Physical Activity 2

Correlates of physical activity: why are some people physically active and others not?

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This is the second in a Series of five papers about physical activity

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Physical inactivity is an important contributor to non-communicable diseases in countries of high income, and increasingly so in those of low and middle income. Understanding why people are physically active or inactive contributes to evidence-based planning of public health interventions, because effective programmes will target factors known to cause inactivity. Research into correlates (factors associated with activity) or determinants (those with a causal relationship) has burgeoned in the past two decades, but has mostly focused on individual-level factors in high-income countries. It has shown that age, sex, health status, self-efficacy, and motivation are associated with physical activity. Ecological models take a broad view of health behaviour causation, with the social and physical environment included as contributors to physical inactivity, particularly those outside the health sector, such as urban planning, transportation systems, and parks and trails. New areas of determinants research have identified genetic factors contributing to the propensity to be physically active, and evolutionary factors and obesity that might predispose to inactivity, and have explored the longitudinal tracking of physical activity throughout life. An understanding of correlates and determinants, especially in countries of low and middle income, could reduce the effect of future epidemics of inactivity and contribute to effective global prevention of non-communicable diseases.

Key messages

- Population levels of physical activity participation are low, and improved understanding of why some people are active and others are not is needed
- Some consistent correlates of physical activity are individual-level factors such as age, sex, health status, self-efficacy, and previous physical activity
- Ecological models posit that the physical and social environments—ie, economic conditions, societal norms, urbanisation, industrialisation—are important determinants of physical activity
- Correlates have been less studied in low-income and middle-income countries than in other nations, and although broadly similar to those in high-income countries, they are more focused on the prevalent domains of physical activity in developing countries—ie, correlates of transport and occupational activity
- New research has identified genetics, evolutionary biology, and variation in physical activity behaviour throughout life as important determinants
- Improvement of the research base, with a stronger focus on determinants research (with improved causal inference rather than repetition of cross-sectional correlates studies) will further an understanding of physical activity in populations and interventions designed to increase activity levels

Introduction

Globally, many adults and children do insufficient physical activity to maintain good health.[1] Furthermore, the population burden of inactivity is unacceptably high.[2] Although strategies to increase physical activity are being developed,[3,4] effect sizes are usually small to moderate, and effective interventions are not widely applied. The prevalence of physical activity is slow to improve and is worsening in some countries.[5] As the global burden of non-communicable diseases increases, risk factors such as physical inactivity become relevant in low-income and middle-income countries, not just in the most developed nations.[6] Understanding the causes of physical activity behaviour is essential for development and improvement of public health interventions,[7] much as aetiological studies of disease provide information about treatments. Of particular interest is how aetiological factors differ between physical activity domains—ie, areas of life in which activity is done (at home, at work, in transport, and in leisure time)—and with country, age, sex, ethnic origin, and socioeconomic status.

One challenge in the interpretation of evidence is that most studies have used cross-sectional designs. This so-called correlates research assesses only statistical association, rather than providing evidence of a causal relationship between factors and physical activity.[8,9] Longitudinal observational studies and experimental data could identify factors that have strong causal associations with physical activity.[9] When such factors are identified in studies of aetiological design, they are described as determinants.[8]

Because physical activity is affected by diverse factors, behavioural theories and models are used to guide the selection of variables for study.[8] Integration of ideas from several theories into an ecological model (including inter-relations between individuals and their social and physical environments) is now common.[10] This approach uses a comprehensive framework to explain physical activity, proposing that determinants at all levels—individual, social, environmental, and policy—are contributors. A key principle is that knowledge about all types of influence can inform development of multilevel interventions to offer the best chance of success.[10] Figure 1 shows a multilevel model of physical activity influences, which guided our classification of variables in this report. The model is ecological because inter-relations between individuals and their social and

physical environments are included. A key principle is that understanding of all levels of influence can inform development of multilevel interventions that offer the best chance for success.[10] Variables within individuals, such as psychological and biological factors, are widely studied, as are interpersonal variables. Environmental, policy, and global variables are less studied, but are thought to have widespread effects. The combination and interaction of factors and at these levels are expected to influence physical activity.

Physical activity is done for various reasons, and the SLOTH (sleep, leisure-time, occupation, transportation, and home-based activities) model[11] delineates the domains of physical activity. Ecological models of physical activity have been developed that suggest correlates are specific to domains.[12] All domains are important for understanding of worldwide physical activity, because frequency of activity in each domain varies greatly between countries.[13,14] For example, occupational, household, and transport domains are the most common types of physical activity in low-income and middle-income countries, whereas leisure-time activities contribute more to total physical activity in high-income countries than elsewhere.[14]

We have three objectives. First, we aim to summarise present knowledge about correlates and determinants of physical activity in adults and children, on the basis of evidence from systematic reviews of physical activity correlates.[15,16] We provide an outline of new research into physical activity domains, particularly exploring correlates of active leisure and recreation, and active transportation. Additionally, we describe the rapidly evolving field of environmental correlates of physical activity. Second, we examine correlates and determinants research in countries of low and middle income, where physical inactivity is rapidly becoming a major risk factor for non-communicable disease.[17] Third, we analyse correlates and determinants of physical activity that are least studied, such as genetic factors, lifecourse trajectories, evolutionary and societal factors, and obesity (figure 1).

Studies of correlates and determinants

We identified individual, social, and environmental correlates of physical activity in studies with adults (aged ≥18 years) and children (aged 5–13 years depending on the study) or adolescents (aged 12–18 depending on the study), with variables categorised with our ecological model. Reviews published after Jan 1, 1999, were obtained with a systematic search of Academic Search Premier, Medline, PsycInfo, SportDiscus, and Web of Science (appendix). We used the search terms "physical activity", "physically active", "exercise", "exercising", "motor behavior", "active living", "active transport", "inactivity", "inactive", "walk", "walking", "cycling or cycle or bike or biking or bicycle or bicycling", "determinants", "correlates", "demograph*", "biologic*", "psychosocial", "environment*", "genetic", and "review". We did the final search in April, 2012. We used no language restrictions. Additional papers were retrieved from our individual databases and from references within the reports identified.

The outcomes in the reports identified by the initial search were mostly leisure-time or recreational physical activity. Some reviews reported on total physical activity,[18] often measured objectively with accelerometers, especially in children,[16,19] and a few provided correlates of other domains of activity,[20] particularly active transportation.[21] For each report, we coded variables on the

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See **Online** for appendix

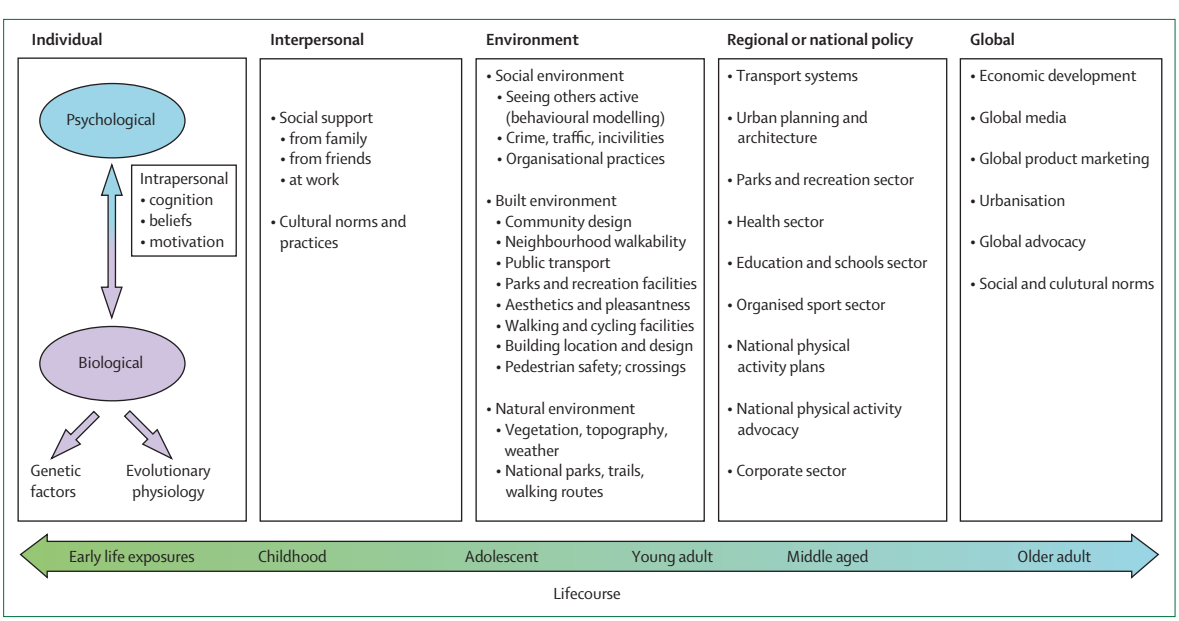

Figure 1: **Adapted ecological model of the determinants of physical activity**

basis of clear evidence that the factor was a correlate or determinant, evidence of no relationship (not a correlate or determinant), or no evidence (not reported). A limitation of this approach was that we obtained narrative reviews describing the consistency—not the magnitude—of associations, so formal pooling of data or meta-analyses was seldom undertaken. We sought correlates for all ages, and used a five-category classi—fication system:[15] demographic or biological, psychosocial, behavioural (including previous activity participation and other health-related behaviours), social and cultural, and environmental factors.

Studies of physical activity correlates in low-income and middle-income countries have not been previously summarised. We searched Medline and Web of Science with the term "'physical activity' or 'exercise' and 'correlates' or 'determinants'" as title, topic words, keywords (appendix). We included studies published in English, Spanish, Portuguese, French, and German. We identified original reports and separated results by type of physical activity, because leisure-time activity made only a small contribution to overall activity in many nations.[22] We used the World Bank definitions of countries of low and middle income. We categorised variables into broad groupings as for high-income countries, because we had insufficient studies to undertake a detailed review of individual correlates.

For more on **World Bank definitions** see http://data.worldbank.org

Finally, we investigated correlates that are studied less than are others, on the basis of our conceptual framework (figure 1). We chose to investigate variation with time (tracking), heritability, the role of evolutionary biology, and obesity as determinants. Finally, we examined potential policy, macrosocial, and global determinants, because they might be important at the population level.

Correlates and determinants of physical activity

Demographic, psychosocial, behavioural, and social factors

We initially identified 32 reviews of demographic, psychosocial, behavioural, and social factors in adults, adolescents, and children, of which 16 systematic reviews were used (appendix). Of those, seven reviews of children and adolescents met our inclusion criteria (appendix) and were used for the final synthesis. Reports varied from comprehensive reviews[16,23] to those that focused on only longitudinal studies.[20,24] Other reviews were of adolescent girls,[25] pre-school children (aged 2–5 years),[26] and parental correlates of physical activity.[16,20,23,24,26] In those published since 2000, consistent evidence has emerged for 39 separate correlates and 11 separate determinants (identified in longitudinal studies only) in children, and 51 correlates including seven determinants in adolescents (appendix).

Male sex is a consistent positive determinant in children aged 4–9 years; for other age groups of children and adolescents, sex is a correlate but not a consistent determinant (table 1). In children, parental marital status, including single-parent status, was identified as a non-determinant (table 1). No relationship was noted for body-mass index and other anthropometric measures in children or adolescents (table 1). A white ethnic origin was a consistent positive determinant in one systematic review of adolescents,[24] but not in another (table 1).[20]

Of psychosocial factors, self-efficacy (confidence in the ability to be physically active in specific situations) was a consistent positive correlate and determinant of physical activity in children and adolescents (table 1). Perceived behavioural control (general perceptions of ability to be physically active) is a determinant in adolescents, but evidence is inconclusive in children (table 1). The findings for valuing physical activity for health status (appearance or achievement), and barriers to physical activity in children are inconsistent (table 1). Perceived competence and attitude are not determinants in adolescents (table 1). Findings for behavioural factors in children and adolescents vary: smoking seems to be unrelated to physical activity, but previous physical activity does seem to be a predictor (table 1).

Of social and cultural factors, parental activity was not a determinant in children or a correlate in adolescents. Family support was identified as a correlate in children and adolescents, but it was not a determinant in children. Children's perception of their parents' behaviour was not a determinant of their own activity, and in adolescents it was not a correlate. In adolescents, general social support for physical activity was confirmed as a determinant in one review (table 1).

In adults, research into correlates started with theoretical approaches to understanding individual behaviour. This field expanded to subsequently consider environmental correlates within an ecological framework.[27] In this review of non-environmental adult physical activity correlates, we identified nine reviews meeting the inclusion criteria (table 2). Chronologically, reviews were initially generic,[15] or focused on older adults,[28] women,[18] special issues (eg, personality),[29] life events,[31] and occupational correlates of physical activity.[30,33] The most recent reviews identified determinants and used longitudinal designs.[29,32,34] Consistent evidence has emerged for 36 separate correlates since 1999, including 20 separate determinants in adults (appendix).

Health status and self-efficacy are the clearest correlates in adults, with consistent evidence for a direct role in four of seven reviews (table 2). Consistent evidence from one of two reviews shows that both are determinants (table 2). The next clearest are personal history of physical activity during adulthood and intention to exercise, both with consistent evidence for a direct role from two correlate reviews and one determinant review. The stages of behavioural change according to the transtheoretical model were direct correlates in one review and direct determinants in another.

Additionally, we noted that age (inversely), male sex, education level, ethnic origin, overweight (inversely), perceived effort (inversely), and social supports are

reported correlates of activity, but were not determinants. Marital status and social norms were not determinants. In Kirk and Rhodes's review of determinants in the work setting,[33] occupational category was directly associated with leisure-time physical activity, but inversely related to total activity. Other factors (job strain, working hours, and overtime) had inverse associations with leisure-time physical activity.[33] Finally, the most recent reviews[32,34] (with data from only longitudinal studies) showed that stress is an inverse determinant and that physical and psychological outcome realisations are direct determinants of

	Children							Adolescents					
	Sallis (2000)[16]	Van Der Horst (2007)[23]	Hinkley (2008)[26]	Edwardson (2010)[19]	Craggs (2011)[20]	Craggs (2011)[20]	Uijtdewilligen (2011)[24]	Sallis (2000)[16]	Biddle (2005)[25]	Van Der Horst (2007)[23]	Edwardson (2010)[19]	Craggs (2011)[20]	Uijtdewilligen (2011)[24]
Study characteristics													
Ages	3–12 years	4–12 years	2–5 years	6–11 years	4–9 years	10–13 years	4–12 years	13–18 years	10–18 years*	13–18 years	12–18 years	14–18 years	13–18 years
Publication period of studies included	1970–98	1999–2005	1980–2007	To 2009	To 2010	To 2010	2004–10	1970–98	1999–2003	1999–2005	To 2009	To 2010	2004–10
Number of quantitative studies included	54	57†	24	41	46†	46†	30†	54	51	57†	60	46†	30†
Endpoints	Overall	Sitting; overall	Overall	Leisure; overall	Leisure; occupation; transport; home	Leisure; occupation; transport; home	Sitting; overall	Overall	Leisure; overall	Sitting; overall	Leisure; overall	Leisure; occupation; transport; home	Sitting; overall
Proportion of longitudinal studies included	13 (24)%	6 (11%)†	3 (13%)	8 (20%)	46 (100%)	46 (100%)	30 (100%)	7 (13%)	10 (20%)	6 (11%)†	7 (12%)	46 (100%)	30 (100%)
Accumulated number of review citations for consistent evidence‡													
Correlates and determinants	24	38	47	53	54	64	64	35	49	68	76	82	84
Determinants only	0	0	0	0	1	11	11	0	0	0	0	6	8
Demographic and biological variables													
Male sex	Correlate	Correlate	Correlate	NR	Determinant	Inconclusive	Inconclusive	Correlate	Correlate	Correlate	NR	Inconclusive	Inconclusive
Ethnic origin (white)	Inconclusive	Not correlate	Not correlate	NR	Inconclusive	Inconclusive	NR	Correlate	Correlate	Not correlate	NR	Not determinant	Determinant
Marital status of parent	Not correlate	Not correlate	NR	NR	Inconclusive	Not determinant	NR	NR	NR	NR	NR	NR	NR
Body-mass index or anthro-pometry	Inconclusive	Not correlate	Not correlate	NR	Inconclusive	Not determinant	NR	Not correlate	NR	Not correlate	NR	Inconclusive	Inconclusive
Psychosocial variables													
Perceived competence	Inconclusive	NR	NR	NR	Inconclusive	Inconclusive	NR	Correlate	Correlate	NR	NR	Not determinant	NR
Self-efficacy	Inconclusive	Correlate	NR	NR	NR	Determinant	NR	Inconclusive	Correlate	Correlate	NR	Determinant	NR
Attitude	Not correlate	NR	NR	NR	Inconclusive	Inconclusive	NR	NR	NR	Correlate	NR	Not determinant	Inconclusive
Perceived behavioural control	NR	NR	NR	NR	NR	Inconclusive	Inconclusive	NR	NR	NR	NR	Determinant	Inconclusive
Value of health and status	NR	NR	NR	NR	NR	Not determinant	NR	Correlate	NR	NR	NR	NR	NR
Barriers to physical activity	Inverse association	Not correlate	NR	NR	NR	Not determinant	NR	Not correlate	Inverse association	NR	NR	Inconclusive	NR

(Continues on next page)

	Children							Adolescents					
	Sallis (2000)[16]	Van Der Horst (2007)[23]	Hinkley (2008)[26]	Edwardson (2010)[19]	Craggs (2011)[20]	Craggs (2011)[20]	Uijtdewilligen (2011)[24]	Sallis (2000)[16]	Biddle (2005)[25]	Van Der Horst (2007)[23]	Edwardson (2010)[19]	Craggs (2011)[20]	Uijtdewilligen (2011)[24]
(Continued from previous page)													
Behavioural variables													
Previous physical activity	Correlate	NR	NR	NR	NR	Determinant	Inconclusive	Correlate	NR	NR	NR	Inconclusive	Determinant
Smoking	Not correlate	NR	NR	NR	NR	Not determinant	NR	Inconclusive	Inverse association	Not correlate	NR	NR	NR
Social and cultural variables													
Perceived parental role models	NR	NR	NR	NR	NR	Not determinant	NR	NR	NR	NR	Not correlate	NR	NR
Parental activity	Inconclusive	NR	Correlate	Not correlate	Inconclusive	Not determinant	Inconclusive	Not correlate	NR	Not correlate	Not correlate	Inconclusive	Inconclusive
Support for physical activity	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	Determinant	NR
Support for physical activity from parents and family	NR	Correlate	NR	NR	Inconclusive	Not determinant	NR	Correlate	Correlate	Correlate	Correlate	Inconclusive	NR

Only variables with consistent evidence[16] for their role as a determinant of physical activity in longitudinal studies are shown. NR=not reported. *Girls only. †Studies of children and adolescents. ‡Three or more original reports cited in review; at least 60% of them show the same association (after Sallis et al[16]).

Table 1: **Systematic reviews of correlates and determinants of physical activity in children and adolescents**

maintenance of physical activity, but action planning is a determinant of initiation of physical activity.

Environmental correlates

Although research into environmental correlates of physical activity began only slightly more than a decade ago, many reports are already available (table 3, appendix). A 2011 review of 103 papers[42] showed results for children and adolescents. Generally, findings were inconsistent across studies. For both children and adolescents, the most consistent associations were derived from objectively measured environmental variables and reported domain-specific physical activity. Objectively measured environments might be more accurate, and reported physical activity allowed investigators to match environmental attributes with activity domain. The most robust correlates for children were walkability, traffic speed, and volume (inversely), land-use mix (proximity of homes and destinations such as shops), residential density, and access or proximity to recreation facilities.[42] Land-use mix and residential density were the most robust correlates for adolescents.[42]

Most information comes from cross-sectional studies in adults, although Van Stralen and colleagues[32] confined their analysis to longitudinal research designs. In adults, only two of nine reviews identified neighbourhood design aspects, such as walkability (designed so that residents can walk from home to nearby destinations) and street connectivity (grid-like pattern of streets), as correlates of transport-related activity, with no other consistent correlates of this outcome. Leisure activity was consistently related to transportation environment (eg, pavement and safety of crossings) in two reviews, to aesthetic variables (eg, greenness and rated attractiveness) in another two, and to proximity to recreation facilities and locations in one review (table 3). Total physical activity was related to environmental variables in all five categories, most convincingly with recreation facilities and locations, transportation environment, and aesthetics (table 3). Essentially no consistent environmental correlates of physical activity among older adults were identified (table 3).

Low-income and middle-income countries

We identified 68 original investigations into correlates from low-income and middle-income countries (appendix). Half the studies are from the past 2 years. Nearly all were done in countries of upper-middle income rather than in those of low income. Many studies were from Brazil (n=39) and China (n=7), together accounting for two-thirds of studies identified.

The most frequently reported categories of correlates are demographic and biological (figure 2), of which sex, age, and socioeconomic status are the most consistent. As reported in high-income countries, male, young, and wealthy groups are more active than are others.

	Rhodes (1999)[28]	Trost (2002)[15]	Plonczynski (2003)[18]	Rhodes (2006)[29]	Kaewthummanukul (2006)[30]	Allender (2008)[31]	Van Stralen (2009)[32]*	Kirk (2011)[33]	Koeneman (2011)[34]
Study characteristics									
Ages	≥65 years†	≥18 years	≥65 years‡	≥18 years	NR	NR	≥40 years; >50 years†	18–64 years	≥55 years
Publication period of studies	To 1999	1998–2000	1994–2001	1969–2006	1990–2002	1977–2007	1990–2008	1984–2010	1990–2010
Number of quantitative studies	41	38	16	32	11	19	59	62	30
Endpoints	Exercise	Leisure; overall	Leisure; overall	Leisure; overall	Leisure; overall	Leisure; overall	Initiation; maintenance	Leisure	Exercise; overall
Proportion of longitudinal studies included	14 (34%)	7 (18%)	1 (6%)	16 (50%)	0	9 (47%)	59 (100%)	11 (18%)	30 (100%)
Accumulated number of review citations for consistent evidence§									
Correlates and determinants	13	41	47	53	58	60	80	84	87
Determinants only	0	0	0	0	0	0	20	20	23
Demographic and biological variables									
Age	Inverse correlate	Inverse correlate	Inconclusive	NR	Inverse correlate	NR	Not determinant	NR	Not determinant
Education	Inconclusive	Correlate	NR	NR	Inconclusive	NR	Not determinant	NR	NR
Male sex	Correlate	Correlate	NR	NR	Inconclusive	NR	Not determinant	Inconclusive	Inconclusive
Income and socioeconomic status	Inconclusive	Correlate	Correlate	NR	Inconclusive	NR	Not determinant	NR	NR
Marital status	NR	Inconclusive	Inconclusive	NR	Inconclusive	Inconclusive	Initiation not determinant; maintenance inconclusive	NR	NR
Ethnic origin (white)	NR	Correlate	Inconclusive	NR	Inconclusive	NR	Not determinant	NR	Not determinant
Health status or perceived fitness	Correlate	Correlate	Correlate	NR	Inconclusive	Correlate	Initiation inconclusive; maintenance determinant	NR	Not determinant
Overweight or obesity	NR	Inverse correlate	NR	NR	NR	NR	Initiation inconclusive; maintenance not determinant	NR	Inconclusive
Psychosocial variables									
Attitudes	Correlate	Not correlate	NR	NR	Inconclusive	NR	Initiation inconclusive; maintenance not determinant	NR	NR
Intention to exercise	Correlate	Correlate	NR	NR	Inconclusive	NR	Initiation determinant; maintenance inconclusive	NR	NR
Action planning	NR	NR	NR	NR	NR	NR	Initiation determinant; maintenance NR	NR	NR
Self-efficacy	Correlate	Correlate	Correlate	NR	Correlate	NR	Initiation determinant; maintenance inconclusive	NR	Inconclusive
Stage of change¶	Inconclusive	Correlate	NR	NR	Inconclusive	NR	Determinant	NR	NR
Stress	NR	Inconclusive	Inconclusive	NR	Inconclusive	NR	Initiation NR; maintenance inverse determinant	NR	NR
Physical activity characteristics and perceived effort	NR	Inverse correlate	NR	Inverse correlate	NR	NR	Initiation NR; maintenance not determinant	NR	NR
Physical outcome realisations	NR	NR	NR	NR	NR	NR	Initiation NR; maintenance determinant	NR	NR
Psychological outcome realisations	NR	NR	NR	NR	NR	NR	Initiation NR; maintenance determinant	NR	NR
Behavioural variables									
Activity history during adulthood	Inconclusive	Correlate	NR	NR	NR	NR	Determinant	NR	Inconclusive
Social and cultural variables									
Social support from friends and peers	Correlate	NR	Inconclusive	NR	NR	NR	Initiation inconclusive; maintenance not determinant	NR	NR
Social norms	Not correlate	NR	NR	NR	Inconclusive	NR	Initiation NR; maintenance not determinant	NR	NR

Only variables with consistent evidence[16] for their role as a determinant of physical activity in longitudinal studies are shown. NR=not reported. *Van Stralen and colleagues consistently reported the endpoints separately and they are mutually exclusive. †Study mean. ‡Women only. §Three or more original reports cited in review; at least 60% of them show the same association (after Sallis et al[16]). ¶As per the transtheoretical model.

Table 2: **Systematic reviews of correlates and determinants of physical activity in adults**

	Humpel (2002)[35]	Cunningham (2003)[36]	Owen (2004)[37]	Duncan (2005)[38]*	Wendel-Vos (2007)[39]	Saelens (2008)[40]	Van Stralen (2009)[32]	Panter (2010)[21]	Van Cauwenberg (2011)[41]
Study characteristics									
Ages	Adults	Adults	Adults	NR	≥18 years	Adults	≥40 years†	18–65 years	Mean >65 years
Publication period of studies included	NR	1966–2002	To 2004	1989–2005	1980–2004	2005–06	1990–2007	1990–2009	2000–2010
Number of quantitative studies included	19	27	18	16	47	29	59	36	31
Proportion of longitudinal studies included	1 (5%)	NR	2 (11%)	0	3 (6%)	NR	59 (100%)‡	NR	3 (10%)
Report type	Systematic review	Systematic review	Systematic review	Meta-analysis	Systematic review	Systematic review and review of reviews	Systematic review	Systematic review	Systematic review
Transport activity outcome									
Neighbourhood design	Inconclusive	NR	Inconclusive	NR	Not correlate	Correlate	NR	Correlate	Inconclusive
Transport environment	Inconclusive	NR	Inconclusive	NR	Inconclusive	Inconclusive	NR	Inconclusive	Inconclusive
Social environment	NR	NR	NR	NR	Not correlate	Inconclusive	NR	NR	Inconclusive
Aesthetics	NR	NR	Inconclusive	NR	Not correlate	Inconclusive	NR	Inconclusive	Not correlate
Leisure activity outcome									
Recreation facilities and locations	Correlate	Inconclusive	Inconclusive	NR	Not correlate	Inconclusive	NR	NR	Inconclusive
Transport environment	Correlate	Inconclusive	Inconclusive	NR	Not correlate	Correlate	NR	NR	Inconclusive
Social environment	Inconclusive	NR	NR	NR	Not correlate	Inconclusive	NR	NR	Not correlate
Aesthetics	Correlate	NR	Correlate	NR	Not correlate	Inconclusive	NR	NR	Not correlate
Total physical activity outcome									
Neighbourhood design	Inconclusive	NR	Inconclusive	Correlate	Not correlate	Inconclusive	Inconclusive	NR	Inconclusive
Recreation facilities and locations	Correlate	Inconclusive	Correlate	Correlate	Correlate	Inconclusive	Determinant	NR	Inconclusive
Transport environment	Correlate	Inconclusive	Correlate	Correlate	Inconclusive	Inconclusive	Determinant	NR	Inconclusive
Social environment	Inconclusive	Inconclusive	Inconclusive	Not correlate	Inconclusive	Inconclusive	Determinant	NR	Inconclusive
Aesthetics	Correlate	Correlate	Correlate	NR	Inconclusive	Inconclusive	Inconclusive	NR	Not correlate

Correlate categories with consistent evidence from at least one of the reviews or with a significant association in Duncan et al[38] are listed. Categories are adapted from Ding.[42] Reviews were included when they had at least one variable with consistent evidence. NR=not reported. *Distinction between inconclusive and not correlate impossible because of the way in which results were presented. †Study mean >50 years. ‡All determinants studies.

Table 3: **Systematic reviews of environmental correlates of physical activity in adults**

Differences exist between cultures—eg, physical activity increases with age as people retire in China and some east Asian nations,[43] indicating possible country-level patterns in leisure-time and other domains of physical activity. We note a positive association between socioeconomic status and physical activity in countries of low and middle income, by contrast with the inconsistent or inverse results from high-income countries.

Behavioural variables are the second most studied correlate in countries of low and middle income, mostly in adults and adolescents. The little evidence available shows that previous participation and present physical activity are positively associated. One study established that risk behaviour (eg, drug misuse) and other risk factors (eg, hypertension) had inverse associations with physical activity (appendix).

Very few studies in low-income and middle-income countries have addressed psychological, cognitive, and affective variables. Of six that have, only barriers to exercise and depression were consistently inversely associated with physical activity in adults (appendix). That measures adapted to different cultures and contexts are unavailable could explain why such little research into psychological, cognitive, and affective correlates has been done in these countries.

Additionally, social and cultural factors have been infrequently studied. Social support has consistent associations with activity, and in adults, family support is positively associated (appendix). The finding from high-income countries that parental social support is important for physical activity in young people is not supported by studies in low-income and middle-income countries (appendix).

Environmental correlates of physical activity have been reported in 11 studies in countries of low income and middle income (appendix). None were in children, and only one was in adolescents (appendix). Most reports show associations with perceptions of environment rather than with objective measures (appendix). Perceived access to recreation facilities is the most consistent environmental correlate; a positive association with leisure-time, transport, and total physical activity was reported in nearly all

studies (appendix). Safety from crime and traffic is not associated with physical activity, although one study did show an inverse association in adults (appendix). Few built-environment and walkability variables have been investigated and results are not consistent (appendix). However, density of exercise facilities and urbanisation (ie, urban versus rural residences) are positively associated with physical activity (appendix).

A broader investigation: from genes to policy

Genes, evolution, and obesity as determinants

Besides published reviews of well studied correlates of physical activity, additional correlates and determinants have been investigated (figure 1, panels 1–3, appendix). Genetics and genetic profiles could affect physical activity in populations (panel 1). Additionally, ideas and data from investigations of evolutionary biology can help to explain the mismatch between the human need for physical activity and an environment that generally discourages such activity (panel 2). Whether physical activity level persists within individuals with time is another area of research. Tracking coefficients are high in short periods but lower with time, and attenuates through the lifecourse (appendix).[87] Further research is necessary to establish whether persistence in physical activity behaviour within individuals is a function of the individual (eg, personality or physiology) or environmental stability.[88]

A new idea is that obesity might be a driver of physical inactivity (panel 3). This notion is quite different to the expected causal direction, in which low total physical activity is assumed to lead to obesity through reduced energy expenditure.[89] The relation might be bidirectional, and high rates of obesity might be a contributing factor to low total physical activity (panel 3).

Policy correlates

Figure 1 shows high-level factors that affect physical activity. Policy is now described in many ecological models.[10] Policy interventions can affect whole populations for long periods. For the physical activity field, policy provides guidance for collective and individual behaviour and can be informal or formal legislative or regulatory actions taken by governmental or non-governmental organisations.[90,91] Policies can affect physical activity at local (school or workplace), regional government, or national levels.[91,92] They usually require partnerships and actions outside the health sector to improve conditions, support services, and environments that enable physical activity, and are an integral part of national physical activity planning.[93] Policies can mandate investments in resources (eg, bike paths, parks, and sports programmes) or develop relevant public health regulations (eg, pavement specifications, stair design standards, and payment for physical activity counselling in health care).[94]

Cross-sectional analyses show that policy is a correlate of physical activity.[95–98] For example, Pucher and Buehler[95]

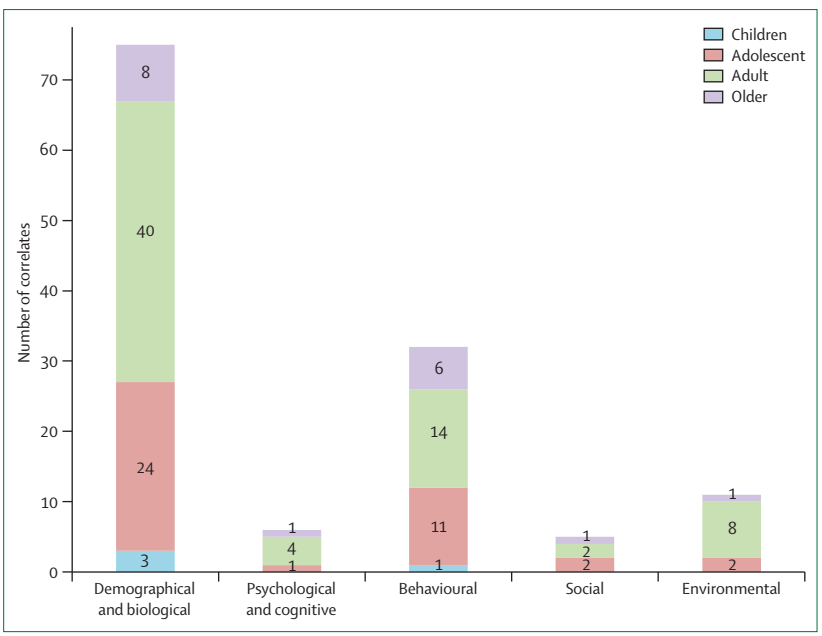

Figure 2: **Correlates of physical activity identified in countries of low and middle income**
Total number of correlates divided into five broad categories. More than one correlate could be reported in one study.

Panel 1: Genetic determinants of physical activity

Genetics is a possible determinant of physical activity—ie, a heritable component affects activity behaviours, not just measures of fitness. Similar to other behaviours, such as eating (appetite), evidence from human and animal studies[44–48] indicates that physical activity is regulated by intrinsic biological processes. Animal studies[44,45] suggest that CNS mechanisms might regulate daily physical activity. Twin and family studies have shown that genetic factors contribute to variation in reported daily physical activity levels, with heritability estimates ranging from small (h^2 <30%)[49–52] to moderate (h^2=30–65%),[53–58] and even high (h^2=78%; appendix).[59] The large heterogeneity might be due to the large ranges in age within and between studies, the accuracy with which daily physical activity is assessed, and study design.

Substantial individual differences have been noted in the acute averse and rewarding effects of physical activity, implicating genetic factors.[60] Specifically, reward systems will be activated in individuals with above-average abilities, those who crave activity, and those who feel rewarded by accomplishing an activity; adverse effects will be reported in those who feel pain, fatigue, or even exertion. As such, candidate genes might be part of the reward systems and pain sensation.[60] Candidate gene studies have mainly focused on genes that constitute the dopaminergic[61–63] and melanocortinergic[64,65] pathways. So far, associations between genetic variants in the melanocortin 4 receptor (MC4R),[66] the leptin receptor,[67–69] the dopamine receptor D2,[70] and daily physical activity have been most consistent. Two genome-wide linkage studies[56,71] have showed promising linkage with chr2p22-p16 on chr18q,[71] a locus harbouring MC4R.[56] The most recent and successful gene-discovery framework is genome-wide association studies, but no such investigation into daily physical activity has been done. A fairly small study of exercise participation did not identify any significant genome-wide associations.[72]

Overall, despite evidence for a genetic contribution, candidate gene and genome-wide studies have not yet identified genetic loci that have robust associations with daily physical activity. Large-scale genome-wide association studies that comprehensively survey the genome will identify new loci, which in turn may point towards new insights into the biology that underlies variation in physical activity.

Panel 2: From evolutionary biology to societal determinants

An evolutionary perspective assumes that many components of our physiology are adapted to a range of expected behaviour. Is there evidence that people became physically active out of necessity and biological adaptation, and then had to reduce activity because of mechanisation and culturally and technologically induced decreases in the need for energy expenditure?

Physical activity level can be calculated as the ratio of total energy expenditure to basal metabolic rate. Ancestral foragers—of larger body size on average than are contemporary foragers—had estimated mean physical activity levels of roughly 1·7 (range 1·5–2·1),[73] which is little different from those in industrialised populations with moderate activity levels.[74] Non-human primates do less activity than do human beings (1·2–1·5),[75] suggesting that our species adapted to increased physical activity for foraging. Subsistence farmers have variable levels of activity, with a mean of about 1·9 in men and 1·8 in women, but ranging up to roughly 2·5.[76] However, in urban populations, the most sedentary individuals do little activity (about 1·5).[77] Overall, people could be encouraged to achieve levels of about 1·75, as was recommended by WHO and the Food and Agriculture Organisation for health in 2004,[78] but this value is much higher than is that of sedentary populations.[77]

Panel 3: Is obesity a determinant of physical activity?

The notion that physical activity is a key determinant of body fat in individuals and populations is common, seemingly supported by the logic of the energy-balance equation and empirical reports of cross-sectional associations between adiposity and activity.[79] On this basis, clinicians assume that physical activity will induce weight loss in overweight individuals, but secular declines are also judged a key driving factor in the worldwide obesity epidemic.[80,81] However, in the past decade, studies have begun to challenge both these assumptions, suggesting instead that adiposity could be a determinant of physical activity. In several longitudinal studies,[82,83] baseline activity did not predict follow-up adiposity, whereas baseline adiposity predicted follow-up activity. Promotion of physical activity has little effect on prevention of obesity in children, adolescents, or adults.[84] Although long-term trends in mechanisation and transport, and equivalent behaviours such as rural–urban migration, could reduce activity and hence cause weight gain,[85] whether substantial reductions in physical activity in industrialised populations have occurred since the 1980s is a matter of debate.[86] Conversely, some believe that real decreases in total physical activity have occurred,[80] which indicates a possible role of physical activity in obesity prevention. Clearly, further work is needed, but evidence does suggest that increasing obesity could be a contributor to high levels of inactivity in human populations.

identified policies and environmental supports in Germany, Denmark, and the Netherlands that explain high levels of cycling in those countries. Investigators of a 2011 review[96] identified 13 quasiexperimental studies of built-environment changes, and reported that cycling infrastructure, trails, and park upgrades lead to increased physical activity. However, the findings were inconsistent, and improved study designs might lead to null results. The effect of policy and legislation on physical activity participation in schools is mixed.[97,98]

Societal-level factors and social norms also affect physical activity. Some are acute societal events, such as economic crises, civil unrest, or natural disasters.[99] Societal trends probably have different effects on physical activity domains. Responses to economic crises might reduce leisure-time activity participation and increase transport-related activity.[100] The opposite circumstance—ie, economic growth—could be noted in many developing countries, with a corresponding change in trends. Additionally, long-term social mores and cultural values could affect physical activity patterns in communities and regions. The social value attached to physical activity can vary widely between cultures and change with time. For example, cycling can either be perceived as tiresome and socially undesirable or can become normative and even fashionable.[95] There is some evidence for the interaction between social values and other determinants of physical activity, but interventions to change social norms could be an effective way to change physical activity.[101] International sporting competition and large events are often advocated to enhance physical activity, but the evidence for any measurable effects on population physical activity is scarce.[102]

To show that global factors are correlates is difficult, but the pervasive forces of urbanisation, mechanisation, and changes in transportation patterns probably affect total physical activity. Both increased affluence and geographical shifts to megacities reduce so-called active living in countries of low and middle income.[103,104] Changes to work patterns, with an increase in sedentary occupations in most countries, have also contributed to total physical activity reductions.[80]

Discussion

Research into physical activity correlates is an evolving field showing that the aetiology of physical activity is complex and varies by domains, such as leisure time and transport. In the past two decades, an expansion has occurred in the number and type of factors examined as correlates and determinants, moving beyond individual factors and adopting multilevel ecological models.[10] These approaches draw attention to the fact that there are several levels of influence across a wide range of age and geographical groups, including those in countries of low

and middle income. Evidence for demographic and genetic correlates could identify subgroups that need intensive intervention. Research into psychological, interpersonal, and environmental correlates can identify new potential mediators for use in interventions[8]—ie, programmes affecting these correlates would be expected to lead to changes in physical activity behaviour. Targeting evidence-based mediators in interventions is a crucial step in improvement of the effectiveness of physical activity interventions.

Thus, the purpose of the study of correlates is linked to improvement in intervention development.[7] This linkage is infrequently made explicit, and correlates studies remain as stand-alone hypothesis-generating research, typically in small, non-representative samples, with sub-optimal measures of both exposures and physical activity. Furthermore, fairly few consistent correlates of physical activity have been identified, suggesting that intervention approaches targeting unsupported mediators (ie, knowledge or attitudes) could be ineffective. Our review has identified a small number of variables as consistent correlates. They include: reported health and intention to exercise in adults; male sex, self-efficacy and previous physical activity at all ages; and family social support in adolescents.

The new area of environmental correlates research shows that few consistent correlates have been identified for specific domains of transport and leisure activity. However, reviews of adults have identified consistent correlates with total physical activity in four of five categories of environmental attributes. The strongest findings were with recreation facilities and locations, transportation environments, and aesthetics. A comprehensive review of young people supported neighbourhood design, recreation facilities and locations, and transportation environment as consistent correlates. Environment correlates have not been extensively studied in older adults. Environmental changes can be achieved through population-wide changes to policy. Because these policy decisions are made outside the health sector, cross-sectoral partnerships are needed to influence physical environments in countries at all levels of development to make them more supportive of physical activity behaviours.[91,92]

A limitation of the correlates literature is that most studies have used a cross-sectional design.[8] Nonetheless, these studies have some advantages. They provide evidence about potential mediators for planning of interventions and help to prioritise population target groups. Cross-sectional studies allow several variables to be

Panel 4: The next steps

Future research needs improved measures of exposure (correlates), objective physical activity measures, prospective designs, and advanced data modelling to assess causal determinants rather than just associations between variables. For this field to become more useful in designing interventions than it is presently, we draw attention to a few areas of potential improvement.

Standardised comparisons of correlates are needed, with similar measures in high-income and low-income countries, that take into account strengths of different correlates and an investigation of cultural and country-level factors. Increased research emphasis is suggested for physical activity correlates research in countries of low and middle income, and in special populations, socially disadvantaged groups, and obese individuals. Building research capacity might be needed to achieve these goals.

An understanding of environmental correlates of transport and leisure-time activity in low-income and middle-income countries is urgently needed to support the development of interventions to reverse the rapidly changing determinants of inactivity occurring through urbanisation, passive entertainment, and motorised transport. Multilevel models to explain all domains of physical activity (transport, leisure, occupation, home) will lead to improved, contextually tailored interventions.

The potential of ecological approaches in correlates research has not been fully realised, although there is good evidence that variables at all ecological levels are significantly related to physical activity.[8] Interactions across levels are a principle of ecological models—eg, the combination of favourable psychosocial and environmental variables should improve prediction of high physical activity, but they are infrequently assessed. Such findings are becoming available,[107,108] supporting multilevel interventions.

New methods to analyse mediators of physical activity interventions are accumulating. Possible mechanisms of change are measured repeatedly to establish whether they account for recorded intervention effects on outcomes.[108] A review of early studies of mediators[109] had inconsistent results, so improved measures and studies are needed.[105,106] New areas, such as behavioural economics can also provide conceptual foundations for experimental studies of physical activity determinants.[110]

In addition to the ecological model previously described, new and innovative categories of correlates should be sought (panels 1–3). A growing area of study is brain mechanisms of physical activity.[111] Reductions in dopamine receptors contribute to the age-related fall in physical activity,[112] and strong evidence has been reported that the brain continually adjusts power output of muscles during exercise to limit exertion to safe levels.[113] Finally, further cross-sectional studies in high-income countries are unlikely to be informative. A change in research could lead to scientific progress and increased relevance for design of physical activity interventions.

assessed at low cost, providing an evidence base for improvement of intervention design.[7] A limitation is that most research has reported leisure-time activity, which could provide a small window on total physical activity. Self-report of correlates is a methodological concern, and consistency of data across measures and settings is needed to strengthen evidence for a specific correlate. Reporting biases might differ between cultures, so creative investigations are needed to understand these variables.

A next step to verify the causal role of consistent correlates is to examine them in intervention trials and in generalisable samples. For more definitive understanding of why people are active, longitudinal determinants research is needed into what predicts changes in physical activity.[32,34] This research will need improved methods, including use of multilevel theories of change, tests of causal pathways of mediator variables, and more robust statistical assessment of the several levels of influence on physical activity. This work has started to accumulate, with summary reviews of mediators of physical activity now reported for adults and children.[105,106]

One new area in this review is the study of correlates and determinants in countries of low and middle income. This evidence is increasing rapidly and strengthens the call for correlates research across domains of physical activity and with time. Internationally, researchers need to investigate why residents of some countries are more physically active than are those residing in demographically similar countries. The study of developing countries emphasises potential differences in correlates between domains of physical activity. For example, active transportation could be normal for poor people in low-income and middle-income countries, and as affluence increases, active transportation decreases. A different socioeconomic gradient might be apparent in high-income countries, where leisure-time activity predominates and social class and physical activity are directly related.

In summary, the study of correlates is well advanced and can provide an evidence base for the improvement of interventions, but the field has room for improvement. This contradiction comes about because many correlates reports are published each year, but many identify similar—usually psychosocial and environmental—correlates in cross-sectional samples. Furthermore, true multilevel studies are needed, as are studies targeting subgroups at risk of low activity levels. Innovative frameworks for correlates research—eg, consideration of genetic, evolutionary, societal, and macroeconomic factors, and improved designs and statistical methods—could contribute to the next generation of correlates research (panel 4). Additionally, correlates should be included in public health surveillance systems, such as in the Physical Activity Monitor in Canada.[114] The greatest challenge for this field will be translation of research into public health action.

Contributors

All authors devised and developed the approach, with detailed discussions and meetings at all phases, and read and commented on every version of the report. AEB is guarantor, and did searches and reviews, synthesised data, and led the writing of the report. RSR and BWM did detailed searches and syntheses of systematic reviews, and edited drafts. JFS reviewed all content and all drafts, and worked especially on figure 1 and the ecological model. JCW wrote the obesity and evolution panels, and commented on and edited drafts. RJFL wrote the genetics section, and commented on and edited drafts.

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Conflicts of interest

We declare that we have no conflicts of interest.

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