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Running Head: **Physical Activity and Socio-economic Position**

A systematic review of evidence of the relationship between socio-economic position and physical activity

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Abstract

Objective

The aim of the present review was to examine epidemiological evidence to determine if there is strong evidence of a positive gradient of increasing physical activity across the socio-economic strata, and how relationships are affected by socio-economic measurement.

Design

Systematic review.

Method

A search of major databases was conducted to identify published studies that reported physical activity in relation socio-economic position (SEP) in adults.

Results

Twenty-nine cross-sectional and five longitudinal studies met the inclusion criteria. Approximately half of these were American. Consequently education and income were most commonly used to represent SEP. The majority of studies were secondary analyses of existing health survey data, which could explain the generally large sample sizes and methodological weaknesses in terms of physical activity and SEP measurement. There was consistent evidence of a higher prevalence or higher levels of leisure-time or moderate-vigorous intensity physical activity in those at the top of the socio-economic strata compared with those at the bottom. Evidence for positive gradients across the socio-economic strata was less consistent. Education produced

the most stable relationships, less susceptible to confounding effects of ethnicity and the environment.

Conclusion

Those at the top of the socio-economic scale appear to perform more leisure-time activity than those at the bottom. Diverse and often crude physical activity and socio-economic measurement made it difficult to distinguish between artefact and true effect in a relationship with so many potential confounding influences. Future studies using up-to-date methods of socio-economic and physical activity measurement are necessary to further explore this relationship and its confounders.

Introduction

In Britain, higher rates of mortality [1-4] and various morbidities [2, 4-6] in more socio-economically disadvantaged individuals have been recognised for many years. More recently the gap between health in the best and worst off in society has widened at an increasing rate and this discrepancy is evident across the socio-economic spectrum [7]. These health inequalities, combined with evidence of similar social patterning in health behaviours such as smoking and dietary behaviour [2, 8-11], has led to assumptions of socio-economic gradients in physical activity levels that mirror those for health [12]. Indeed, interest in physical activity inequalities has grown [13, 14] and there is evidence that those lower down the socio-economic scale face greater barriers to increasing physical activity [14, 15].

Evidence for such socio-economic gradients in physical activity is reportedly less consistent than for other health behaviours [2, 12], which could be a consequence of the considerable problems associated with measuring this relationship. Measurement of both physical activity [16] and socio-economic position (SEP) [17] are hindered by a common problem; the absence of a 'gold-standard' and the subsequent lack of consensus on how best to measure these variables has created diversity in methods. Further, both physical activity and SEP are multi-dimensional [18, 19], leaving researchers with a choice; to focus on a single component and use this as a proxy for overall physical activity or SEP; alternatively, to use a composite SEP score (or deprivation index) or measure total (habitual) physical activity

Background

Socio-economic Measurement Issues

There are many ways of measuring SEP reviewed in detail elsewhere [18, 20]. In epidemiology, the most commonly used socio-economic indicators are social class based on occupation, income, and education, in addition to asset-based outcomes such as housing tenure and car ownership. In Britain, priority areas for funding by government or local authorities tend to be identified using area-level deprivation indices composed from several socio-economic indicators [21].

The original social classification schema of the British Registrar General (BRG) (classes I- V) developed in Britain, was based on occupational skill, as have been many subsequent derivations. However, accusations of statistical manipulation to engineer smooth class-mortality gradients in the absence of a sound theoretical base led some to question the validity of this approach and the relevance of skill-based classifications in modern society [17]. Other shortcomings of social stratification on the basis of occupation include an inability to account for changes in the nature of the employment market and the common exclusion of non-working individuals [22]. Income is considered a good measure of material well-being [23]; yet it fails to account for assets, accumulated wealth and the number of people supported by the income [20]. In Britain, due to sensitivity of income-related information, it is rarely collected. Education has strength as a socio-economic indicator in its relative stability after a certain age and ease of data collection [18]. However, when using education as a proxy for material wealth there is an underlying assumption that a better education will lead to more highly paid occupations. Further, the value of educational achievement changes over time and for different generations [18]. Asset-based outcomes such as housing tenure and car ownership are used less frequently, usually to compensate for the lack of income data, and they have been criticised as markers for income in Britain due to rises in car and home ownership in recent years [24].

There has been tendency in health inequalities research to assume that the best measure of SEP is that which produces the steepest socio-economic gradients in health [20]. In reality none stands out as best for all or even most circumstances [17, 18] and which socio-economic indicator(s) is most appropriate depends on the population in question and the society and culture in which they live.

Physical Activity Measurement Issues

Physical activity is characterised by frequency, intensity, duration and mode [25] and is therefore difficult to measure. Again this is discussed in more detail elsewhere [19, 25]. Traditionally, when measuring physical activity epidemiologists have emphasised feasibility over validity, relying on large sample sizes for statistical power [26].

It is most commonly self-reported through retrospective questionnaires or interview methods, favoured for their relatively low cost and ease of administration; yet a review of ten physical activity questionnaires estimated that, at best such instruments explained just forty-five per cent of variance in physical activity [27]. The disadvantages of using these subjective self-reports include recall bias (recalling more structured high-intensity activities more easily), overestimation of activity by less fit individuals and social desirability bias [19, 26, 28]. Furthermore, there is inconsistency in whether researchers measure habitual or total physical activity, leisure-time (LTPA), work-related (WRPA), or household activity. Leisure-time and vigorous activities are often chosen as they are easier to recall than lower intensity habitual activities such as walking or household chores [19].

In recent years attention has turned towards objective physical activity measurement using devices such as heart rate monitors, pedometers, and accelerometers that can be worn over several days or weeks to measure habitual physical activity. They enable more accurate measurement of low intensity activities which account for most daily activities, and circumvent some of the problems associated with self-reports [19]. However, in addition to weaknesses associated with each device [19], all require that participants wear monitors for several days or weeks and are relatively expensive, increasingly so with the sophistication of the device. Therefore, in practice such objective methods are rarely employed in favour of retrospective self-report methods of physical activity that can be administered to a large number of people, over a small period of time, at low-cost.

International and Cultural Factors

When exploring the relationship between SEP and physical activity in studies from around the world, there are several considerations that relate to economic development, culture, and socio-economic measurement.

First of all, the physical activity-SEP relationship is thought to be largely dependent on a country's level of development [29]. In developing countries, an active lifestyle tends to be a necessity for those at the bottom of the social strata, whereas adopting less healthy Western lifestyles is viewed as a privilege, affordable only by the wealthy. In contrast, as a result of economic technological advances in developed countries, less healthy behaviours have evolved such that healthy lifestyles require deliberate choices that the affluent can most easily afford [29, 30]. A country's development might also influence the relative contributions of different types of activity to daily energy expenditure (i.e. leisure-time, work-related and household activity). There is an increasing prevalence of sedentary occupations in developed societies where sedentary behaviours are strongly reinforced [31-34]; yet in countries where labour-saving developments in areas of transport, communications, the workplace and so on are less advanced, the balance between LTPA and other traditional sources of energy expenditure is likely to be different.

Secondly, there are some regional differences in socio-economic measurement [20, 29, 35]. For example, in America education is often the indicator of choice, whereas in Britain it is not [20, 29, 35] as the high proportion of people completing the minimum sixteen-years of compulsory education reduces its effectiveness as a socio-economic discriminator.

There are additional considerations of how the SEP-physical activity relationship might be influenced by gender and age [36, 37] through the different roles of men and women in different cultures, and possibly how different societies provide for older people. As a result of these and numerous other possible contributory factors, the present review focuses on evidence from Western countries in an attempt to minimise such regional and cultural effects.

The aim of the present review was to examine epidemiological evidence for a SEP-physical activity relationship: (i) to determine if there is strong evidence of a positive gradient of increasing physical activity from the bottom to the top of the social strata, and (ii) to explore patterns for different socio-economic indicators.

Methods

Search of Literature

A search of major databases (PubMed, PsychInfo, Sports Discuss, and Web of Knowledge) was conducted in October 2004. Figure 1 and 2 illustrate the search strategies used and study selection process, respectively. For inclusion studies were required to meet the following criteria:

1. English language
2. Published in peer-reviewed journal
3. Report a recognised socio-economic outcome: social class, income, education, asset-based, or based on area of residence
4. Report physical activity as a separate outcome
5. Original study (reviews were excluded)
6. Adult populations (≥16yrs, at baseline if longitudinal)
7. Conducted in Western countries to limit cultural differences

************ Insert figure 1 here**************

************ Insert figure 2 here**************

Quality Assessment

In order to make an informed judgement about the strength of evidence from the present review it was necessary to assess the quality of included studies. A quality assessment instrument was developed and Table 1 presents the criteria developed from both criticisms of epidemiological studies made in a recent review [38] and issues relating specifically to the measurement of physical activity and SEP. Quality assessment was undertaken independently by two assessors and where disagreements occurred, they were discussed until a consensus was reached.

**************Insert Table 1 here***************

Results

Country of Origin

Twenty-eight cross-sectional and five longitudinal studies conducted in ten different countries met the inclusion criteria: America (n=16) [39-54], Australia (n=5) [55-59], Canada (n=3) [60-62], Spain (n=1) [63], England (n=3) [64-66], Finland (n=1) [67], Sweden (n=1) [68], France (n =1) [69], the Netherlands (n=1) [70] and Greece (n=1) [71]. Two cross-sectional studies by Crespo et al [46, 47] reported different analyses of data from the same sample and are treated as a single study (n=32). Table 2 presents the frequency with which different indicators were reported and physical activity-SEP relationships were observed.

************** Insert table 2 here*****************

Table 3 summarises study design, quality and sample characteristics presented by country of origin to illustrate international differences. Over half of studies were American, all of which reported income and education. Consequently, education was most frequently reported overall and social class was least popular.

Table 4 summarises the main outcomes from studies in order of socio-economic indicator to facilitate the identification of consistent themes. These findings are discussed in the following sections. As a result of the diversity in SEP and physical activity the relationships are described and consistent themes identified, with consideration for methodological issues.

************** Insert table 3 here*****************

************** Insert table 4 here*****************

Study Quality

According to the criteria listed in Table 1 the number of studies with different quality ratings (*QR*) are presented in Table 3 (highest quality *QR1* n=0; *QR2* n=3; *QR3* n=15; *QR4* n=8; *QR5* n=4; *QR6* n=2). Two-thirds of studies (n=22) relied on data from previous health surveys whose original focus and methodological quality thus dictated the quality of the featured studies. This is a possible explanation for the common methodological weaknesses, including the use of unvalidated self-reported measures of physical activity (n=17), failure to justify which measure(s) of SEP was chosen (n=16), dichotomising socio-economic variables (n=10) and failure to report response rate (n=8). Further, although several authors gave some justification for their association economic indicators (in terms of citing previous research), few provided a conceptual rationale which is a major criticism in the socio-economic measurement [17, 18].

Study samples were generally large (range=84 to 61,239; mean=6960, calculated using numbers available for analysis in longitudinal studies). Where response rate was reported it was relatively high, with some exceptions (range=31.3 to 97.5; mean=68.0%, calculated from mean response at baseline and follow-up in longitudinal studies) thus reducing the potential for response bias in most studies. It is likely that response bias would increase the proportion of respondents higher up the socio-economic strata. Therefore, poor (or unspecified) response rates are pertinent to the present discussion. In addition to the likely influence of some response bias, the representativeness of samples was further reduced by over half of studies delimiting to certain age groups.

The majority of studies performed multivariate analysis and reported significant levels. Logistic regression was most common; consequently the frequent use of dichotomous physical activity outcomes was not viewed as a weakness because use of a binary dependent variable is required in basic logistic regression analysis [72]. The following sections describe the main findings with consideration for the methodological strengths and weaknesses.

Outcomes for Occupational Social Class

Of the ten studies reporting occupational class, only one collected original data [64]; the remainder relied on existing survey data. Despite generally large samples (range=1000 to 61,239), all but one study [68] used just three occupational classes. This reduces the sensitivity of classification and increases intraclass heterogeneity. In most studies that specified, non-working adults were excluded from analyses or treated separately [56, 59, 64, 68]. This is a potential limitation given that several studies included samples with both young and older adults who are more likely to be students and retired respectively [46, 47, 56, 59, 62, 64]. Therefore, the proportion of non-working adults is likely to have been higher in these studies.

As Table 4 illustrates, all eight cross-sectional studies reported significantly higher physical activity in the highest versus lowest social classes. Four of these found positive gradients across classes [56, 59, 64, 65]. Wardle and Steptoe [64] classified occupations of British adults according to the much criticised British Registrar Generals schema and found an increased likelihood of performing no vigorous intensity activity in sequentially lower classes (I/II OR=1.00; III OR=1.65 1.31-2.09; IV/V OR=2.17 1.60-2.94). Similar trends were reported for LTPA in two analyses of Australian survey data [56, 59] that were significant in women only ($P<0.01$). Conversely, analysis of data on habitual physical activity from the British Whitehall II study [65] revealed a far stronger relationship in men. The latter study was, however, restricted to only those employed in the civil service so results were not generalisable. Nevertheless, the advantage was that relative position within a well-defined occupational hierarchy would have been more easily determined thus reducing misclassification.

Both of the aforementioned Australian studies [56, 59] reported significant LTPA differences between men in highest and lowest social classes; the study by Salmon et al [59] was one of the better quality studies reviewed (*QR2*). Similar patterns were apparent in men and women in three large studies [46, 47, 62, 68]. The only American study used blue- and white-collar classifications in a multi-ethnic sample [46, 47]. Researchers reported a positive association. They also stated that this failed to fully explain the lower prevalence of leisure-time inactivity in Caucasians, yet the report lacked information on participant response rate and apparently conducted no the statistical analysis to support this (*QR5*). Significant LTPA differences between late middle-aged Swedish adults in manual and non-manual occupations were revealed ($P<0.05$) in analysis of data from a survey that used five social classes and an extensive, pre-validated activity questionnaire (*QR3*) [68]. Similarly, a significant positive relationship with LTPA was evident ($P<0.05$) in sixty-one thousand Canadians [62]. However, the sample was stratified into just three classes of occupational prestige and the physical activity measurement was inadequately described.

The only study to measure social class and physical activity in *older* adults [57] reported high versus low social class differences for moderate-vigorous intensity activity ($P<0.05$). The crude physical activity measurement (a single closed question) was a limitation. Furthermore, occupational classification in older adults according to last occupation would not have adequately account for those who chose semi-retirement or less demanding occupations nearer to retirement that might have been unrepresentative of lifetime social class.

Neither longitudinal study reporting occupational class [54, 66] was of high quality (*QR4*). Boniface et al [66] found that occupational class measured using two different scales was not a significant predictor of uptake or maintenance of physical activity in British men. Kaplan and Lazarus [54] reported that being in a white- versus blue-collar occupation was positively associated with physical activity change in basic regression analyses (adjusting for gender, age, BMI, smoking and baseline physical activity), although income was used as the sole socio-economic variable in the full model.

Outcomes for Income

Out of the eighteen studies that reported income only six analysed original data [40, 41, 44, 51, 53, 71], which was reflected in generally smaller Sample size is compared with the analyses of existing data. Similar to social class measurement, the majority of studies used only two or three income categories; only five used four or more categories [41, 49, 54, 67, 70] and one study used a continuous variable [48]. The consequences in terms of misclassification might be less serious than for occupation because income boundaries are clear (e.g. $20,000-25,000) although arbitrary, whereas the absence of such a linear scale for a diverse range of occupations makes boundaries less defined. Eight studies focused on middle-aged [42, 43, 53], or middle-aged and older adults [40, 41, 49, 57, 71]; the remainder included a full age range. Age is likely to be less pertinent when using income rather than social class or education: non-working individuals can still be classified by income but are often excluded from occupational classification; furthermore, current income is unaffected by temporal change, unlike education (changes in the education system and employment market mean that obtaining the same qualification thirty years ago would have had different consequences in terms of subsequent employment opportunities and relative income than nowadays).

Nine cross-sectional studies found that income and physical activity were positively related, six reported no relationship, and a negative association was reported in one of only two European studies [67]. Tudor-Locke et al [44] conducted the only objective measurement of physical activity. Participants warp odometer is for seven days and a *gradient* of increasing number of steps per day in sequentially higher income categories (P=0.006) was observed. Despite the advantages of the objective physical activity measure, greater participant burden is likely to have contributed towards the poor response rate (31.3%), which reduced sample size (n=209) and increased selection bias; the 209 participants were more likely to be white, more educated and have higher incomes than the original sample (n=1200). The only other study that reported a positive *gradient* between income and *habitual* physical activity (P<0.001) analysed data obtained using a ‘physical activity index’ that was unvalidated and appeared to focus primarily on the leisure-time activities [39]. One other study (*QR2*) [48] reported a positive *gradient* that was for vigorous intensity activity but in women only (P<0.05). This could be a reflection of the age of data that were collected prior to changes in the physical activity guidelines from less frequent vigorous activity to regular moderate activity [73].

The aforementioned analyses of survey data from older Australians by Kendig et al [57] was similarly limited to moderate-vigorous activity. Higher levels were reported by those with incomes above pension level. This might be a more appropriate discriminator than absolute income in older people (as used by Clark et al [49]), although comparability with other studies is reduced. Another study of older adults conducted in Greece reported a positive association between income and physical activity level [71]; yet the brief report failed adequately describe study methods, participants or statistical analysis. Moreover, in addition to the small sample (=84) including only residents of a rehabilitation centre meant that results were not even generalisable to other all the people (*QR6*).

Several studies that did not find a gradient, observed higher activity in the highest versus lowest income groups, in terms of LTPA [41, 46, 47] and the likelihood of meeting physical activity guidelines [43, 51]. Crespo et al [46, 47] boasted a large study population and adjusted income by household size but was limited as detailed previously (*QR5*). McTiernan et al [41] collected data in a population (n=492) of white, late middle-aged women and found that those in the highest income group were twice as likely to perform LTPA than those in the lowest (OR=2.3, CI=1.2-4.5). Similarly, Eyler et al [43] analysed data from white women in rural America and found that being in the highest versus lowest income group significantly increased the likelihood of meeting guidelines for moderate or vigorous activity (OR=2.76, CI=1.08-4.01). Parks et al [51] reported the same findings in men and women but data were not presented. The income effect was only apparent once the sample was divided according to the morphology of participants' area of residence (rural, urban, or suburban), which highlighted the potential for environmental factors to mask socio-economic effects on physical activity.

Out of the two longitudinal studies is exploring changes in LTPA, Droomers et al [70] reported that being in the highest versus lowest income quintile at baseline had a positive effect on subsequent LTPA changes (P<0.01). In basic regression Kaplan and Lazarus [54] observed a similar positive association that remained only in women when all variables were entered into the model.

A total of six studies did not find a significant relationship [40, 42, 49, 53, 58, 62]. This could have been attributable to ethnic variation in four of these; two analysed survey data on African-American women [42, 53]; an original study that used a well-validated physical activity measure (*QR2*) involved a multi-ethnic sample of women [40]; and Clark et al [49] failed to find an association in a multi-ethnic sample of older Americans. However, in the latter study, measuring absolute income (rather than relative to pension level) could have contributed to this finding that conflicted with the study of older Australians [57]. In the aforementioned analysis of health survey data from Ontario [62] an apparent income effect was attenuated beyond significance (P=0.10) when occupation and education were entered into the regression model; sample ethnicity was not reported. Ethnicity was not reported in the Australian study by MacDougall et al [58] that dichotomised income and determined LTPA using only two questions (*QR4*).

One study reported a significant *negative* relationship. It was conducted in Finland and found higher LTPA in women on lower incomes (P<0.05) but not men [67]. It is, however, reported that Finnish adults have particularly high physical activity levels [74] and therefore cultural differences in physical activity participation could be responsible.

Outcomes for Education

Education was the most commonly used socio-economic indicator. Out of twenty-four studies that reported education (in years or qualifications), six analysed original data [40, 41, 44, 51, 53, 71]. Most of these studies and their respective strengths and weaknesses have been described previously and are therefore not discussed in detail.

Given the temporal changes in the value of education it is worth noting that almost half of the studies limited the sample age ranges to young or middle-aged [42, 43, 52, 53], or middle-aged and older adults [41, 49, 57, 60, 69, 71], which is likely to have reduced temporal effects.

As illustrated in Table 4 the majority of cross-sectional studies found positive relationships between education and physical activity; seven did not. Positive *gradients* were reported in six studies (mostly those with a broad age range), in terms of habitual activity [39, 44, 49] or LTPA [46, 47, 52, 59]. These relationships were stronger than found for income or social class in several cases [39, 44, 46, 47, 49].

Dowda et al [52] reported this relationship in a multi-ethnic sample of young, although an independent ethnic effect was also apparent and the study had numerous methodological weaknesses (*QR6*).

The remaining positive associations generally manifested as differences between highest and lowest education groups in terms of LTPA [41, 58-60, 62], vigorous activity [48], habitual activity [42, 53, 69] and meeting physical activity guidelines [51]. Again these were often stronger or more consistent than found for other socio-economic indicators [42, 48, 53, 58, 59, 62]. Five studies found that education, not income, was significantly related to physical activity in multivariate analysis [42, 49, 53, 58, 62] despite ethnic variation in three of these.

In contrast, out of the seven studies that failed to find significant association, three found that income and *not* education predicted activity outcomes [51, 57, 71]; one of these was not particularly poor quality [71]. The absence of associations in two analyses of all-female data samples [40, 43] conflicted three other all-female studies [41, 42, 53]. Area morphology and ethnicity might have contributed, although study differences make it difficult to determine the dominant influence.

Four longitudinal studies measured education. Three that have been described previously reported a positive effect of education on changes in LTPA [60, 70] and habitual physical activity [66], although the size and consistency of the effect across educational groups varied and was influenced by age in the latter study [66]. Further, Kaplan and Lazarus [54] excluded education from the full regression model. Another longitudinal study analysed data from repeated Canadian Health Surveys [61]. The findings indicated that less educated men were more likely to be inactive in 1985 and 1991 (OR=2.26 and OR=1.55 respectively) and a similar but less marked pattern was evident in women (OR=1.86 and OR=1.52 respectively). However, neither significance levels nor confidence intervals were reported.

Outcomes for Area of Residence

Despite the wide availability of area-level socio-economic data from censuses, only three studies [45, 50, 55] socially stratified by area of residence. Study populations were surprisingly small (n=559-1803); possibly a limitation of collecting additional individual socio-economic data. Yen and Kaplan [45] used data from the Alameda County Study, which began in 1965 and compared individuals living in *poverty* and *non-poverty* areas according to the 1965 census tract. Researchers found lower LTPA at baseline (1965) and follow-up (1974) (P=0.0001) and a greater decrease in physical activity (=0.0001) in residents of poverty areas. Using 1980 census data Ford et al [50] found significant differences between women in low and high SEP areas in almost all physical activity categories in women, whereas in men, differences in total and LTPA were non-significant. The most recent study by Giles-Corti and Donovan (2002) found that those in low SEP areas were less likely than the high SEP group to meet recommendations for total and vigorous physical activity (26% and 46% respectively).

Despite similarities, some study differences are worthy of note. Firstly, there was inconsistency in area classification: Yen and Kaplan [45] compared poverty and non-poverty areas; the Australian study compared those living in areas at the top and bottom of the socio-economic scale (<20th vs. >80th percentile); Ford et al [50] did not specify how SEP areas were defined. Secondly, all studies reported significant differences in education and income between high and low SEP groups (at the individual level) to validate classification. However, Yen and Kaplan [45] also found an independent area socio-economic effect, which is consistent with health inequalities literature [75-77]. Thirdly, ethnicity was an important factor in both American studies [45, 50]; Caucasians and African-Americans were overrepresented in high and low SEP areas respectively. Indeed, in analysis of data from 1965 adjusting for ethnicity reduced the SEP-physical activity difference by fifty-five per cent [45]. Finally, Giles-Corti and Donovan [55] found that objectively measured environmental variables offset SEP differences.

Outcomes for Asset-based Indicators

Housing tenure was used as a main socio-economic variable in the analysis of data from older Australians (n=1000) [57] and the longitudinal British survey [66]. Despite finding significant associations for social class and income in the former, researchers failed to find significant differences in moderate-vigorous activity between homeowners and those renting properties. Boniface et al [66] on the other hand, found that uptake of LTPA was more likely in British men in privately owned compared with local authority properties ($P \leq 0.05$).

Discussion

A recent growth of interest surrounding inequalities in physical activity was evident as out of thirty-four studies, thirty were conducted in the last decade and twenty-three since 2000. Despite the wide availability of area-level socio-economic data from censuses, most researchers favoured using individual level data. In many cases this involved analysis of existing survey data collected up to twenty (and in one case, forty) years earlier. Possibly as a consequence of this reliance on old data, the scope and quality of physical activity or SEP measurement were often limited.

Is there strong evidence of a SEP-physical activity relationship?

Regardless of socio-economic indicator, higher levels of leisure-time or moderate-vigorous activity (which are often equivalent) in those at the top versus the bottom of the socio-economic strata were consistently demonstrated. Gradients of increasing physical activity in sequentially higher socio-economic groups were reported less frequently. This could be the result of either, crude SEP or physical activity measurement, able only to detect extreme differences, or alternatively those closer to the middle of the social strata might have similar physical activity levels. Where relationships were not reported, ethnic and possibly urban-rural differences were likely contributors. Most studies were delimited to measurement of LTPA (or similar outcomes), often favoured as they are more easily recalled than less structured lower intensity activities [16, 19]; indeed, work-related physical activity was reported as a separate outcome in only one study. Self-reporting of any physical activity is fraught with problems that make *accurate* measurement of habitual activity virtually impossible. Some studies that attempted to measure habitual physical activity reported relationships but they were less consistent.

Although longitudinal studies are intended to give a better impression of causality than simple prevalence or cross-sectional studies, failure to report socio-economic data at follow-up in three out of five longitudinal studies [54, 66, 70] and the absence of statistical analyses in another [61], meant that this was not the case.

Within the evidence hierarchy, observational studies such those reviewed here are positioned near the bottom [78]. Guidelines on the strength of evidence from reviews [79] state that those including primarily nonrandomised trials or observational studies rank third in the hierarchy (Category C from A to D). On this basis it would not be possible to claim that evidence from the present review was *strong*. This said, evidence for the presence of a socio-economic effect on physical activity was *consistent*, despite the range of approaches and variable study quality, and therefore should not be dismissed but used to inform on how to improve investigations of this relationship in future.

Differences between socio-economic indicators

Most studies defined SEP by occupational social class, income or education. Occupational social class is categorical by its very nature but with few exceptions income and education were categorised, often with large samples stratified into just two or three socio-economic categories. This reduced the sensitivity of measurements and increased heterogeneity within groups. Presumably such restrictions were imposed by the pre-collected survey data in most cases.

In general, associations between physical activity and education tended to be stronger and more resistant to ethnic variation than those for income or occupational social class, and the impact of reporting education in populations with a broad age range was not apparent. Social classification by occupation was less commonly used than income and education because historically, the lack of a clearly defined class structure in America has restricted its use in American epidemiology (which was dominant here). Most classified occupation using skill-based distinctions, similar to the much criticised British Registrar General's schema; another possible consequence of relying on old survey data. Despite this, all of the studies found a positive association, with some inconsistencies by gender, although only one study with a multi-ethnic sample reported social class. Income produced the least consistent trends, which could be the result of a number of factors: inaccurate reporting of sensitive income data; failure of many studies to adjust for household size; insensitivity of broad income categories; ethnic variation. Alternatively, income might be less strongly related to physical activity.

Use of asset-based indicators and area-level socio-economic classification was rare. The latter was always supported by individual level data, yet an independent area-level effect was also evident. This supports the concept that socio-physical environment can independently influence health and health behaviours independent of individuals' circumstances [75] as did the apparent environmental influence reported in other featured studies [51, 55] and elsewhere [32]. Furthermore, a strong ethnic effect was evident at the area-level with disproportionately high concentrations of different ethnic groups in different SEP areas.

Other factors

Several studies found that relationships between SEP and leisure-time or vigorous intensity activity were stronger in women than men [50, 54, 56, 57, 59, 69], whereas one study found the opposite [65]. Five all-female studies and just one all-male study [66] might reflect recent interest in gender health inequalities [80-82]. However, attempting to draw meaningful conclusions from this pattern is complicated by diversity in study designs and samples. Age was identified as an important factor in fewer studies and no consistent themes emerged.

The present review was limited to studies from Western countries to minimise the impact of cultural differences on the physical activity-SEP relationship. In addition, non-English language studies were excluded; this was primarily for logistical reasons and is a limitation of the present review. Dominance of studies from countries with English as their first language was apparent, although a range of countries were nevertheless represented.

Conclusion

In summary, there was consistent evidence of a higher prevalence or higher levels of leisure-time or moderate-vigorous intensity physical activity in those at the top of the socio-economic strata compared with those at the bottom. However, the assumption that socio-economic gradients for health are mirrored by those for physical activity was not justified. In order to determine whether this is an accurate reflection or a result of insensitive physical activity or socio-economic measurement, objective physical activity measurement and greater consistency in socio-economic measurement are required. In practice the former is unlikely in anything other than small populations, whereas collecting original data would enable the use of more up-to-date socio-economic classification. Which measurements are most appropriate will always vary by region or country, and ethnicity and environmental variables should be considered. In Britain, differences in our education systems and the lack of income data reduce comparability with American studies, which dominated the present discussion.

There is potential for further use of area-level socio-economic measurement in epidemiology; firstly because the most up to date and sophisticated socio-economic measurements are readily available in the census and an independent association with physical activity should be explored; and secondly, because they enable the study of large samples. Indeed, it is increasingly recognised that interventions to modify physical activity behaviour of the individual are costly and difficult to implement and therefore community level interventions with the potential to modify the behaviour of a larger number of people could be targeted using such area-level data.

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