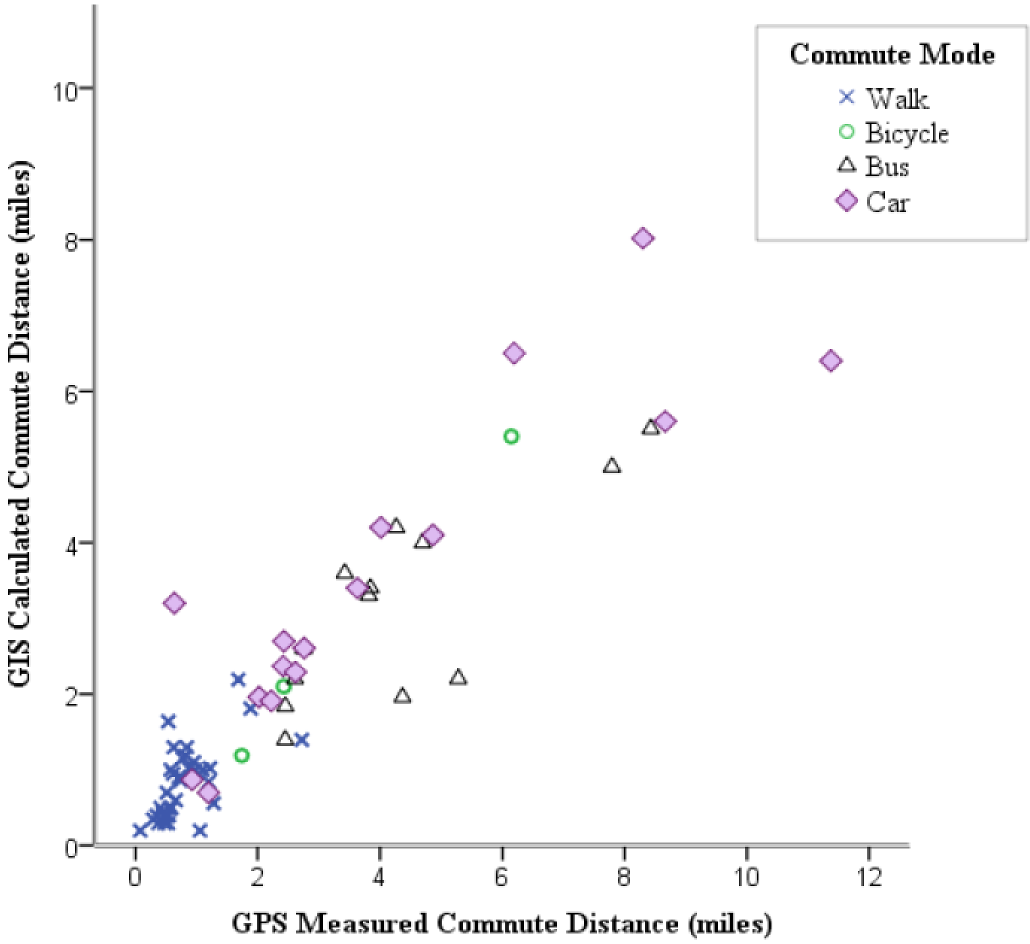

Figure 2. The correlation between GIS and GPS measured distance (r=0.919, p<0.001) and the impact on distance to commute type.

Table 1. Mean (±SD) BMI, PA and commute variables for active and passive commuters

Variable	**ACTIVE COMMUTERS**			**PASSIVE COMMUTERS**		
	Male ***n*=24**	**Female** ***n*=22**	**Total** ***n*=46**	**Male** ***n*=13**	**Female** ***n*=16**	**Total** ***n*=29**
Sample total (%)	32%	29.33%	61.33%	17.33%	21.33%	38.67%
BMI(Kg/m^2)	20.62±3.3	21.90±4.94	21.23±4.17	23.01±5.31	21.12±4.63	21.97±4.95
Commute MVPA (>120 bpm) (mins) **	12.89±15.71	10.48±11.85	11.72±13.82	2.22±3.35	4.78±6.82	3.5±5.66
Commute MVPA (>140 bpm) (mins) **	4.07±6.85	3.79±6.75	3.93±6.71	0.58±0.71	0.8±2.31	0.69±1.74
Average distance (miles) **	1.13±1.12	0.78±0.43	0.95±0.85	3.56±1.85	3.23±1.74	3.38±1.77
Total Daily MVPA >120 bpm (mins)	44.41±49.83	41.83±42.48	43.16±45.70	60±70.37	31.78±40.98	45.89±58.1
Proportion of total MVPA (>120 bpm) attributed to commute journey (%)	35.84±23.26	34.61±28.59	35.25±31.22	12.88±33.61	23.76±39.57	18.32±36.87
Total Daily MVPA >140 bpm (mins)	16.89±29.26	14.52±17.16	15.74±23.71	12.53±19.18	5.74±11.69	9.14±15.85
Proportion of total MVPA (>140 bpm) attributed to commute journey (%)	44.55±55.26	27.7±48.61	36.38±52.55	22.99±50.19	18.23±41.22	20.61±44.63

** Statistically significant difference between active and passive commuters ($p < 0.01$).