

Environmental Correlates of Physical Activity And Walking in Adults and Children: A Review of Reviews

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NICE guideline PH8 (published January 2008) has been updated and replaced by NG90.
New recommendations have been added on strategies, policies and plans to increase physical activity in the local environment (1.1.1 to 1.1.3); active travel (1.2.1 to 1.2.4 and 1.2.6 to 1.2.9); public open spaces (1.3.1 to 1.3.3). NICE has deleted some recommendations from the 2008 guideline because the evidence has been reviewed and the recommendations have been updated.
This evidence review is relevant to the updated guideline.
See www.nice.org.uk/guidance/ng90 for more details.

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EXECUTIVE SUMMARY

The purpose of this report is to summarise evidence on the environmental correlates of physical activity and walking. A review of reviews was undertaken to identify evidence on the strength of association between environmental factors and physical activity for both children and adults. The exposure variables were a range of measures reflecting elements of the physical environment, and the outcomes of interest were total physical activity and specifically walking behaviour.

Electronic searches were conducted using Medline Cinhal, ERIC, Psychlit and Sportsdiscus databases as well as hand searches of references list and selected key journals. The focus was to identify published papers reporting on the factors associated with physical activity in children and adult populations; these are referred to as ‘correlates’ or ‘determinants’ studies. The initial search identified over 200 papers, of which only 13 papers met the inclusion criteria and were included. These review papers varied in quality and approach taken to reviewing and presenting their results. Despite these variations some common themes were identified across the studies in terms of both results on environmental correlates and the methodological weaknesses of this field of research.

A summary table presents the key environmental factors that show consistent and statistical association with physical activity behaviour in adults. For physical activity, 11 review papers provided evidence and results across them revealed reasonably consistent associations between access to physical activity facilities, convenient and proximate access to destinations, high residential density, land use and urban ‘walkability’ scores. There were also reasonably consistent associations between perceived safety, exercise equipment, pavement (‘sidewalks’) and physical activity participation. Less clear associations were noted for aesthetic features of the environment, parks, and perceived crime. Four review papers provided evidence specific to walking and the results showed the correlates of walking were similar to those found for physical activity in adults.

One review paper assessed the evidence on the environmental correlates of physical activity in children, it included 33 primary studies. The most consistent associations were for the provision of pavements (‘sidewalks’), destinations to walk to, few intersections to cross and low road traffic hazards. Aspects of the recreation infrastructure were also found to be strongly associated with increased levels of activity, these included proximity to, and availability of to parks, playgrounds, and recreation areas. Less consistent results were found for perceived safety however some studies show crime rates may be significantly (negatively) associated with physical activity in children.

The literature for both adults and children populations was mostly from cross sectional study designs, most studies were conducted in USA or Australia using a variety of outcome and exposure measures. There were few clear differences in the results across the studies included to identify patterns by age, sex or ethnicity, in adults or children

Limitations in this literature include the reliance on cross sectional study design, thus this temporal relationship is not known for environmental measures and it is not possible to infer a causal or true 'determinants' relationship. The lack of standardisation of measurement of environments is another limitation. Both the independent and dependent variables in this area of research pose measurement challenges. A wide variety of methods are used to collect, derive, analyse and present data. This makes the task of assessing and comparing the results across studies more difficult. Few reviews identified separately the findings by objective or subjective measurement methods yet this will remain an important issue. Future research should make an explicit attempt to do so. Limited research is available on correlates of physical activity in minority and specific sub-populations.

Research on correlates has been carried out almost exclusively in North American and Australia, with limited published literature on environmental correlates from the UK. Thus, the evidence base for understanding the role of the environment and physical activity in England is very limited. Until primary research studies are undertaken in the UK, the application of the findings to date will rely on the generalisability of the available literature.

Limitations due to the methods of this review may include limiting the review to a review of reviews, including studies published only in English between 2002-2006 and applying search terms to only title and key words.

1. INTRODUCTION

1.1 Scope of the review

The purpose of this report is to summarise evidence on the environmental correlates of physical activity. In this relatively new field of study of physical activity, the evidence most often comes from cross sectional studies rather than cohort or intervention research designs. The results will present a summary of identified environmental factors that show consistent and statistical association with physical activity behaviour in adults and children from a review of the published literature. Given the publication of well over a hundred papers addressing association between the environment and physical activity and the time limitations of this project, the evidence presented is derived from review level evidence and presents a narrative summary of the strength, consistency and direction of these associations. As there are different ways that exposure and outcome factors have been measured, a formal synthesis and quantitative comparison is not possible, but the objective, to provide a narrative review, will inform policy makers on the strength of the evidence to date.

The results section of this report is divided into several sections covering firstly the literature identifying the environmental correlates of physical activity and secondly the environmental correlates of walking. For both outcomes the available evidence for both children and adults is covered and, where possible, the results are presented to show results from objective measures and subjective perceptions separately. An additional final section provides commentary on the measurement methods used in this field of research.

The overall purpose of this review is to provide a synthesis of the available evidence on the potential environmental determinants of physical activity. An understanding of these factors can inform the development of more effective interventions and direct policy action that will assist in the development of promising areas for intervention to change the environment which may positively influence physical activity at the population level.

1.2 Summary of health benefits of physical activity

Physical inactivity has been identified as one of the leading causes of many chronic conditions, and it contributes substantially to the burden of disease, disability and premature death, with heavy

resulting economic costs (Department of Health, 2004). Recent efforts to promote and increase physical activity at the population level have focussed heavily on individual and behavioural interventions and yet rates of physical activity remain relatively static and at the same time sedentary activities have increased. This has contributed to increasing non-communicable diseases, and partially contributed to the rise in obesity rates. Understanding the correlates and determinants of physical activity is essential in the development of a comprehensive population-based approach to the promotion of physical activity.

1.3 Conceptual Model for Understanding Correlates and Determinants of PA

The socio-ecologic model posits that comprehensive approaches to change physical activity levels need to consider interventions at multiple levels, individual, social and environmental. The latter component, environmental influences on physical activity, is the subject of this report.

As a new field of research, a large number of different characteristics of the environment have been identified and explored. These include single and aggregated constructs, at varying levels of scale (local neighbourhood such as a few streets through to characteristics assessed at the suburb or city level) and can include: density of shopping facilities; distance to destinations; mixed land use; level of connectivity; provision of walking and cycling facilities; street lighting; access to open spaces and population density. Consideration has also been given to objectively assessed characteristics as well as subjective (perceptions) assessments of the environment (such as perceived safety, perceived levels of traffic, aesthetic qualities, convenience of access to facilities).

Two examples of socio ecologic models adapted to apply to physical activity are shown in Figure 1. There is however no consensus on any one specific ecologic model although more recent work has called for greater specificity in the development of models for specific types of physical activity outcome variables (Giles-Corti et al., 2006).

Figure 1 Examples of Socio-Ecologic Models applied to Physical Activity

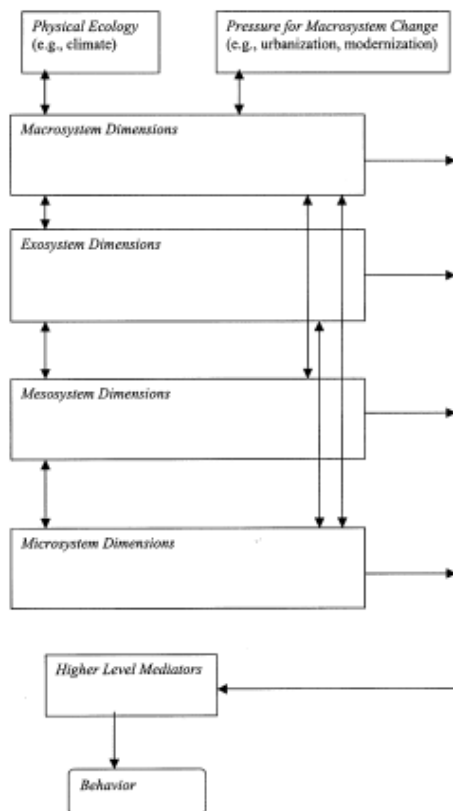


Fig. 1. A structural model of environmental influences on behavior (adapted from Wachs, 1992).

A) Example 1: Spence and Lee, 2003¹

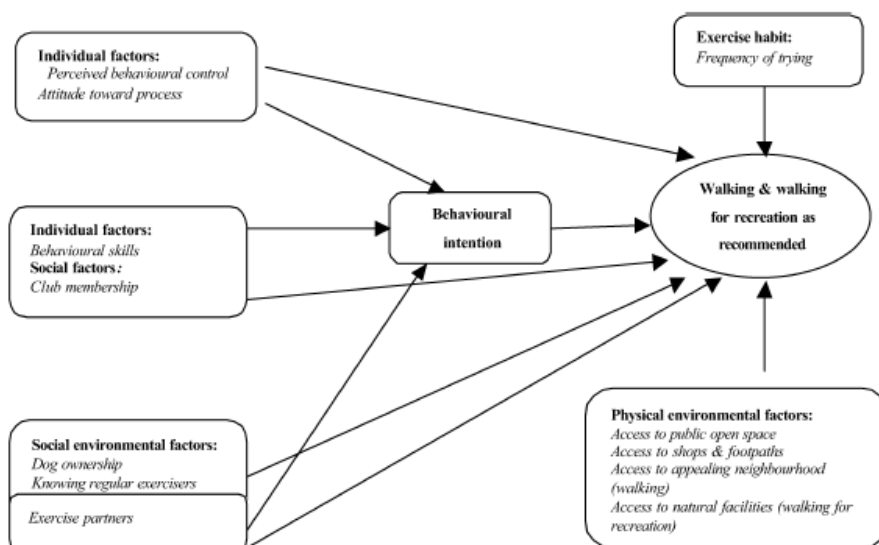


Fig. 1. Social ecological model of influences on physical activity (adapted from Corti, 1998).

B) Example 2: Pikora et al., 2002²

¹ Spence J. C. and Lee, R.E. (2003) Towards a comprehensive model of physical activity Psychology of Sport and Exercise. 4: 7-24.

² Pikora, T., Giles-Corti, B., Bull, F.C., Jamrozik K., Donovan, R. Developing a Framework for Assessment of the Environmental Determinants of Walking and Cycling. Social Science and Medicine. 2003: 56: 1693-1703

1.5 Individual and Social Correlates of Physical Activity

Much of the available evidence on correlates of physical activity has been collected at the personal or individual level. A recent review was undertaken for the World Cancer Research Fund by the authors of this report and the main findings are summarised in Table 1 (Bauman and Bull, In press).

Among adults, there are consistent demographic factors associated with physical activity in populations. These include age and gender, with most leisure-time physical activity measures showing lower prevalence of physical activity among women and older adults, compared to men and young adults. In addition, some socio-economic individual level attributes, especially educational attainment and income are positively related to leisure-time physical activity.³

One of the most consistent intra-personal factor consistently associated with physical activity is self efficacy, part of social cognitive theory, and is related to the person's situation-specific confidence that they can be physically active. Self-efficacy and related constructs are measured frequently, and remain positively associated with physical activity across diverse population groups and populations.

Other intra-personal variables, including attitudes and beliefs are inconsistently associated with activity. Perceived barriers to physical activity especially perceived lack of time [adults] and 'feeling too old' or having chronic illness' [older adults] were consistently and inversely related to activity. Exercise habit or a history of previous participation earlier in adult life were identified as correlates of current adult participation.

In adults, social support is associated with physical activity, particularly among older adults, women, and some minority populations. Cultural factors have some influence, but it is not consistent and is an area in need of more research

Among children and adolescents, consistent associations were noted for sex [males more active], and for age, with declines in physical activity through adolescence. Some intrapersonal perceptions, such as body image and self perceptions [inverse] and self-esteem [direct] are associated in some studies.

³ Note that other relationships may exist for other types of physical activity – for example active commuting may show an inverse association with socio economic status, as those of least income may not be able to afford cars and other sedentary transport modes.

Table 1 Summary of the coverage of Inter- and Intra- individual, barriers and social correlates of physical activity in adult populations*

	Recent Review Papers					
	Trost et al. 2002	Seefeldt et al., 2002	White et al., 2004	Sherwood & Jeffery 2000	Speck et al., 2003	Keating et al., 2005
Demographic and Biological Factors						
Age	√	√	√		√	√
Gender	√	√	√		√	√
Indicators of socio-economic status: educational attainment, occupational status and measures of SES)	√	√	√			
Ethnicity/race	√	√	√		√	√
Dependent children	√				√	
Marital status	√	√	√		√	
Year of study in higher education						√
Overweight or obesity or body weight	√			√	√	
General health (or health status)			√		√	√
Level of fitness		√	√			
Functional status			√			
Mental wellbeing			√			
Psychological, Cognitive, and Emotional Factors						
Attitudes	√					
Barriers	√		√	√		
Enjoyment	√		√			√
Expected benefits	√		√		√	
Value of outcomes	√	√			√	
Outcome expectancy					√	
Intentions	√					
Normative beliefs	√	√	√			
Self efficacy	√			√	√	
Self motivation	√			√		√
Stage of change	√			√		
Self efficacy	√		√	√	√	√
Barriers						
Lack of time	√			√	√	
Too weak (elderly populations)	√					
Fear of falling (elderly populations)	√		√			
Bad weather	√		√			
No facilities	√					
Lack of exercise partner	√					
Lack of energy	√					
Self consciousness	√					
Fear of joint pain / MI / chest pain			√			
Injury				√		
Attitudes	√					
Knowledge	√					
Adherence related correlates						
Mode (type) of physical activity			√	√		
Duration of activity sessions			√	√		
Setting (home / workplace)			√			
Choice / variety			√	√		
Behavioural attributes and skills						
Diet habits	√		√	√		
Past exercise behaviour	√	√		√		
Past sports participation		√				
Smoking status	√		√	√		
Decisional balance	√					
Stress levels		√	√	√		

* Adapted from a recent review by Bauman and Bull (In Press)

Intention to be active and leisure time preferences are important in younger children, but not apparent in adolescents. Previous physical activity and membership of community sports associations were associated with being active in adolescence. Among younger children, social influences are quite important. Consistently, parental and other adult role models are important, but this becomes less important among adolescents. Peer influences and teacher modelling of active behaviours is unrelated to youth physical activity.

1.4 Outcome Variables: Physical activity and walking

This review will consider environmental correlates of total physical activity as measured in the studies and usually this involves self report instruments that address a range of domains of activity, such as, leisure, transport and possibly at work. Correlates of specific behaviours, namely walking, will also be identified, where possible from the literature.

The term ‘exercise’ may be used in this report as this is still a common term in the relevant literature base. Whilst the terms are often used interchangeably in studies, it is important to note that the concepts of physical activity and exercise do differ, with the former being a broader term, the latter a term used to describe activity undertaken in usually more structured ways and with specific purpose of improving aspects of fitness (e.g., cardiovascular, muscular strength, flexibility).

1.5 Correlates versus determinants of physical activity

A synthesis of evidence on the determinants and correlates of physical activity is presented. Strictly speaking, the focus here is on the *correlates*, as in measures of associations that are consistently reported within the data, rather than results on antecedent causal variables [or determinants]. This field of research has a history of using both terms and often (incorrectly) interchangeably; it is only more recently that the strict use of the terms has been evident in published papers. In this review we incorporate all evidence that is, in the ‘epidemiological sense’ conceptualised as ‘correlates’ of physical activity to identify those environmental factors consistently and statistically associated with physical activity behaviour.

2 METHODS

This report summarises the evidence on studies that have examined the relationship between ‘physical activity’ or ‘walking’ and aspects of the built or physical environment. This report uses a ‘review of reviews approach’, with the following steps undertaken:

- i. A search strategy prepared and undertaken
- ii. Assessment of ‘hits’ for relevance and inclusion
- iii. Synthesis of each included review paper to provide a narrative description, considering, where possible, all the following:
 - a. Research purpose
 - b. Search strategy and timeframe
 - c. Number of studies included and their study designs
 - d. Main findings from each review
 - e. Main conclusions from each review
 - f. Implications for policy
- iv. An additional focus was included to identify the measurement methods used in the papers reviewed, and thus provide a general discussion of measures of levels of physical activity or walking, and measures of environments, and where possible, to identify any differences in findings between results and conclusions based on studies using self report and objective measurements
- v. Assessment of robustness and / or weaknesses of the evidence base in this area.
- vi. Consideration of these findings in terms of the context and relevance for the UK
- vii. Identification of future research needs and directions to enhance the evidence base for action

Search strategy

An electronic search was undertaken to identify papers reporting on factors associated with physical activity in children and adult populations; these are referred to as ‘correlates’ or ‘determinants’ studies. Given this diverse and large body of evidence, and in order to undertake a review in the timeframe provided, review-level evidence was sought, with a preference for systematic methodologies. Thus, the search strategy focused on identifying (quantitative and qualitative) review papers with a focus on the correlates of physical activity that emphasized the ‘built’ environment or physical environment. Studies of individual level and social environmental

correlates were excluded. In addition, the review was limited to papers published in English language and published between 2002-2007.⁴

Searches were conducted in Medline and four other data bases (Cinhal, ERIC, Psychlit, SportDiscus) and separately run in ISI Web of Science. In addition, the authors undertook hand searching of reference lists, key journals and used their network of researchers working in the area of physical activity and the physical environment to identify additional studies.⁵

Search terms used were ‘physical activity’ or ‘walking’, ‘correlates’ or ‘determinants’, environment* or built environment or physical environment as key words or title words (Table 2). In addition, ISI Web of science was examined, for *physical activity* (topic search or title search along with *environment* as a topic word or title work, OR title words of ("public health" OR ecolog* OR transport* OR "urban planning" OR "urban design" or transport*).

Table 2 Search terms for review of physical activity and environments

Category	Search terms used
Physical activity	Physical activity or exercise or walking in title or key word
Review paper selection	Defined as a ‘review’ paper or with key word or title word of [any of] ‘review /systematic /research synthesis /summary’
Environment	environ\$ or built environment or physical environ\$ in title, or keyword
Association	‘correlates’ or ‘determinants’ title or key word

Reviews were excluded if their focus was not on physical activity but rather studies of correlates of solely strength training or clinical exercise programmes (such as exercise for rehabilitation), if the paper reported results of a single study; or if there was no clear evidence of a review or summary process. In addition, papers were excluded if the focus was on a single disease or specific clinical setting as this report aimed to assess the correlates of physical activity that might be of potential population or public health usefulness (Table 3). Four reviews of interventions studies on the environment and physical activity were identified but excluded (McCormack et al., 2004; Owen et al., 2004; Saelens et al., 2003; Wendel-Vos, G.C. 2004).

⁴ The reason for the recent time frame is that all the most useful reviews have been written in the past five years because more than 80% of the primary source studies have been published in the period since 2002 (Wendel Vos et al., 2005).

⁵ Note that the three separately conducted search processes identified some of the same review papers this overlap is useful as it utilises a triangulation approach to optimise bibliometry and collect a more comprehensive set of reviews.

Table 3 Inclusion criteria for Review papers on “physical activity and environments”

Criteria	Study included if:
Study focus and design	<ul style="list-style-type: none"> i. Was classified as a <i>review paper</i> ii. Used a clear measure of ‘physical activity’ (PA) or ‘walking’ specifically; studies were excluded if they only examined other aspects of physical activity, such as <i>fitness, exercise training or strength training</i>, and if they related the PA measures to studies of the <i>individual, social or behavioural correlates</i>, although these are referred to in the discussion section iii. There was evidence of a <i>review or summary process</i>; single studies of the associations between physical activity and environments in particular populations or samples were not included; iv. Was published in English, in 2002-2007

Table 4 Summary of search results by method obtained or data base searched [note results in each column not independent]

Stage		Medline or any of the five * data bases # identified	ISI web of science ‘Current Contents’ papers extracted # identified	Personal communications or reviews carried out by authors’ research teams # identified
1	All papers identified using search terms in Medline and in other data bases* or ISI Web of Science	192	148	115 primary papers for PA and environments; 72 for walking and environments identified
2	All Review papers	58 classified as reviews	12 classified as reviews	17 reviews identified
3	Reviews for further consideration	12	9	10

Note: These sources produced several reviews in common; the final 13 chosen for direct inclusion in this report were derived from the three sources together [Medline, ISI web of science and personal sources].

* the five databases : Medline Cinhal, ERIC, Pyschlit, Sportsdiscus

note that review papers not available from other databases directly – search term included ‘review’, ‘systematic’, ‘research synthesis’, ‘summary’

A total of 192 ‘hits’ were identified on Medline and related databases and 148 ‘hits’ were identified in Current contents ISI Web of Science; additional papers were manually considered from personal communications and networks, and from the reviews conducted or in progress by the authors’ research groups to further extend the search. After reviewing for relevance and against the inclusion criteria, a total of 13 reviews were included.

3 RESULTS

The search strategy identified 13 review papers that explored the relationship between physical environments and physical activity or walking. Eleven of these focused on identifying environmental correlates of physical activity. One review focused exclusively on walking and three reviews provided information on both physical activity and walking. Only one review specifically examined the correlates of activity in children and adolescents (Davidson et al., 2006).

Included studies all met the search term criteria, and were classified by the electronic databases and by the authors of the papers as a “review paper”. All extracted some studies and commented on the overall pattern of the relationships seen between environments and physical activity; in other words, they were quantitative studies. However, the quality of the review methods and process, for example in terms of conducting systematic searches and providing the details and numbers of studies obtained and reviewed, were not consistent across the reviews. Conducting a formal quality audit of this set of reviews was beyond the scope of this ‘review of reviews’, but the variation in quality across the review papers made it more difficult to find and report on all aspects of interest. Nonetheless, efforts were made to extract details from each review that were comparable in terms of research purpose, search strategy and timeframes, main findings and implications for policy.

Table 5 presents the review papers included in this review on environmental correlates of physical activity. Below is a descriptive synopsis of each of the included review papers with an emphasis on the providing information on the following sections (where relevant details could be extracted from the review): the main purpose or research question; search strategy and databases used; the studies included, and in turn, their study design and methods; estimates of association; and country and/or context (population). Review papers are presented in alphabetical order.

Table 5 Reference of Included Review Studies

1	Badland, H., Schofield, G. (2005). Transport, urban design, and physical activity: an evidence-based update. <i>Transportation Research Part D: Transport and Environment</i> , 10(3), 177-96.
2	Cunningham, G. and Michael, Y. (2004). Concepts guiding the study of the built environment on physical activity for older adults: a review of the literature. <i>American Journal of Public Health</i> , 18(6), 435-43.
3	Davidson K.K. and Lawson C. (2006) Do attributes of the physical environment influence children's level of physical activity? <i>International Journal of Behavioural Nutrition and Physical Activity</i> . 3 (19) 1-17.
4	Duncan, M. Spence and Mummery K. (2005) Perceived environment and physical activity: a meta-analysis of selected environmental characteristics. <i>International Journal of Behavioural Nutrition and Physical Activity</i> 5; 2-11.
5	Humpel, N., Owen, N. and Leslie, E. (2002). Environmental factors associated with adults' participation in physical activity. <i>American Journal of Preventive Medicine</i> , 22(3), 188-99.
6	Lee, C. and Moudon, A. (2004). Physical activity and environment research in the health field: implications for urban and transport planning practice and research. <i>Journal of Planning Literature</i> , 19(2), 147-81.
7	McCormack, Giles-Corti, Lange A. Smith T. Martin K, and Opikora T. (2004) An update of recent evidence of the relationship between objective and self report measures of the physical environment and physical activity behaviours. <i>Journal of Science and medicine in Sport</i> , 7 (1) 81-92.
8	Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. (2004) Understanding environmental influences on walking: Review and research agenda. <i>American Journal of Preventive Medicine</i> . 27(1):67-76.
9	Saelens, B., Sallis, J. and Frank, L. (2003). Environmental correlates of walking and cycling: findings from the transportation, urban design and planning literatures. <i>Annals of Behavioural Medicine</i> , 25(2), 80-91.
10	Sallis, J., Frank, L., Saelens, B. and Kraft, M. (2004). Active transportation and physical activity: opportunities for collaboration on transportation and public health research. <i>Transportation Research</i> , 38, 249-268.
11	Trost S.G., Owen N., Bauman A.E., Sallis J. F., Brown, W. (2002) Correlates of Adult's participation in physical activity: Review and Update. <i>Med Sci Sports and Exercise</i> 34 (12) 1996-2001.
12	Vojnovic, I. (2006). "Building communities to promote physical activity: A multi-scale geographical analysis." <i>Geografiska Annaler Series B-Human Geography</i> 88B(1): 67-90.
13	Wendel-Vos, G.C. Schuit, A. Jantine ; De Niet R. Boshuizen H Saris W. Kromhout D. (2004) Factors of the physical environment associated with walking and bicycling. <i>Medicine & science in Sports & Exercise</i> . 36(4):725-730.

3.1 Environmental correlates of physical activity among adults

1. Badland and Schofield (2005)

This review paper provided a narrative description of earlier review papers and then described the origins of the study of urban form that were potentially related to physical activity. The primary studies were included if they examined differences in neighbourhoods and physical activity [n=13] or factors associated with non-motorised transport [n=11 studies]. Neighbourhood difference factors revealed significant correlates with activity. These included residential age of houses,⁶ walkability,⁷ mixed land use, street connectivity and the number of intersections, access to facilities within walking distance, parks, lower traffic and public transport. Factors associated with non-motorised transport usage included shorter distance to destinations or transport, gender, social status, aesthetic factors and access to public open spaces.

Badland and Schofield (2005) indicated that the limitations of the field include a lack of causal evidence, as well as the limitations imposed by reviews focusing on academic publications only; the 'grey' literature may have additional information of use to policy makers. This is especially true around travel choice behavioural studies, few of which are in the scientific published literature.

2. Cunningham and Michael (2004)

This review focused on studies [particularly in older adults] that explored the relationship between physical environments and physical activity. The Cunningham review identified studies published between 1966-2002, and 27 papers in English were located. Of these, 6 studies were specific to older adults. A strong emphasis was to identify theoretical frameworks for these studies [found in 17 papers]. Travel demand theory, environmental press theory, and socio-ecologic models were identified. All except two studies used representative population samples.

The correlates were not grouped or categorised, but described by author and year of publication. In this review, one third of the 65 estimates of association reported in these studies were non significant. The correlates that generally showed significant associations with physical activity were

⁶ the era when houses were built is a proxy measure for medium density, as increased urban density in planning housing developments characterised suburbs before the 1960's

⁷ Walkability is the sets of physical environmental attributes associated with increased probability of walking – there are no agreed definitions of walkability; this is because the environmental factors associated with walking are only now being distilled in review papers. One example is Saelens et al., (2003) who propose and report on a validated measure of walkability that includes measures of land use mix, density, and connectivity.

neighbourhood safety, footpath safety, access to convenient facilities, enjoyable scenery, shorter distances to facilities or parks, low perceived crime rates and low traffic density. Similar correlates applied to older adults, with a specific emphasis on convenience, access and safety.

The authors identified the limitations of the literature in terms of study design and measurement. Cunningham and Michael asserted that limited inferences could be made from studies using cross-sectional designs, and further work is needed to characterise and assess the environment factors that may be relevant or older adults. Ageing-specific frameworks for this research were recommended.

3. Duncan, Spence and Mummery (2005)

This paper is the only attempt at a quantitative review of the association between (perceived) environmental attributes and physical activity. The authors describe the need for a quantitative review because the '*associations between the perceived environment and physical activity are ambiguous*' (Duncan et al., 2005; p2). They proposed a formal meta analysis and identified papers through Medline, Proquest, Infotrac between 1989 and 2005, along with a manual search of five key identified journals. They found 50 candidate studies, with 138 estimates of environment – physical activity associations. Studies were screened for inclusion, based on populations chosen, independent samples, and if multiple environmental attributes were considered. Sixteen primary studies were included and effect sizes were calculated and compared, albeit from slightly different exposure and outcome measures. The authors examined the presence of covariate data, such as gender, country of research (93% were conducted in the USA), rurality, and coded for type of physical activity or walking behaviour that was measured.

The meta analytic effect size (ES) results were summarised as pooled odds ratios with confidence intervals. The results showed that unadjusted, no pooled odds ratios from the meta-analysis were significant, but adjusting for age, education and gender provided some evidence of significant effect sizes. Those that reported physical activity facilities in the neighbourhood were 20% more likely to be active, the presence of pavements increased the likelihood of being active by 29%, and shops and services in walkable distance increased the likelihood of activity by 30%. Absence of heavy traffic also increased the likelihood of physical activity by 22%. These results were significant however, the adjusted pooled odds ratios for perceived rates of crime, street lighting, and unattended dogs were non significant. The authors opined that these effect sizes might be different for different sub-groups, but there were not enough primary studies to assess the veracity of this hypothesis, but it is

of future research importance, in refining our understanding of these correlate studies. This issue is also raised in the review of Wendel Vos et al (2005).

The authors (Duncan et al.,) used estimation techniques to approximate the percent of variance in physical activity explained by each environmental attribute. The results showed R^2 ranging from values of 4% for 'traffic' to 7% for 'proximity to shops and services'. This is similar to the estimates to total environmental contribution to physical activity among adults (Sallis et al., 2000) and among children (Fein et al., 2004).

This meta-analytic study provides evidence that physical environments are related to the presence of physical activity facilities, proximate destinations, pavements and perceiving traffic not to be a problem. These findings were based only on self-reported perceptions of the environment, but are consistent with other reviews described, especially one of the earliest and comprehensive reviews by Trost et al., (2002), and the careful review also published in 2005 by Wendel Vos et al., (2005).

4. Humpel, Owen, Leslie et al., (2002)

This comprehensive systematic review identified 19 studies, of which 16 described the relationship between physical environments and physical activity. This review only focused on physical activity behaviours as the outcome variables of interest. Four of these studies reported an objective measure of the environment, eleven used self-report measures and one used both objective and self-report. Fifteen of the 16 studies were cross sectional in design. A secondary assessment of the studies in this review indicates that 14 observed associations in large representative population samples.

The factors positively associated with physical activity include accessibility of facilities [cycle path; facilities, nearby park or beach or shops in walkable distance], and opportunities for activity [home equipment; satisfaction with facilities; local clubs that provide opportunities to be active; coastal residence]. Factors that reduce the likelihood of being active include hills, busy traffic, low density residential regions, no facilities nearby, and a lack of equipment. There were some aesthetic factors associated with increased physical activity such as the perception of a friendly, pleasant and attractive neighbourhood. In addition, other factors such as safe pavements, low perceived crime rates were also associated with physical activity; however, weather, unattended dogs, presence of streetlights and daytime perceived safety were not related to activity levels.

Implications of this review were to reinforce the consistency of observations regarding the physical environment. Objective measures of the environment, such as using geo-coding through geographic information systems [GIS] seemed to be differently related to some perceived [self report] environmental questions. The authors argue against the summation of physical activity ‘items’ into total environmental measures or scores, as the different elements might relate in different or even opposite ways with respect to physical activity.

5. Lee and Moudon (2004)

This paper, written by urban planning academics, and published in the planning literature, provides a descriptive summary of urban form features identified as associated with ‘health enhancing physical activity’.⁸ A diverse range of environmental exposures were assessed. These included locations where people preferred to be active were assessed, and local streets, parks and sports fields, public open space (including beaches), specific trails and paths, and shopping malls were the most frequently reported. Research identifying environmental barriers to physical activity was categorised as lack of access to facilities, travel distance and safety concerns.

The authors reviewed three electronic databases (Medline, Psychinfo, ISI web of science), as well as the grey literature from federal and state agencies. The literature review was conducted during 2002-2003, but the number of initial candidate studies was not stated. Of these candidate studies, the authors reported findings from 20 studies, some of which used qualitative research methods or did not report quantitative data.

These authors divided these correlational studies into those that assessed environments objectively, and separately described those that self-report measures of environments. They developed a theoretical framework, described as the ‘behavioural model of the environment’, considered route specific attributes and origin/destination specific attributes of the physical environment. The results showed that objective measures of environments generally assessed objective characteristics of origins / destinations [such as distance to the shops], and route-based measures [such as the presence of a bike lane or footpath] were often assessed by self-report measures. Some geographical ‘area’ level variables, [e.g. coastal residence, age of housing, hilliness] were examined as proxy indicators of general urban form characteristics.

⁸ The paper identified the prevalence rates of walking and cycling for different purposes, including active commuting and activities of daily living. Walking for transport was often reported by Australian and Canadian adults – with a quarter of adult Australians reporting walking and <10% cycling for transport in the previous week. Among Canadians, 26% biked for transportation and 85% walked for transport ‘at least sometimes’.

Lee and Moudon concluded that destination availability and quality were related to usage. Other ecological factors, such as coastal proximity, urbanisation, density and convenience were also related to physical activity levels and usage. In studies with self-report measures of environmental attributes, local neighbourhood features and quality, the presence of destinations, access to facilities and the existence of feasible routes, as well as other aspects of walkability were related to undertaking sufficient physical activity for health. Perceived safety was also positively associated with physical activity levels.

This review concluded that there was a latent or unmet demand for transport-related walking and biking, and that these activities were in turn related to macro-scale environmental variables such as urban density, land use, street design, and the availability of destinations. The authors suggest greater investments in public transportation, facilitating direct active commuting through better pavements and bike lanes, and other activity and environment-friendly improvements.

6. McCormack, Giles-Corti, Lange et al., (2004)

This review paper focused on the built environment and identified papers published since 2000. Only quantitative studies were included, with self-report or objective measures of the environment. The theoretical framework used was one that was previously developed by the authors, and was comprised of functional attributes of the physical environment, safety aspects, aesthetic aspects, and destinations. The total number of studies considered is around 30, but is not explicitly stated. From these studies, 20 significant estimates of association with physical activity measures were reported, and a further 15 significant estimates of correlates with walking.

McCormack et al., identify that functionality, in terms of environmental sprawl, lower population density, and low walkability were associated with lower rates of physical activity. An overall sprawl index was related to walkability and to activity levels. Across the included studies, safety was usually assessed using self-report measures and showed inconsistent relationships to activity, but 'pavement safety' seemed to be regularly associated with higher activity levels. Self-reported measures of aesthetic factors, such as cleanliness, scenery, varied building designs, low traffic and greenery, were found to be positively associated with activity. None of the included studies assessed the aesthetic factors using objective measures. Topographic factors were inconsistently related; sometimes, hilly terrain and busy roads and freeways were a barrier to activity, but these were not

consistent results. Destinations, in the form of access to facilities, proximity to walking and activity opportunities and shops were positively associated with activity.

The review concluded with the limitations imposed by self report and by cross-sectional designs in producing evidence relevant for public health policy. The needs for better [causal] designs, and objective measures of both physical activity and environments is recommended.

7. Saelens, Sallis and Frank (2003)

This review summarised studies that examined neighbourhood characteristics associated with walking or cycling for transport. The theoretical underpinnings were socio-ecological models, that include intra- and interpersonal factors, as well as social and physical environments in contributing to physical activity participation. This review summarised data from four studies that identified higher rates of walking or cycling for transport in neighbourhoods that were deemed ‘highly walkable’, compared to ‘low walkable’ regions. The environmental attributes that comprised walkability included population density, mixed land use [both residential and non-residential purposes in the same region], and the presence of facilitatory infrastructure [bike lanes, pavements]. Selection of studies was not clear, but the authors examined the health, transport and urban planning literatures. The differences between high and low walkable regions were most marked for transport-related physical activity, more than for leisure time ‘exercise’ behaviours.

The policy relevance of this review was to highlight the potential contribution that transport related physical activity might make to reaching recommended levels of ‘total physical activity for health’ (USDHHS, 1996). In addition, transport related activity can contribute to overall obesity prevention, through the increased and habitual energy expenditures attributable to these regular activities.

8. Sallis, Frank, Saelens and Kraft (2004)

This paper described the relationships between community design and active transport. Much of this review described the principles of active commuting, and the concept of ‘travel distance’. Studies conducted by the authors had described the trips people made for different purposes, and that some trips to school, work or for shopping were less than a mile, but still undertaken using motorised transport. The authors then describe a systematic review of land use and active transport research. Theoretical frameworks included the socio-ecologic model, and also travel demand theories.

This research is based on the concept of walkability, a construct comprised of environmental characteristics, including population density, land use mix, and urban infrastructure [including street connectivity, and street amenities, such as well maintained pavements]. Several research projects have noted that walking trips were more prevalent in ‘high walkable’ neighbourhoods, compared to ‘low walkable’ neighbourhoods’. The new studies reviewed here were six studies of active commuting and health outcomes, and were conducted in China, Japan, France, Ireland, Denmark and the Netherlands. Increased transport-related physical activity was associated with improved lipid profiles, lower body mass index (BMI), reduced hypertension rates, and lowered risks of all-cause mortality. The effects on BMI seemed stronger for males than for females.

The authors describe additional outcomes of increased active transportation at the population level. These include improved air quality and reduced traffic congestion. It was suggested that solutions to low rates of transport-related activity pose an intersectoral set of problems, and require trans-disciplinary solutions, beyond simply work from within the health sector alone.

9. Trost, Owen, Bauman, Sallis and Brown (2002)

This was a systematic review that provided an update of previous summaries of the correlates of physical activity in adults (Sallis and Owen, 1999). In the earlier 1999 review, Sallis and Owen concluded that adult participation in physical activity was influenced by a diverse range of personal, social, environmental factors. This 2002 review used the same search terms as in 1999, and identified 38 new studies that were published since 1998. Seven of these used a longitudinal design, none used objective measures of physical activity and all relied on self-report. Most measures provided a global assessment of physical activity with the majority focusing on measures of leisure time activity only. Only 3 studies specifically focused on adherence to a structured exercise programme and these were retained in the pool of studies.

The review summarised demographic factors associated with physical activity, including age, gender, educational attainment, and measures of socio-economic status. The detailed findings of these psychological, cognitive, and emotional factors assessed in this review are beyond the scope of this report.⁹ The new part of this review was to add “Physical Environmental Factors” as a new

⁹ In brief, behavioural attributes and skills, such as previous habits, past exercise behaviour, smoking status and decisional balance for activity, were associated with participation in physical activity. Social support was consistently and positively associated with levels of physical activity. Overall the variance in physical activity explained by measured correlates ranged from 3-50% with an average $21.2 \pm 15\%$.

set of correlates, identified in the published literature for the first time in studies since 1998. Ten studies generated the correlates between aspects of the physical environment and physical activity. Factors that emerged as potentially showing an association were: [i] exercise equipment in the home and [ii] access to and satisfaction with facilities; [iii] neighbourhood safety, [iv] a hilly terrain, [v] frequent observation of others being active (modelling) and [vi] enjoyable scenery. Urban/rural location was explored in 6 studies and all found physical activity to be significantly lower among adults living in rural areas compared with urban. Factors not found to be associated with physical activity in these studies included street lighting, programme costs, crime rates, sidewalks (pavements), and unattended dogs.

This was one of the earliest review papers (published in 2002) and made a significant contribution to setting the agenda for the investigation of environmental correlates of physical activity, as well as demographic factors associated with being active. Although the notion of environmental influences on physical activity had been suggested well before this review (Nurmela, 1995) it was around this time that the evidence base started to accumulate. A major limitation of research published up until this point was a reliance on measures of leisure time physical activity, and not examining correlates of other measured domains – especially transport and lifestyle-related physical activities. The other major limitation identified this review paper was the reliance on cross-sectional correlates, rather than longitudinal studies or interventions to assess the causal relationship between environmental factors and becoming physically active.

10. Vojnovic (2006)

This review emanates from the planning literature, and it contributes a few innovative ideas. In particular, it proposes that the urban form and environmental correlates may be different at a micro-scale environment [local neighbourhood factors that encourage walking to the shops] compared to macro-scale environments [city design factors that encourage the development and use of public transportation systems, and facilitate active commuting to and from this public transport].

The review is not systematic, in that the sampling frame and selection of studies is not described. It is included here as it emanates from a planning perspective, and the theoretical and conceptual ways in which studies are described is quite different to other reviews. The environmental characteristics related to walking or cycling choices are characterised as personal factors (including perceptions of distance, safety, convenience, monetary cost, and time taken, as well as traditional intra-individual

factors such as attitudes, values, outcome expectancies), and physical environmental factors [such as climate, topography, presence of infrastructure, access and linkage, lighting and aesthetics of places to walk or cycle to].

The most useful feature of this review is to estimate the walkable distance [<0.8 km] and cyclable distance [<5 km] for active transport and short trips for everyday tasks. This has urban planning relevance for multiple-centred cities, versus traditional ‘single downtown’ urban form. The review also summarises the literature that increased density leads to increased public transport usage, albeit from cross sectional [correlational] study designs. The implications for policy are that increased density will encourage public transport and walking for trips, and that micro-level planning changes can influence the streetscape and street-connectivity to increase the probability of active commuting. The author also points out the interplay between social norms and physical environments – one has to increase community values around walking before the policy development would be sufficiently advanced to re-engineer physical environments and make them more ‘walkable’.

11. Wendel Vos, Droomers, Kremers et al., (2005)

This detailed systematic review selected only studies in adults aged over 18, published in 1980-2004 and examining the relationship between environments and physical activity. Nearly two thirds of the final studies used were published 2002-2004, indicating that research interest in the relationship between environments and physical activity is of recent academic interest. They defined local or micro-environments, and broader macro-environments, and separated evidence for diverse physical activity measures [sedentary, walking, active commuting, moderate, vigorous, and total physical activity measures]. They initially identified 2,609 potential candidate papers, and systematically considered these, finally reaching consensus around 47 papers for inclusion, from which they identified 721 correlates. The authors note that overall, 55% of the total number of papers in this area were published in the USA, and a quarter in Australia. In addition, most [44/47] of these studies used a cross sectional research design.

The environmental correlates of ‘total levels of physical activity’ were studied, and clear evidence for a positive association was found for only one environmental correlate. This was social support, which is a socio-cultural and micro-environmental correlate that was positively associated with general physical activity in 6 of 11 estimates. The correlates of sedentary behaviours’ were examined, and no clear correlates could be identified. Consistent environmental correlates of

vigorous activities and sports included the presence of equipment and proximity and convenience of recreational facilities, and the presence of social support. The correlates of active commuting activities included trail and street connectivity. No correlates of cycle commuting were identified.

The strongest evidence was for the socio-cultural environment, especially social support and having a companion for PA, rather than the physical environment alone. Within the built [physical] environment, access to equipment, facilities or venues were consistent correlates.

The methodological limitations included self report for most environmental correlates, and lack of longitudinal data limiting causal inferences. The author suggests that “*people’s perceptions of their environment is more important for their behaviour than objectively assessed attributes of the environment*” (Wendel Vos et al., 2005). The issue of causal designs was considered, but within the constraints of fewer longitudinal studies, the correlates did not differ from those observed using cross sectional designs.

Of the 9 possible environmental correlates, this carefully conducted review suggested only two were consistently associated with physical activity: the availability of facilities in the physical environment and social support in the social-cultural environment. They report that three quarters of the estimates in this review showed null association; this leads to the thoughtful suggestion that “*either environmental factors are not as important to PA as proposed in recent literature or that environmental attributes included in the various studies were defined or measured in a wrong way compared to the type of PA under study*” (Wendel Vos et al., 2005).

3.2 Environmental correlates of walking among adults

Our review indicates there is less review-level evidence on the associations between walking and physical environments than the evidence base for overall physical activity. The challenges in this area of research are: the different settings and purposes for walking [recreation, transport, occupational], and the scale of the environments in which people walk – larger scale macro-environments may contribute to walking to get to transport, but local micro-environments may contribute to local community walking.

We found only one review specifically dedicated to the question of walking correlates (Owen et al., 2004) and three other reviews examined walking alongside their more general reviews of physical activity and environments (Wendel Vos et al., 2005; Cunningham and Michael, 2004; McCormack et al., 2004).

1. Owen et al., (2004)

This systematic review focused specifically on the environmental correlates of any type of walking. Eighteen studies were located, of which 16 used cross sectional designs. A total of 10 estimates examined correlates of walking for exercise or recreation, 10 examined correlates of total walking and four examined walking as transport. Walking for exercise was usually related to an aesthetically pleasant environment, convenient facilities to walk, coastal location, and other access or convenience attributes of the environment. However, nearly half of the estimates were non-significant. In considering 'walking for transport, significant correlates were access to public open space, safety, perceptions of traffic, pavements present and high overall walkability scores. For 'total walking', correlates included aesthetics, access to places to walk, convenience, the presence of destinations, pavements and easy access to a public transport system. The authors concluded that the evidence base was moderate, with a high proportion of non-significant estimates. Further, that the correlates of different types of walking may differ, and that this indicates the behavioural specificity of environments for walking. This means that the data indicate that the attributes associated with walking for exercise or recreation may differ from those associated with walking for transport.

2. Wendel Vos Droomers and Kremers et al., (2005)

The review by Wendel Vos et al., (2005), described above under reviews with physical activity outcomes measures, also examined the environmental correlates of walking. The social environment (having someone to walk with, social support) was regularly associated with walking behaviours''. This set of social environment variables was not examined by other reviews that considered walking. The presence of pavements appeared to be associated with increased walking, as did overall 'walkability' indices, but this review did not find that environment aesthetics were as consistently related as was reported in the Owen (2004) review. Neighbourhood-level walking in adults was related to environment aesthetics, particularly among men.

3. McCormack et al., (2004)

McCormack et al., (2004), also previously introduced, separated out the correlates of walking from those found with total physical activity levels. Sprawl indices showed ecological associations with walking rates. Significant associations with objective measures of the attributes of sprawl, such as accessibility, connectivity and destination information, further confirm these findings. Walking for recreation has been shown to be associated with functionality, which includes objective aspects of the environment such as walking surface, pavements and traffic. Safety has been less well studied, but width of pavements and separation from motorised transport may be correlated with walking patterns. Aesthetics seemed to be related to recreational walking in several studies, but this finding was not uniform. The presence of convenient and proximate destinations fostered local walking – to a beach, shop, park or other public open space.

4. Cunningham and Michael (2004)

Cunningham and Michael (2004) indicated that 10 of the 27 studies they reviewed had provided estimates of walking relationships to physical environments. Among these studies, walking to work was correlated with a total score of environmental attributes in Canada, walking for exercise was correlated with safety and convenience (in San Diego), all walking with aesthetics (in Australia), but walking was not significantly associated with convenience (in Portland, Oregon), or a neighbourhood environment score among US College students. The source studies reported different types of walking [for exercise, for transport] but the review did not differentiate these, and hence the only conclusion was that walking showed a mixed pattern of relationships to physical environmental factors.

3.1 Correlates of Physical Activity and Walking: Children

To develop effective interventions to increase levels of physical activity in children, the influences on, and determinants of activity levels need to be well understood (Sallis et al., 2000). As with adult populations, much of the work undertaken to date has predominantly focussed on individual level correlates, with the inclusion of environmental variables being a recent development. In this review, our search identified only one review paper that specifically addressed environmental correlates in children (Davidson and Lawson, 2006) and it provided an update to an earlier

published systematic review assessing the correlates of physical activity in children conducted in 2000 by Sallis et al. (Sallis et al., 2000).

Davidson and Lawson, 2006

Davidson and Lawson conducted a rigorous, systematic, semi-quantitative review of studies addressing environmental correlates of physical activity in children and adolescents. Their electronic search included PubMed, CINHALL, EBESCO, PsychInfo and TRANSPORT and looked for studies published in the English language between 1990 and 2006. Using a set of standard search terms the electronic search identified 106 'hits' of which 29 were deemed relevant, of which 23 met the selection criteria and were included. A further 10 articles were found by hand searching resulting in a final total of 33 studies. Studies were reviewed and the results categorized using 3 a priori categories: 1) recreational infrastructure; 2) transport infrastructure, 3) local conditions (e.g., crime, safety, weather). Using a similar system to the earlier systematic review by Sallis et al., (2000) the results were summarised as: positive and significant (+); negative and significant (-); or not significantly associated (0). In addition, results were reported separately for subjective and objective measures of the environment and, where possible, results from bivariate analyses (in contrast to multivariate) were used to allow comparison between studies.

Figure 3 provides the summary table of results as presented by Davidson and Lawson. The authors conclude that the most consistent findings was found for transport infrastructure, followed by recreational infrastructure, and the least consistent patterns were noted for local conditions. There appeared to be no consistent differences between age or ethnic groups but some indication that association between environmental features were more commonly found with girls compared with boys (Davidson and Lawson, 2006).

Transport infrastructure

Results for transport infrastructure were available from 9 studies (5 from the USA and 4 from Australia and Portugal). All were cross sectional study designs, 2 used objective measures of physical activity and 6 studies used objective measures of the environmental characteristics. The summary conclusions were that the results from these studies showed that children were more active when:

there were pavements ('sidewalks') - with 3 out of 4 studies reporting a significant association, stronger association noted for studies with objective measures and those studies using a more specific measure of activity (walking not generalised physical activity level);

there were destinations to walk to – 3 of 4 studies showed a positive relationship between destinations and activity levels although a variety of measures of ‘destinations’ were employed;
public transport was available – one study showed a positive association;
there were few intersections to cross – 2 studies reported that the provision of controlled crossings was positively associated with level of activity (boys but not girls) and walk/cycle to school.; and
density of traffic was low – 3 studies reported on measures of road safety or traffic hazards and results indicate a negative association with levels of physical activity; all 3 studies were conducted in Australia using parental reports along with subjective and objective measures of environment. (Davidson and Lawson, 2006).

Recreation Infrastructure

Results on recreation infrastructure (which included ‘private’ defined as in the home; ‘public’ defined as in community or school areas; ‘private-public’ defined as commercial play areas) were provided by 21 studies, most of which were cross sectional study designs (1 longitudinal study and 1 intervention). Five studies used objective measures of activity (accelerometry or heart rate), and 4 studies used direct observation of physical activity. Twelve studies used self report measures of the environment, 7 used objective measures of the environment and 2 studies used both. Significant positive associations were found for:

proximity to parks and playgrounds – 3 out of 5 studies, some gender and ethnicity differences may exist but too few studies to be conclusive

availability of recreation areas / presence in vicinity of home – 8 out of 10 studies which used a variety of outcomes measures and explored a variety of facilities including sporting arenas, sports pitches, and ‘recreational facilities and parks.’ There were no clear differences across studies to identify clear patterns by age, sex or ethnicity, but Davidson and Lawson note that the associations were more likely in the studies with larger samples (>1000) and that the association between facilities and physical activity may be small in magnitude and thus only detectible in studies with large samples.

Local Conditions

Results on local conditions were least consistent, and Davidson and Lawson suggest this reflects the broader range of measures being used in studies conducted to date. No effects were found for perceived safety (in neighbourhood or in play areas) however studies using objective measures of crime rate did report a significant (negative) association with physical activity in children. This was also found for objectively measured area deprivation. Weather was inconsistently associated with activity in children. Overall these results show more research in this area is warranted.

In addition to the above results, no associations was found between cycling infrastructure and levels of cycling and the review authors suggest this may in part be explained by limitations of the measures of activity used in these studies, namely there were not cycling measures and accelerometry has limitations in measuring cycling). Two of four studies reported an association between connectivity and children's level of activity and Davidson and Lawson indicate that differences in measures of connectivity may explain some of the results but that the finding of one study showing a negative association between connectivity and activity remained unexplained.

Figure 3 Extract of Table of Results from Davidson and Lawson (2006)

Table 2: Pattern of findings for links between environmental attributes (perceived and objective) and children's physical activity.

Environmental Attribute	Associations with physical activity		
	Perceived Environment		Objectively measured environment
	Adult report	Child report	
Recreational infrastructure			
Private			
Home equipment		0 ⁽¹⁹⁾ 0 ⁽²²⁾ 0 ⁽²⁴⁾ + ^F (²¹) + ⁽²⁶⁾	0 ⁽²²⁾
Public			
Proximity of playgrounds and parks	0 ⁽⁸⁾ (¹⁴) 0 ⁽²²⁾ + ⁽²²⁾	0 ⁽⁸⁾ (¹⁴) + ⁽²⁴⁾	+ ^F (²¹)
Availability recreation facilities	0 ⁽²⁸⁾ + ⁽¹⁹⁾	0 ^F (¹⁹) + ⁽²⁷⁾ + ⁽²²⁾ + ⁽²⁰⁾ + ⁽⁵⁾ (²⁴) + ⁽⁵⁾ (²⁴)	+ ^F (¹⁷) + ^F (²⁷)
Spending on recreational infrastructure			0 ⁽¹⁷⁾
Distance to school (school location)			- ⁽²⁴⁾ - ^F (²⁶) - ⁽²²⁾
School size			0 ⁽²⁰⁾ 0 ⁽²²⁾
Equipment/play structures in school play areas		+ ⁽²⁰⁾	0 ⁽²²⁾ + ⁽²³⁾ + ⁽²⁹⁾
Transport infrastructure			
Provision of amenities			
Presence of sidewalks		0 ⁽²²⁾	+ ⁽²²⁾ + ⁽²⁹⁾
Street and sidewalk conditions			+ ⁽⁴⁰⁾
Presence of bike lanes/ease of cycling		- ^F (¹⁸)	0 ⁽⁴⁰⁾ 0 ⁽²²⁾
Presence of controlled crossings	+ ^F (²⁴)		+ ⁽²²⁾
Connectivity of street network		0 ⁽²²⁾	+ ⁽²⁰⁾ - ⁽²⁴⁾ + ^F (²⁷)
Access to destinations		+ ⁽²²⁾ - ^F (¹⁸)	+ ^F (²⁷)
Availability of public transportation	+ ^F (²⁴)		
Road hazards			
Number of roads to cross	- ⁽²⁴⁾		
Traffic (density/speed)	- ^F (²⁴) - ⁽¹⁸⁾		- ⁽²⁴⁾
Pedestrian and cyclist safety	+ ^F (¹⁸)		
Steep terrain			- ⁽²⁴⁾
Local conditions			
Safety and neighborhood disorder			
Perceived safety	0 ⁽⁴⁵⁾ 0 ⁽⁸⁾ (¹⁴) 0 ⁽²²⁾ 0 ⁽⁴⁸⁾ + ⁽⁴⁴⁾	0 ⁽²⁷⁾ 0 ⁽⁸⁾ (¹⁴) 0 ⁽²²⁾ + ^F (²¹)	- ^F (¹⁷) - ^F (²¹) - ⁽⁴²⁾
Area deprivation and crime			
Roaming dogs		- ⁽¹⁸⁾	
Social disorder/stranger danger	0 ⁽²⁴⁾		- ⁽⁴⁴⁾
Physical disorder/tidiness of area			0 ⁽⁴⁰⁾ - ⁽⁴⁴⁾
Aesthetics of neighborhood		+ ⁽²²⁾	
Region and weather			
Month of year (average temperature)			0 ⁽⁴²⁾ - ⁽¹⁾ - ^F (¹⁷)
Unsuitable weather		0 ⁽⁴⁴⁾	0 ⁽⁴⁷⁾ - ⁽¹⁷⁾
Region of the United States			0 ⁽⁴²⁾
Rural/suburban versus urban			0 ⁽⁴⁷⁾ + ⁽⁴²⁾ - ^F (⁴²)
Population density			+ ⁽²⁰⁾ 0 ⁽²²⁾

Note:

¹ Associations identified with physical activity: +, significant positive association; -, significant negative association; 0, no association.

Superscript numbers = reference number.

Effects that are specific to particular demographic groups are noted as follows: M = males; F = females; B = Black/African American sample or subgroup

In addition to the review by Davidson and Lawson, two of the 11 review papers addressing physical environmental correlates of physical activity in adult populations also discussed studies which addressed children and adolescent population groups (Badland and Schofield, 2005; Sallis et al. 2002).

Sallis et al., (2002) reported on two primary studies with children and stated that both studies indicated that preschool children were more active in areas where they had places ‘nearby’ in which they could play (for example, parks) (Sallis et al., 2004). Two other primary studies are cited as providing some evidence that children rely on ‘parents for transportation to opportunities to be physically active’ and that this may be a function of suburban land use patterns and the lack of planning for youth mobility. Sallis et al., note however that these relationships remain unproven.

Badland and Schofield identify children as an ‘at risk’ population and discuss several primary studies that indicate some likely associations between characteristics of the environment and physical activity (Badland and Schofield, 2005). Specifically, it is noted that two studies provide evidence on a negative association between household car ownership and children’s travel behaviour (in this case, walking). Both studies are non UK, one studies an Australian population and the other American children. Parental perception of safety is noted as a potential correlate as fear for children’s safety may increase parents reluctance to allow children to play outside where they may be less able to monitor their behaviour.

Neither Sallis et al., (2004) nor Badland and Schofield (2005) portend to be systematic reviews of the evidence base on children. However they report results on ‘access to facilities’ that seem consistent with the findings of the more recent review by Davidson and Lawson. In contrast, while it may seem intuitive that ‘safety’ would be positively associated with physical activity, there does not appear to be a large body of supporting evidence. This may be due to measurement issues.

3.5 Measurement Methods and Instruments

Measures of physical activity

Measurement of physical activity is known to pose a number of challenges due to the complexity of the behaviour and interest in a number of different attributes (type, setting, purpose, duration, frequency, intensity). Various measurement methods can be used but the two most commonly found in this field of research are self report instruments (completed as a written survey or a telephone/household interview) and, to a lesser extent, objective measures of movement (such as

pedometers or accelerometers). The majority of the research undertaken to date has used self report measures of physical activity, however there is great variation in the amount of detail collected and the presentation of the outcome variable. Data may be dichotomized or categorised, for example, 'meeting recommended levels of activity for health benefits'; or whether particular activities have been undertaken (walked, cycle). Alternatively, a continuous variable of physical activity can be presented such as minutes of activity. In either approach, single or multiple domains of physical activity can be incorporated (e.g., total activity, leisure-time only, walking for recreation, cycling to work).

Across the review papers assessed for this report, it is evident that many of the early primary studies assessed total physical activity and often this was a measure of only leisure-time activity. In the last 3-4 years there has been an increase in studies focussing on solely walking and these sometimes differentiate between walking for transportation and walking for recreation. Some results suggest that different environmental correlates are more or less important for different types of physical activity. These early indicative findings have prompted calls for more specificity in the dependent variables used in this field of research.

Across the physical activity research field there is well recognised limitations to the use of self report measures of physical activity and thus the use of objective measures of the behaviour of interest are encouraged. This use of objective measures was seen more often in the literature on children (see Davidson and Lawson 2006).

Measures of the physical environment

It is evident from the summaries of the reviews papers provided above that a large number of independent variables have been subject to investigation (see Table 6 and Appendices for examples of the many environmental characteristics under investigation). In much of the published research, environments are measured by self-rating, that is, perceptions of aspects of the built environment are reported. These are usually measured using a self completed questionnaire to assess an individual's perceptions of, for example, safety, convenience, or aesthetics.

Many environmental variables can be assessed objectively, often by deriving variables using GIS, such as availability of facilities, road network distances, land use mix, population density. It appears from this review of reviews that, to date, only a few studies are attempting to capture both an objective and subjective measures of the same construct. Also, only the minority of primary studies and review papers are teasing out results by type of measure (objective versus subjective). Lee and

Moudon (2004) did identify 3 out of 20 included studies that had both subjective and objective measures and presented their results for both objective and subjectively assessed variables separately. They identified that presence of and proximity to exercise facilities in the neighbourhood, whether perceived or actual, were associated with level of physical activity. A finding they note that is consistent with the planning literature that distance to destinations is a determining factor for transportation mode choice (Lee and Moudon, 2004). In the review of physical activity in children, Davidson and Lawson did present results by objective and subjective measurement (Davidson and Lawson, 2006).

Characteristics of the built environment can also be assessed using proxy measures. For example several studies have used age of house as a proxy indicator for urban form noting that, in the USA at least, houses built before 1940 are typically in areas where the urban form provides a grid street layout, closer proximity to destinations and mixed land use. Results showed these areas were associated with higher levels of physical activity. However, using proxy variables and even aggregating variables into an index may obscure associations. Humpel et al., (2002) noted that conflicting results from one study with college students may have been due to the use of a composite summary variable (comprising aesthetics, neighbourhood features and safety).

Although GIS is becoming an established tool for developing measures of various characteristics of the environment, many studies combine this with the use of a data collection instrument aimed at assessing environmental characteristics. This measurement area is new and therefore required the development of new tools, these in turn need testing themselves. Several instruments have become well known (e.g., SPACES, NEWS) but there is no consensus on any one instrument.

In summary, both the independent and dependent variables in this area of research pose measurement challenges. A wide variety of methods are used to collect, derive, analyse and present data. This makes the task of assessing and comparing the results across studies more difficult. Few reviews identified separately the findings by objective or subjective measurement methods yet this will remain an important issue. Future research should make an explicit attempt to include this assessment.

3.6 Summary of findings on environmental factors and physical activity

This review summarises the strength of association or correlation between aspects of the physical and built environment and physical activity and walking. Table 6 presents a summary of the overall findings of this systematic review of the reviews. For the direction of findings on each available

environmental correlate by each review paper included, for physical activity and for walking outcomes, see Appendix 1 and 2, respectively. For the summary in Table 6 below, the associations were coded as ‘an association’ [+] or no association [0]. Where there was a consistent finding of an association in at least five review studies, the coding [++] was used (Table 6). Note that equivocal observations by the authors of a review paper was coded as [0/+] and if there were mixed findings, then the overall coding in the Appendix was to summarise the most frequent rating [for examples; three ‘+’s and only one ‘0’ would be coded as ‘+’ in the ‘summary score across reviews’ column in the Appendix].

Environments and physical activity - There are reasonably consistent associations between access to physical activity facilities, convenient and proximate access to destinations, high residential density, land use and urban ‘walkability’ scores and measures of physical activity. There are also reasonably consistent associations between perceived safety, exercise equipment, footpaths and physical activity participation. Less clear associations are noted for aesthetic features of the environment, parks, topographic factors and perceived crime. No association with physical activity has been found for unattended dogs (see Table 6).

Environments and walking - The correlates of walking are more similar than different to those found for physical activity, although there are some differences between the correlates of walking for exercise and walking for transport.

Physical environments seem to be consistently related to physical activity, predominantly from an evidence base of cross sectional studies. Overall this review of reviews provides some initial evidence that aspects of the built environment and of urban form may influence physical activity. The key question is whether a public policy conclusion that “environmental changes would lead to increased population levels of physical activity participation” is tenable at this stage. The reviews on adult populations are divided on this point. One clear issue is that other environmental correlates, especially those from the social environment, are almost always ignored in reviews, although they seem strongly correlated with physical activity in the primary source studies that measured them.

Table 6 Correlates of physical activity and of walking : summary of review findings

Summary of Correlates	Correlated with Physical Activity	Correlated with walking
Proximity to recreation facilities, convenience, walkable distance to facilities	++	+
Destination factors , micro-scale design, footpaths, trails	++	+
Route related factors: hilliness, traffic	+/ 0	+/ 0
Mixed land use, shops and services nearby	++	+
Walkability [specific mention]	+	+/ 0
perceived safety	+/ 0	0
Lighting, streetlights	0	0
Area based: coastal residence	+	+
Urban/age of suburb	+	+
Culture, social environment as most important	+	+
Aesthetics [perceived]	++	+
High crime rates	0	0
Population density /sprawl	++	+
Unattended dogs	0	0
Connectivity	+	+

Legend

- ++ significantly associated in ≥ 5 reviews
- + more often associated
- +/**0** equivocal association
- 0** not associated

Children

One systematic review provides the basis for the main findings on the environmental correlates of physical activity in children. This well conducted review reveals that the most consistent associations were for attributes of the environment related to transportation infrastructure, specifically the provision of pavements, destinations to walk to, few intersections to cross and low road traffic hazards. Aspects of the provision of recreation infrastructure were also found to be strongly (positively) associated with increased levels of activity, specifically, proximity to and availability of to parks, playgrounds, and recreation areas. There was less consistency in the results on aspects of the local environment but this was considered to reflect the broader range of measures being used in studies and the formative stage of this field of research conducted to date. No effects were found for perceived safety however some studies show crime rates may be significantly (negatively) associated with physical activity in children.

For children most of the studies were cross sectional design, most were conducted in USA or Australia, a variety of measures were used, although more use of objective measures of physical activity is evident. There were few clear differences in the results across the studies included to identify patterns by age, sex or ethnicity.

4. CONCLUSIONS

4.1 Nature of the evidence

The evidence presented in this review is from 13 reviews represents in excess of 100 primary studies. Most of the evidence in these reviews describe correlates of physical activity from cross sectional study designs and thus it is not possible to infer a causal or true ‘determinants’ relationship. Additional evidence from longitudinal and from intervention studies is required.

There is a lack of evidence on the environmental correlates of different types of physical activity; much of the available evidence has a dominant focus on identifying and describing the correlates of total physical activity or leisure-time physical activity. More recently, there has been a shift to increasing interest in ‘active travel’ and thus a focus on walking and cycling as a mode of transport. Few studies present evidence on the environmental correlates for different modes and purposes of activity.

Most work on the environmental correlates of physical activity has been done with adult populations, only more recently has the research extended to explore correlates in young people (children and adolescents) and to a lesser extent older adult populations. Limited research is available on correlates of physical activity in minority and specific sub-populations.

Some of the reviews used systematic approaches to identifying studies, but most did not. A review of reviews (Gebel et al., 2005) noted that many reviews did not examine all the studies that they could have, but these errors of omission did not influence the observed correlates. Gebel et al., also noted that a few of the reviews they reviewed misquoted the evidence they extracted from primary studies, but these ‘errors of co mission’ were relatively rare, and also did not influence the findings (Gebel et al., 2005).

4.2 Methodological caveats in the associations described

1. A methodological strength is that many studies used representative population samples, but a weakness is that these emanate from only a few countries, particularly the USA and Australia.
2. The studies are almost all cross sectional in design, and are reporting statistical associations only; sometimes these estimates are unadjusted for potential confounders.

3. The lack of longitudinal data means that causal inferences about the relationship between environments and physical activity are not strong, and only measures of association are provided as the evidence base. This means that changing the physical environment in a particular way, such as increasing walkability, may or may not subsequently lead to increases in physical activity – this temporal relationship is not known for environmental measures.
4. The measurement issues are complex; self report or perceived environments may relate to physical activity in similar or different ways compared to objective measures of the same environment. Differences in the associations may be apparent for perceived versus objective measures of safety, crime, or the existence of local recreational facilities.
5. There is a lack of standardisation of measurement of environments (or of physical activity), making comparisons among studies difficult. There are also different domains of physical activity, particularly walking for exercise/recreation compared to walking for transport, and these may show different correlates with different aspects of the micro and macro level physical environment

4.3 Generalisability of the review findings

The central public health importance of correlates of physical activity is concerned with the generalisability of the findings. If results are generalisable to diverse populations, then correlates studies can be used to guide public health programs and interventions. For example, the consistent association between self-efficacy and physical activity has led to the development of numerous intervention programs using self-efficacy and other social cognitive theory elements in the intervention design, with the potential for them to effectively support physical activity behaviour change. The same may be true of environments thought to be related to activity, whereby the work of urban planners and transportation systems can utilise the findings from correlates research in intervention design. However, one limitation is that some research, even if systematic and replicated, was carried out in small and non-representative samples, and hence may not be observed as a correlate in all samples.

Finally, the current evidence base is limited by what has been measured and how. If, for example, cultural and social norms foster and support sedentary behaviours, but they are not measured, then identifying ‘social norms’ as a correlate will not have occurred, and this may lead to missed

opportunities for intervention. Integration of variables on social environmental has yet to occur in much of the work on physical activity and the built environment.

Research on correlates has been carried out almost exclusively in North American and Australia, with limited published literature on environmental correlates from the UK. Thus, the evidence base for understanding the role of the environment and physical activity in England is very limited, and no clear patterns are available.

4.4 Limitations of the review / evidence

The total variance explained by environmental factors is still limited, with no more than about 5-10% of the variance in physical activity, even when all the environmental correlates are included together in statistical models. This means much of the variation remains unexplained; either correlates are insufficient, or are poorly measured and assessed. It may be that studies have underestimated the strength of association between proposed correlates and physical activity because of measurement error; this is a problem with self report physical activity measures, especially when various types and intensities of activity are assessed.

Limitations due to the methods of this review may include limiting the review to a review of reviews, including studies published only in English between 2002-2006 and applying search terms to only title and key words. Searching the abstracts was excluded.¹⁰

Across the reviews papers included in this study, common methodological problems are identified, especially in primary studies of correlates in sub-populations. Often studies are based on small sample sizes, lack a theoretical basis, and may use measures of physical activity that have not been validated. Environmental variables may be measured either using objective or subjective (self report) measures and in ways that may differ from other similar studies. This variation in measurement methods and variable definitions makes it difficult to summarise and compare between and across the growing literature base. Measures of the outcome variable physical activity also differ, and where this are assessed using self report measures the responses may be unreliable, particularly among children. The assessment of physical (and social) environments remains in a

¹⁰ Inclusion of abstracts was excluded due to prior experience in which including abstracts substantially decreased the specificity of the papers ('hits') identified with many more false positives. The approach undertaken is evidence based as better practice in finding 'physical activity and environments' bibliometry

relatively early stage of development, and researchers may omit important dimensions of these environments in their studies.

The limitations facing the development of evidence in this field are well recognised (Lee and Moudon, 2004) and include:

- Complex and interrelated variables
- Numerous confounding factors
- Difficulty in defining and effectively quantifying environmental variables
- Use of different scales (local to large spatial analytic units)
- Difficulty in establishing causality

4.5 Implications for future research

Despite the fact that numerous questions remain about the determinants of activity, there is clearly a plethora of information available on the multiple factors associated with physical activity, and this information base has increased markedly over the past 5 years. It is clear that multiple determinants, from individual level factors, through to environmental factors, are important. More focused research will identify the specific settings and types of physical activity, and explore determinants of setting-specific behaviours.

Physical activity measurements are improving, with increasing use of objective measures of environments, and of the behaviour itself. Future research should use reliable and valid instruments to assess physical activity and consider the level of specificity of behaviour required, for examples walking for recreation, cycling for transport. Measures of the environmental characteristics are also improving but are very diverse. Further development of these measurement methods, definitions and aggregation is likely in the future and greater consistency will allow for better synthesis and understanding across studies.

More emphasis on longitudinal designs will allow clearer identification of true ‘determinants’ and separate them out from factors that are simply statistically associated ‘correlates’. These determinants can be better understood, and used to develop and test intervention designs. Optimal interventions are likely to be at multiple levels, and attempt to influence multiple domains of physical activity.

The evidence base is sufficient to include environmental thinking in the mix of strategies that might summate to a comprehensive public health approach to physical activity. However, environmental change alone may not be sufficient to influence population level physical activity prevalence, and caution should be exercised, tempering unbridled enthusiasm for environments as the ‘great white hope’ for public health approaches to physical activity (Bauman 2005).

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APPENDICES

Appendix 1: summary from each review of the correlates [associations] with environmental factors and physical activity ¹¹

Physical activity Correlates	Sallis, Frank	Lee and Moudon	Salens, Sallis and Frank	Cunningham	Duncan	Humpel	Badland	Vojnovic	Wendel Vos	McCormack	Trost	SUMMARY ACROSS REVIEWS
Physical Environ Factor												
Proximity to recreation facilities, convenience, walkable distance to facilities		+	+	+/0	+	+	+	+	+	+	+	9[+] 1[+/0]
Destination factors , micro-scale design, footpaths, trails	+/0			+	+	+	+		+/0 Transp +	+	+	6[+] 2 [+/0]
Route related factors: hilliness, traffic		+/0		0	+	+/0			+/0	+/0	+	2[+] 4 [+/0] 1[0]
Mixed land use, shops and services nearby	+		+		+	+/0	+	+				5[+] 1[+/0]
Walkability [specific mention]	+		+				+			+		4+
perceived safety		+		+		0			0	+/0	+	3[1] 1[+/0] 2 [0]
Lighting, streetlights				+/0	0	0			0		0	1 [+/0] 4[0]
Area based: coastal residence Urban/age of suburb		+			+	+	+	+	+			4[+] 3[+] 1[0]
Culture, social environment as most important								+	+			2+
Aesthetics [perceived]		+		+		+		+		+/0	+	5[+] 1[+/0]
High crime rates				0	0	0 Perceived +					0	4[0]
Population density /sprawl	+	+	+			+			+	+		6+
Unattended dogs				0	0	+/0					0	1 [+/0] 3 [0]
Connectivity							+	+		+		3+

¹¹ Notes for this table – Lee and Moudon identified ‘any study with a significant correlate’; data from Wendel-Vos et al., are estimates for whole samples [both male and female genders combined]; Cunningham and Michael estimates are those described as ‘consistently associated’

Appendix 2 : Walking estimates - summary from each review of the associations – environmental factors and WALKING

WALKING Correlates	Wendel Vos et al.,	Owen et al.,	McCormack et al.,	Cunningham & Michael	SUMMARY ACROSS REVIEWS
Proximity to recreation facilities, convenience, walkable distance to facilities	+/0	+	+	+	3[+] 1 [+/0]
Destination factors , micro-scale design, footpaths, trails	+	+	+	+	4[+]
Route related factors: hilliness, traffic	0	+/0	+/0	+/0	1[+] 3 [+/0]
Mixed land use, shops and services nearby	+/0	+	+		2[+] 1[+/0]
Walkability [specific mention]	+	+/0			1[+] 1[+/0]
perceived safety			0	0	2[0]
Lighting, streetlights	0	0			2[0]
Area based: coastal residence Urban/age of suburb		+		+	1[+] 2[+]
Culture, social environment as most important	+				1[+]
Aesthetics [perceived]	+/0	+	+	+	3[+]
High crime rates	0	0			2[0]
Population density /sprawl	+				1[+]
Unattended dogs	0	0			2[0]
Connectivity			+		1[+]

¹ Notes for this table – Wendel-Vos et al., are estimates for whole samples [both male and female genders combined]; Cunningham and Michael estimates are those described as ‘consistently associated’