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An evaluation of distance estimation accuracy and its relationship to transport mode for the home-to-school journey by adolescents

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ABSTRACT

Walking is a feasible activity through which individuals can increase their minutes of physical activity. School proximity to residential homes is an important determinant of active commuting. This study tested the accuracy of participant's perceived distance in comparison to actual distance travelled to school, by mode of commuting, active or passive. Adolescents completed a questionnaire reporting mode and estimating distance and time taken for their usual trip to school. Subsequently, each participant drew the actual route travelled on a detailed street level map. Only those who lived within a criterion home-to-school distance (2.4 km; $N=199$, mean age 15.9 ± 0.56, range 15–17 years) were included in the analysis. Passive commuters erroneously thought they travelled significantly further to school than their active peers, no differences were found. Active commuters were accurate in their perception of distance travelled. For passive commuters, the average actual distance (1350 m) travelled to school was significantly shorter than their perception of this distance (2700 m; $U=2016.500$, $p<0.001$). Distance is an important perceived barrier to active commuting and a predictor of mode choice among adolescents. Interventions where accurate estimation of distance is taught could ameliorate this barrier and promote active transport choices.

1. Introduction

The increasing prevalence of overweight and obesity, coupled with reports of type II diabetes among youth highlights the importance of promoting daily physical activity (Bar-Or and Baranowski, 1994; Baranowski et al., 1992; Ogden et al., 2008). Physical activity guidelines (PAGL) have been developed and adopted by health authorities worldwide (World Health Organisation, 2010). These guidelines stipulate that in order to enhance health, *youth should accumulate at least 60 minutes of moderate-to-vigorous physical (MVPA) activity daily* (World Health Organisation, 2010; Department of Health and Children & Health Services Executive, 2009; U.S. Department of Health and Human Services, 2008). Adherence to these guidelines reduces the risk for cardiovascular disease and enhances mental and musculoskeletal health (Baranowski et al. 1992; Strong et al., 2005). Despite all the evidence of benefit, epidemiological data indicate that on average 80% of children do not meet current PA recommendations. By the age of 15 years, on average, across all Health Behaviour of School Aged Children countries (HBSC, $N=39$ countries; 1500 participants aged 15 years per country; covering most of Europe, North America and Canada), only 10% of girls and 19% of boys self-report sufficient MVPA (Currie et al., 2012).

2. The role of active school transport

Active school transport (AST: walking or cycling to or from school) provides children and youth with an important opportunity to attain daily minutes of MVPA. Those who engage in AST accrue more minutes of activity daily than those who use motorised transport (passive commuters) (Larouche et al., 2014; Faulkner et al., 2009) and expend twice as many calories per minute while walking as opposed to travelling by car (Mackett et al., 2005; Mendoza et al., 2011; Merom et al., 2006). Additionally, the formation of habitual daily patterns of physical activity in the lives of young people may confer lifelong health benefits, as physical activity has been shown to track from

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childhood and adolescence to adulthood (Telema et al., 2005). Conversely, children who are not allowed to walk or cycle to school are being conditioned to a life of inactivity with its associated health problems (Black et al., 2001). Although evidence of stabilisation in rates of AST have been reported in recent years (McDonald et al., 2011), the proportion of youth engaging in AST has declined significantly over the past decade (Department of Transport, 2001; Van DerPloeg et al., 2008; Buliung et al., 2009; Black et al., 2001). Less than half (40%) of Irish adolescents engage in AST (Woods et al., 2010), these levels are similar to those reported in Canada (Buliung et al., 2009), but less than those reported in England, Scotland and Australia (Sirard and Slater, 2008).

Research has found that the actual distance a child has to travel is significantly and independently associated with both frequent and regular active commuting. Essentially, the closer the school to the home, the more likely children and adolescents are to walk or cycle to school (Alexander et al., 2005; Black et al., 2001; Merom et al., 2006; Nelson et al. 2008; Panter et al., 2008; Sirard et al., 2005; Sirard and Slater 2008; Tudor-Locke et al., 2002). Timperio et al. (2006) examined the influence of route length for children aged 5–6 years and 10–12 years separately. For both groups, those who had a journey to school of less than 800 m were over 5 times more likely to report walking or cycling to school than those whose journey was greater. Only 30.6% of US children who live within 1 mile (1.6 km) of their school actively commute (McDonald et al., 2011). In Ireland, 22% of car users live within 1 mile, and 39% live within 2 miles of their school (Nelson et al., 2008). Perceived distance has been established as the most important barrier to AST among children and adolescents (Sirard and Slater, 2008; Nelson et al., 2008; Timperio et al., 2006; Nelson and Woods, 2010). Yet no studies were found that investigated how perceptions of distance can vary from actual distance and how this might impact on an adolescent's behaviour. Research is needed that is focused only on individuals who live close enough to walk or cycle to school, as this will increase our understanding of the determinants of mode choice by removing distance as a confounding factor. Nelson et al. identified this criterion distance −2.4 km within which it is realistic for adolescents to actively commute to school (Nelson et al., 2008). For adolescents living within this criterion home-to-school distance, the purpose of this study was (i) to evaluate how accurate they were at estimating the distance they travel to school and (ii) to establish if mode of commuting influenced the level of estimation accuracy.

3. Methods

3.1. Subjects

An old, established suburban neighbourhood in Ireland, well served with footpaths and pedestrian crossings was selected for study. Within this neighbourhood, all pupils in 5th year in all post-primary schools ($N=3$, one male only, one female only and one co-educational) were recruited. The schools were located within walking distance of each other, ensuring minimal geographical variation for comparative purposes. The study protocol was approved by the Research Ethics Committee at Dublin City University. Youth ≥ 16 yrs provided written informed consent, while those < 16 yrs provided written assent accompanied by parental consent.

3.2. Procedures

Participants self-reported their perceived distance (in metres) of the journey from home to school, their usual mode of travel (foot, bicycle, car, bus) and the time taken (in minutes) for the journey via a questionnaire completed under supervision. Similar questions have previously been used in this age group (Central Statistics Office, 2006). Responses were categorised as active commuting by foot or bicycle, or passive commuting by car or bus.

The actual route travelled to school by each participant, irrespective of mode, was measured using a detailed street level Ordinance Survey Map of the standard scale 1:2500 mm. After completing the questionnaire, each participant, supervised by a member of the research team marked their home on the map and traced, using a coloured ink pen, the exact route they took to school that morning, whether by foot, bike, car or bus. A Scalex Map Wheel, designed to measure straight and curvilinear distance provided a digital read-out of the actual distance (metres) travelled by students. To increase accuracy, the route specified by each participant was measured three times and the average distance was taken.

Standardized testing procedures were used throughout the study. Extensive training was undertaken prior to data collection to minimise potential sources of error in map measurement and questionnaire administration. Testing procedures were evaluated in a pilot study; no problems were reported regarding the comprehension or layout of the questionnaire or the completion of map.

4. Data analysis

Data were stored and analysed using SPSS 17 (Statistical Package for Social Sciences). Only one male cycled to school, and thus cycling was removed from further analysis. Participants that lived within a commutable distance for walking (2.4 km) as per previous research (Nelson et al., 2008) were included in the analysis. Data are presented as means, standard deviations and proportions where appropriate. Actual (map measured) distances were normally distributed; therefore independent t-tests were used to compare differences between active and passive commuters. Perceived (self-reported) distances were non-normally distributed therefore Mann–Whitney tests were used to compare data from active and passive commuters. Wilcoxon Signed Rank tests were used to compare actual (map measured) and perceived (self-reported) distance travelled between active commuters and passive commuters. Finally, the extent of the agreement between the actual and perceived distances recorded by commuters were subjected to a Limits of Agreement (LOA) analysis (Bland and Altman, 1995, 1986), to determine how accurate active and passive adolescents were at estimating distance travelled.

5. Results

5.1. Descriptive characteristics of participants

In total, 271 ($N=280$; 97% response rate) adolescents participated, however 72 were excluded because their map-measured route to school exceeded the criterion acceptable distance for walking to school (2.4 km). There was no difference in age, gender, type of school attended or density of residential area between those living within the criterion distance and those outside of the criterion distance. In support of removing these youth from the dataset, those living outside of the criterion distance were more likely to commute to school passively (64% vs. 28%, χ^2 (1)=29.16, $p<0.0001$), and to travel a greater distance to school (4.02 km vs. 1.23 km, t (75.536)=−15.3.58,

$p<0.001$). Participants' ($N=199$) mean age was 15.9 ± 0.56 years (range 15–17), 52.8% were male, 42% attended a co-educational school, 33% attended a female only school and 25% attended a male only school.

5.2. Incidence of active commuting

Within the criterion distance 72.4% of adolescents actively commuted to school, and 27.4% commuted passively (by either car or bus) (Table 1). No significant gender differences were recorded in mode of commuting to school; females were as likely to actively commute to school as males.

5.3. Time and mode choice

The average journey time reported by participants was 15.2 min (range 1–60 min). Although journey time was lower among active (14.6; range 1–45 min) compared to passive commuters (16.8, range 4–60 min), this difference was not significant. No gender differences were established for journey time to school.

5.4. Distance and mode choice

Table 2 displays the actual (map measured) and perceived (self-reported) distance travelled to school by active and passive commuters. No between group differences were found in the actual distance travelled to school by either group (1.3 km vs. 1.35 km, non-significant). For active commuters, no difference was found between the actual distance they had travelled to school and their estimation of that distance through their self-reported data (1.29 km vs. 1.40 km, non-significant). For passive commuters the actual distance they travelled to school was significantly shorter than their perception of that distance (1.35 km vs. 2.74 km; $U=2016.500$, $p<0.001$). The perceived distance reported by passive commuters was greater than that reported by the active commuters (2.74 km vs. 1.40 km; $z=-4.45$, $p<0.001$), even though no actual difference in distance existed.

5.5. Accuracy of perceived versus actual distance

The extent of agreement between the actual (map measured) and the perceived (self-reported) distance estimation was assessed by following Bland and Altman's Limits of Agreement (LOA) analysis (Bland and Altman 1986, 1995). All participants over-estimated the distance they travelled to school, irrespective of mode used. For active commuters, the mean difference between actual and perceived distance travelled was 113 m, which was not significantly different from zero (t (143)$=-1.101$, $p>0.05$, Table 3). The 95% LOA analysis suggested that active commuters could under-estimate distance travelled by 89 m or over-estimate by 312 m. For passive commuters the mean difference between measured and self-reported distance was 1.4 km, which was significantly different from zero (t (54)$=-5.102$, $p<0.05$, Table 3). The 95% LOA for this sample revealed that passive commuters could over-report distance travelled by between 853 m and 1.96 km. This indicates less optimal agreement than their active commuting peers.

Table 1
Mode of transport to school by gender.

Mode	All % (n)	Male % (n)	Female % (n)
Walk	72.4 (144)	77.1 (81)	67.0 (63)
Car	21.1 (42)	17.1 (18)	25.5 (24)
Bus	6.5 (13)	5.7 (6)	7.4 (7)
All	100 (199)	100 (105)	100 (94)

Table 2
Actual and perceived distances travelled to school by active and inactive adolescents living within a 2.4 km walking route from their school.

	Actual distance (Km)		Perceived distance (Km)		Wilcoxon signed rank
	Mean ± SD	Range	Mean ± SD	Range	
Active ($N=144$)	1.29 ± 901	0.016–2.4	1.40 ± 1.1	0–8.05	Non-significant
Inactive ($N=55$)	1.35 ± 595	0.322–2.4	2.74 ± 1.9	0.531–8.85	$P<0.0001$
	Non-significant (t-test)		$P<0.0001$ (Mann–Whitney)		

Table 3
Descriptive statistics of the differences between the actual distance and perceived distance in kilometres travelled to school.

	N	Mean difference (MD)	SE of MD	95% confidence interval	
Active commuters	144	0.113	0.101	−0.089	0.312
Inactive commuters	55	1.400	0.275	0.853	1.958

6. Discussion

This study measured the actual distance of the route travelled to school by youth from local area maps. Using this information, only youth who lived within a 2.4 km route from home to school were included in the study. Over two thirds of the sample indicated that they usually walked to school; this finding was encouraging as it reinforced the notion that active commuting is a feasible behaviour for many youth (Frank et al., 2003). This high frequency of participation in AST also suggests that the environment in which this study was conducted was supportive for walking.

Within this realistically commutable distance and supportive environment, approximately one in three youth opted not to engage in AST. In this study, as determined by map-measured routes, no significant differences were found in the actual distances travelled to school by active or passive commuting youth. However, in analysing the self-report data, youth who actively commuted accurately estimated the distance of their commute to school. In comparison, passives overestimated the length of their route to school by approximately 1400 m. The study also revealed that inaccurate perceptions of distance were significantly greater in passive commuters when compared to active commuters, even though no actual differences in map-measured distances were found. These findings have significant implications for intervention design.

As distance is such a strong predictor of AST, it is important that we understand this determinant fully. Realistic targets are required for children and variability must be recognised. It is unsuitable for all children in a school to be encouraged to adopt active commuting, as some will live too far away for walking to be feasible, they can be encouraged to mode share, walking some of the way to school. For others, for whom the behaviour is a realistic and viable option, which means that their environment is safe (adequate pedestrian crossings, comfortable environment etc.) and the distance commutable; our research suggests that inaccurate perceptions of distance are a very real barrier. Simple interventions to encourage these children to walk to school are needed. These interventions could be experiential, for example awareness raising of the specific route travelled and actual distance of that route, the purpose to get the child to re-evaluate their understanding of the time it would take them to travel that route. They could be cognitive-behavioural, for example teaching children how to set and walk to time-matched goals. These interventions could be part of the physical education or geography curricula. The potential for this type of low-cost intervention in terms of reach is large; however its efficacy would need to be determined with further research.

Creating environments that allow children and young people to walk and cycle safely is an important public health goal. Placing destinations of interest to this target group within these environments is essential. It also has been linked to greater levels of involvement in extra-curricular and community-based physical activity (Woods et al., 2010). These destinations include schools, green spaces, sport and physical recreational areas. Recently, local government and national governing bodies of sport in Ireland have moved centrally located playing fields or schools from the centre to the outskirts of towns and villages. This has been due to a number of issues like the price of land and changing demographics. However, this policy directly affects whether children could realistically walk to these destinations of interest, as distances become longer. With levels of active commuting currently declining in Ireland (Central Statistics Office, 2006), there is a danger that children will not develop a routine of walking to school. Consequently they will remain untrained and unable to estimate time and distance accurately for walking behaviour. Future longitudinal and experimental work is needed to explore this topic.

The journey time for commuters was fifteen minutes on average. No difference in time estimation for the journey was found between groups. Thus, removing time as a barrier to walking to school as passively commuting to school did not appear to 'save time' for the participants. This further strengthens our argument of the need to increase the skill and accuracy of distance estimation in youth and remove or reduce the likelihood of distance as a barrier to walking to school. If this fifteen minute journey were to happen twice a day, five days a week, it has the potential to add 150 min of moderate intensity physical activity to a child's weekly count, making it a very significant form of physical activity. It has also been found that children that actively commute to school are more active at other times during the day (Kerr et al., 2006; Sirard et al., 2005; Alexander et al., 2005; Cooper et al., 2003; Tudor-Locke et al., 2002).

Research on the relationship between gender and AST is inconclusive. Some studies found that males are more likely to actively commute to school than females (Nelson et al., 2008; Timperio et al., 2006); others found no gender differences in mode choice (Kerr et al., 2006). In this study, no significant differences were found between commuting behaviour by gender. Three factors that may account for this finding are (i) this study controlled for distance making the behaviour more feasible for all participants, (ii) cycling was removed as an active commuting behaviour due to low participation (only one male cycled to school) and (iii) the participants were older than many of the other studies, and therefore may be considered relatively independent which may reduce parental concerns (Merom et al., 2006). Future research should aim to clarify any gender-active commuting relationship. It is now well documented that males are more active than females particularly in the late adolescent years (Currie et al., 2012; Borraccino et al., 2009). Active commuting may be a gender neutral physical activity behaviour which could yield significant behaviour change towards achievement of PAGL.

This study is strengthened by its combination of objective (map-measured) and subjective (self-report) measures of the participants chosen route to school. This methodology involved physically measuring each child's data on an individual map, the detail of which allowed for very precise readings. This type of information can be collected by Geographical Information Systems (GIS), however the GIS information available to the researchers was inconsistent in terms of coverage of the area studied thus limiting its reliability and validity at the individual route level. The area selected for study was an established suburban neighbourhood well served by footpaths and pedestrian crossings. This choice of neighbourhood was to facilitate AST and minimise other barriers like perceptions of safety. There is a need for future research to establish if these findings can generalise to other types of neighbourhoods. The sample size, though inclusive of all post-primary schools in a large suburban area, yielded small numbers of passive in comparison to active commuters. This was due in part to the application of a walkable distance criterion. However, including only those who live close enough to walk or cycle to school was a strength of this study.

7. Conclusions

Walking to and from school is a high frequency, moderate intensity form of physical activity. It has the potential to be age and gender neutral, and as such provide a high number of children and youth with valuable minutes of daily physical activity that will help them to achieve the internationally recognised PAGL. It also has been linked to greater levels of involvement in extra-curricular and community-based physical activity. However, the perception of distance is problematic for passive commuters. Although they live within a realistically