Childhood Socioeconomic Position and Objectively Measured Physical Capability Levels in Adulthood: A Systematic Review and Meta-Analysis

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Abstract

Background: Grip strength, walking speed, chair rising and standing balance time are objective measures of physical capability that characterise current health and predict survival in older populations. Socioeconomic position (SEP) in childhood may influence the peak level of physical capability achieved in early adulthood, thereby affecting levels in later adulthood. We have undertaken a systematic review with meta-analyses to test the hypothesis that adverse childhood SEP is associated with lower levels of objectively measured physical capability in adulthood.

Methods and Findings: Relevant studies published by May 2010 were identified through literature searches using EMBASE and MEDLINE. Unpublished results were obtained from study investigators. Results were provided by all study investigators in a standard format and pooled using random-effects meta-analyses. 19 studies were included in the review. Total sample sizes in meta-analyses ranged from N = 17,215 for chair rise time to N = 1,061,855 for grip strength. Although heterogeneity was detected, there was consistent evidence in age adjusted models that lower childhood SEP was associated with modest reductions in physical capability levels in adulthood: comparing the lowest with the highest childhood SEP there was a reduction in grip strength of 0.13 standard deviations (95% CI: 0.06, 0.21), a reduction in mean walking speed of 0.07 m/s (0.05, 0.10), an increase in mean chair rise time of 6% (4%, 8%) and an odds ratio of an inability to balance for 5s of 1.26 (1.02, 1.55). Adjustment for the potential mediating factors, adult SEP and body size attenuated associations greatly. However, despite this attenuation, for walking speed and chair rise time, there was still evidence of moderate associations.

Conclusions: Policies targeting socioeconomic inequalities in childhood may have additional benefits in promoting the maintenance of independence in later life.

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Introduction

Maintenance of physical capability, that is an individual's ability to undertake the physical tasks of everyday living, is essential in older age. Grip strength, walking speed, time to rise from a chair and standing balance performance are simple, objective measures of physical capability levels that provide a marker of current health and predict subsequent health outcomes [1] including disability [2] and mortality [3,4] in older populations.

Numerous studies have reported associations between socioeconomic position (SEP) and health in adulthood [5–7] with consistent evidence that the socioeconomically disadvantaged have higher chronic disease [8] and mortality rates [9–12] than the more advantaged. Evidence also indicates that socioeconomic disadvantage in childhood is associated with a range of adverse outcomes in adulthood [8,13] often independent of adult SEP [11,12]. Childhood SEP, through its association with a range of factors, including growth and early life nutrition, may influence the peak level of physical capability attained in early adulthood, thereby affecting levels later in life [14]. Adverse effects of SEP may also accumulate across the life course [15]. On the basis of such evidence it is argued that reducing health inequalities is a matter of fairness and social justice and, action to reduce health inequalities must start before birth and continue through life if the close links between early disadvantage and poor health are to be broken [16].

Poor adult SEP is associated with worse objectively measured physical capability levels [17,18]; however, it is unclear whether this effect is also seen with childhood SEP independent of adult SEP. Such an association would have important implications for interventions aimed at improving the physical capability levels of older people and long term trends for 'healthy ageing' because of potential cohort effects and the compression of morbidity phenomenon [19]. To test the hypothesis that adverse childhood SEP is associated with lower levels of objectively measured physical capability in adulthood we have undertaken a systematic review and meta-analyses of both published and unpublished results.

Methods

A systematic review of published literature was undertaken following the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines [20] and the PRISMA statement [21]. Unpublished results were then acquired through analysis of data from studies participating in the Healthy Ageing across the Life Course (HALCyon) collaboration (www.halcyon.ac.uk) and contact with other study investigators.

Selection criteria

Eligible observational studies were those conducted on individual participants that examined the association between any indicator of childhood SEP (e.g. parental occupation or education) and at least one of four pre-specified objective measures of physical capability (grip strength, walking speed or get up and go test [22], chair rises and standing balance) in adulthood. Eligible study populations were community-dwelling adults aged 18 y or over at the time of physical capability measurement (full review protocol at www.halcyon.ac.uk).

Literature search and data extraction

Searches of the electronic databases MEDLINE and EMBASE (up to May 2010) were performed using text word search terms and explosion MeSH terms (Appendix S1) in any language (by KB). Searches were restricted to studies of humans. Duplicate records identified by title, authors, journal citation and date published, were removed. The abstracts of all 1,200 unique records identified were screened independently by two authors (KB and RC). The full text of 24 papers identified as potentially eligible were obtained with a final decision then made by consensus between KB and RC about eligibility. Of the 24 papers examined, five [23–27] reporting on three different studies, one of which participates in HALCyon [24–26], were eligible for inclusion. A sixth paper eligible for inclusion [28], also using data from a study participating in HALCyon, was identified through discussions with the study authors. A further six papers [29–34] identified during the screening process and reporting on five studies were classified as 'pending' because the papers did not present relevant results, but appropriate data might have been available. Figure 1 summarises this initial identification of studies.

Data from the six eligible papers were independently extracted by two authors (KB and RC) onto a standardised form. Information was extracted on associations of interest, the study population, baseline characteristics, details of the ascertainment of childhood SEP and physical capability measures, identification of potential confounders and methods of controlling for these. Any differences between the two sets of information extracted were resolved through discussion.

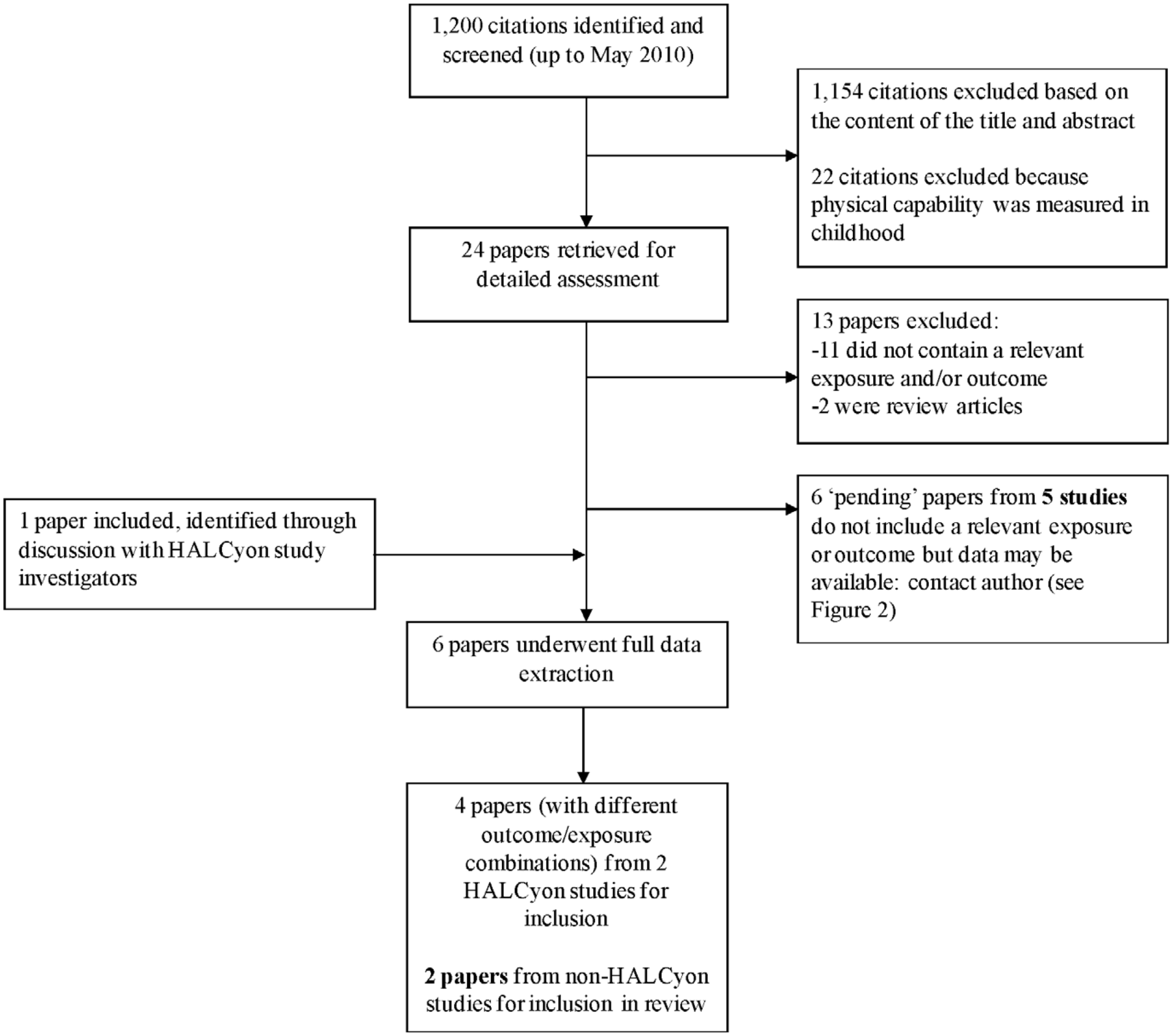

Figure 1. Flow diagram for identification of published studies.
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Inclusion of unpublished results

HALCyon studies. We included data from eight of the nine UK cohort studies involved in the HALCyon collaboration. These are the Lothian Birth Cohort 1921 [35], the Hertfordshire Ageing Study [36], the Hertfordshire Cohort Study [37], the Caerphilly Prospective Study [38], the Aberdeen Birth Cohort 1936 [35], the Boyd Orr cohort [39], the English Longitudinal Study of Ageing [40] and the MRC National Survey of Health and Development [24–26]. Two of these studies [24–26,28] had previously published on the associations of interest with findings from another two currently in press [41].

Other studies with relevant data. To ensure that all results for inclusion in meta-analyses were as comparable as possible, we contacted the corresponding authors of the other two studies [23,27] identified from the electronic search as being eligible for inclusion. We also contacted the authors of the five 'pending' studies [29,31–34] to ask whether they would be willing to provide results (Figure 2).

We identified an additional 13 studies [42–54] that we believed may have exposures and outcomes of interest, but had not published results from tests of these associations, by consulting a review paper on longitudinal studies of ageing [55], relevant websites [56–58] and asking experts in the field of gerontology. Investigators working on these studies were also contacted. In total, emails were sent to 20 study investigators. Responses to 16 of the 20 requests were received with eleven studies, including the two studies which had previously published on the associations, agreeing to provide results for inclusion in meta-analyses. The other five responses informed us of an inability to provide results (see Figure 2).

Analyses requested from eligible studies

Using the eight HALCyon study datasets, we performed individual study analyses in a standard format for inclusion in meta-analyses. Investigators of the eleven other included studies [23,27,32,43,46,48–50,52–54] were asked to perform the same

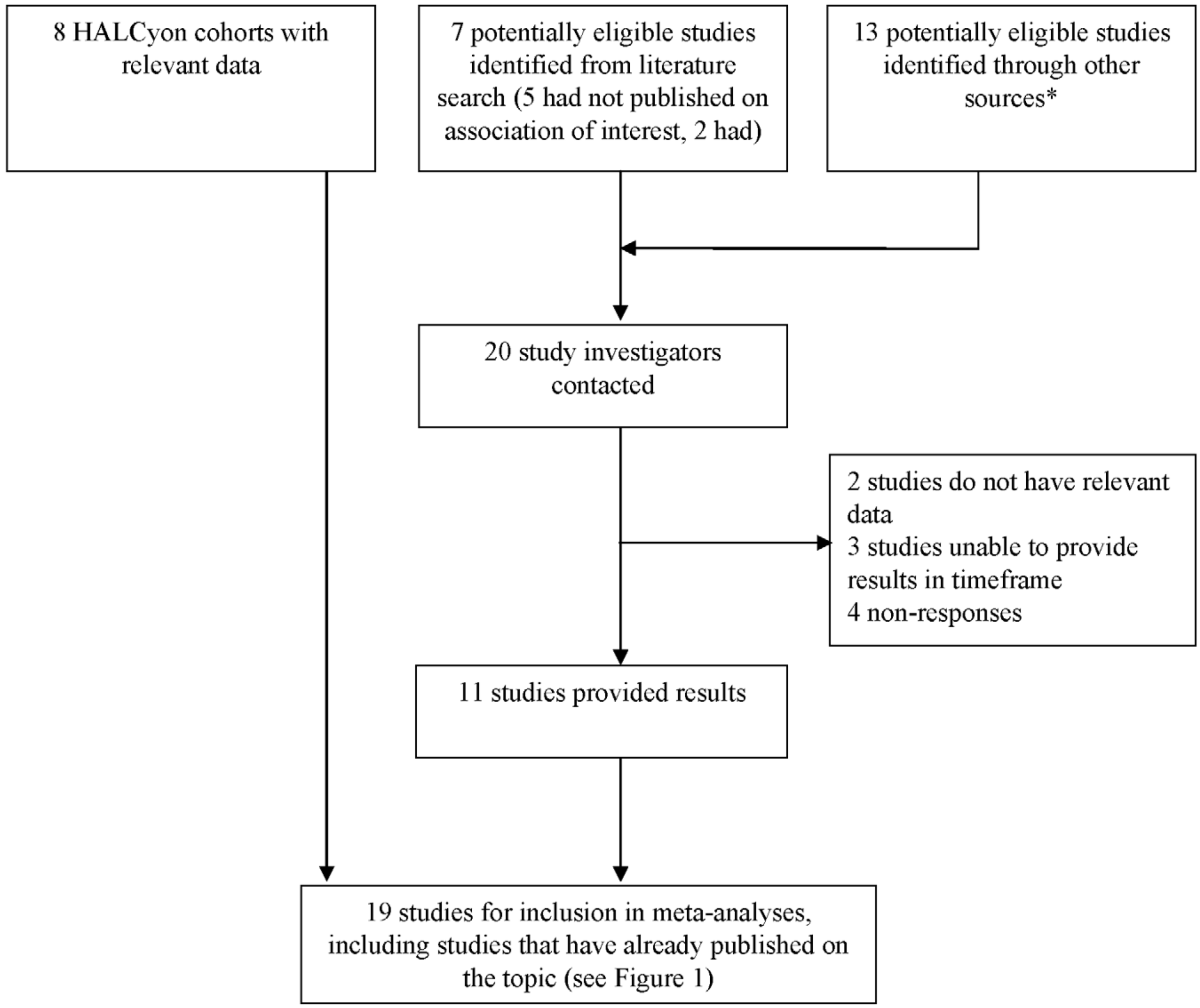

Figure 2. Flow diagram showing contact with authors and ascertainment of results for inclusion in review. * This included a review paper on longitudinal studies of ageing [55], relevant websites [56–58] and experts in the field of gerontology.
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analyses and then complete standardised tables of results personalised for their study. These standard analyses involved testing the associations between *each* individual measure of childhood SEP and *each* measure of physical capability available, using sex-specific regression analyses. The indicators of childhood SEP and the physical capability measures were handled in the same way across studies.

Childhood SEP. Although the study protocol specified that any indicator of childhood SEP would be considered, we chose to focus in analyses on those measures most widely used across studies. These were father's occupation (usually assessed using the UK Registrar General's Social Classification system), childhood economic environment (usually assessed on a three point scale from good to poor or high to low), father's education and mother's education (both of which were usually based on a measure of length of time in education or highest level of education achieved). Each of these measures of childhood SEP was modelled as sex-specific ridit scores to enable direct comparison between cohorts (and SEP measures). The ridit scores take account of variation between studies in the methods of categorising SEP variables and in the proportions of people in different categories of a socioeconomic variable [59]. For each indicator of childhood SEP, after ordering the categories from highest to lowest, a score between 0 (highest SEP) and 1 (lowest SEP) was assigned to each category, based on the proportion of the population above the mid-point in that category. For example, if 10% of the population are in social class I, people in this group are represented by the range 0 to 0.1 and so are allocated the score 0.05 (i.e. divide 0.1 by 2 to obtain the value for the mid-point of the group). If 20% of the population are in the next highest group, social class II, then this social class is allocated a score 0.20 (0.1+0.2/2) and so on. Each of the outcomes can then be regressed on these ridit scores, with the regression coefficients representing the slope index of inequality (SII) for continuous outcomes and the relative index of inequality (RII) for binary outcomes. These are interpretable as comparing people of the lowest SEP (1) with people of the highest SEP (0), either in absolute (SII) or relative terms (RII).

Physical capability measures. Grip strength was analysed as an untransformed continuous variable with effect estimates converted to kg if strength had not been measured in kg. Timed walks and the get up and go test (which involves a chair rise followed by a timed walk) were converted to 'walking speed' in metres/second and analysed as untransformed continuous variables. Time to complete five chair rises was natural log transformed due to skewed distributions in most populations. Linear regression models were used to investigate associations of childhood SEP with grip strength, walking speed and log chair rise time. The regression coefficients for log chair rise time can be multiplied by 100 to represent percentage change in time [60]. Standing balance time could not be analysed as a continuous variable because a large proportion of participants in many studies achieved the maximum time of the test (generally around 30 seconds) and there was variation between studies in the methods of recording times. Standing balance time was thus dichotomised at a cut-point of five seconds, to identify those with the worst standing balance ability. Inability to balance on one leg for five seconds was used as the outcome event (coded as 1) in logistic regression models.

Adjustments. Three separate sets of adjustments were performed to test whether associations found were explained by the continuity of SEP from early life to adulthood and to control for body size which tends to be socioeconomically graded and is an important determinant of physical capability levels [25,26]: (i) age; (ii) age and adult socioeconomic position (e.g. occupational class (of the head of household if available) and education); (iii) age, adult socioeconomic position and body size (height and weight or BMI).

Meta-analyses

Random effects meta-analyses [61] were performed using the 'metan' command [62] in Stata version 11 [63] if sufficient results were available (i.e. more than three sets of comparable results). Random effects models were chosen *a priori* as we expected a large degree of heterogeneity between studies. Sex differences in the age adjusted associations were tested by meta-analyses of the within-study sex differences for each outcome. Where there was no evidence of sex differences within studies, estimates for men and women were included in all subsequent meta-analyses together. Summary estimates of effect were calculated for *each* different indicator of childhood SEP and its association with *each* physical capability measure. Meta-analyses were then used to calculate overall summary estimates of effect for the association of childhood SEP with each physical capability outcome using one childhood SEP estimate for each study and including all studies regardless of the indicator of SEP they had used. In studies with more than one measure of childhood SEP, the choice of indicator was based on the frequency of use across studies. Because it was the most frequently used indicator of childhood SEP among the included studies, paternal occupation was used if this measure was available, otherwise childhood economic circumstances was used and otherwise paternal education. Meta-analyses were first run on the age adjusted estimates, then repeated on the age and adult SEP adjusted estimates and finally on the age, adult SEP and body size adjusted estimates. Effect estimates from analyses of walking speed and timed get up and go speed were included in the same meta-analyses with the measure of walking speed used for those few studies which had measured both walking time and timed get up and go. For grip strength and walking speed, the sex-specific effect estimates were standardised by dividing the coefficients by the standard deviations (SDs). This takes into account variation in the distribution, in particular the SD, of physical capability outcomes between studies and between sexes within studies. For grip strength this also takes account of the differences between studies in the types of dynamometer used. Meta-analyses were performed on the unstandardised and standardised estimates, to examine whether standardisation reduced between-study heterogeneity.

The percentage of variation between studies that cannot be attributed to within-study variation was examined using the I^2 value [64] and 95% CIs based on the statistical significance of Q [65]. Potential sources of heterogeneity were examined by stratifying meta-analyses by each of the following pre-specified factors: mean age of study participants ('younger' <60 y vs. 'older' ≥60 y), method of ascertaining childhood SEP (prospective vs. retrospective, because prospective studies are higher in the hierarchy of evidence) and study location (Europe vs. other, with the classification chosen pragmatically). Where there were sufficient sets of results (i.e. >10) meta-regression [66] was performed using the 'metareg' command [67] in Stata 11 [63] for pooled results for men and women in each study. We did not formally assess the quality of the included studies because, unlike randomised control trials, no validated quality criteria are available [68]. The main meta-analyses were re-run with each study removed in turn to test that no one study explained any heterogeneity found. We used funnel plots to assess bias (i.e. plots of study effect sizes against precision) and tested the symmetry of the funnel plots using Egger's test [69].

Results

In total, 19 studies contributed results to this review; summaries of these studies are shown in Table S1. Most studies were of older populations with a median age at the time of physical capability assessment of 69 years (range 18 to 79 years, Table S1). The Swedish 1969/70 Conscription Cohort [32] was a subset of a study on the Swedish Military Service Conscription Register [49]. To avoid including the same study population in meta-analyses more than once, we included only the results from the Swedish Military Service Conscription Register in meta-analyses due to its greater sample size. The Survey on Health and Wellbeing of Elders (SABE) [23] contributes five data points per sex to the meta-analyses, because this was a multi-city study with heterogeneity in socioeconomic conditions between cities. In some cities, sample clusters were stratified in terms of geography, whereas in others the strata were defined both by geography and by aggregate indicators of socioeconomic conditions. Thus it was not considered appropriate by the SABE study investigators to group the participants from the different cities together when performing individual study analyses.

The total sample sizes included in the meta-analyses for each outcome are: N = 1,061,855 from 12 studies of grip strength; N = 20,770 from 13 studies of walking speed (10 which had assessed walking time and 3 which had used the get up and go test); N = 17,215 from 7 studies of chair rise time; and N = 22,156 from 11 studies of standing balance. There was no evidence of sex differences within studies for any outcome, so results for both sexes are presented in the same meta-analyses (p-values from meta-analyses of overall differences between sexes: grip strength [after standardisation of regression coefficients] p = 0.39; walking speed p = 0.71; chair rise time p = 0.97; standing balance p = 0.17). For walking speed, findings did not differ and heterogeneity between studies was not reduced when using standardised regression coefficients: therefore, for ease of interpretation, results from meta-analyses of unstandardised coefficients (m/s) are presented, however, for grip strength results from meta-analyses using standardised coefficients are presented.

Age adjusted results

In age adjusted models, there was evidence in the majority of studies that lower childhood SEP (i.e. less affluence), however it had been assessed, was associated with poorer physical capability levels, however this was assessed (Figures 3–6). For example, the overall summary age adjusted estimates of effect comparing the lowest with the highest father's occupational class were: −0.14 SDs for grip strength (95% CI: −0.24, −0.04; p = 0.01, N = 1,053,784) (Figure 3), with one SD in grip strength equal to approximately 9 kg in men and 6 kg in women; −0.08 m/s for walking speed (−0.11, −0.05; p<0.01, N = 19,017) (Figure 4); 6% for chair rise time (3%, 8%; p<0.01, N = 9,468) (Figure 5); and the odds ratio (OR) of inability to balance for five seconds was 1.50 (1.06, 2.14; p = 0.02, N = 14,295) (Figure 6). Although summary estimates of effect from meta-analyses of different indicators of childhood SEP are not directly comparable because of differences in the studies included in each comparison, there was a suggestion that the association of parental education with walking speed was stronger than the association of either father's occupation or childhood economic environment (Figure 4).

Overall summary estimates

When combining different indicators of childhood SEP in the same meta-analyses (Table 1), the findings were similar to the results from meta-analyses which assessed each measure of childhood SEP separately (Figures 3–6). The overall summary age adjusted estimates of effect comparing the lowest with the highest childhood SEP were: −0.13 SDs for grip strength (95% CI: −0.21, −0.06; p<0.01, N = 1,061,855); −0.07 m/s for walking speed (−0.10, −0.05; p<0.01, N = 20,770) (−0.31 SDs for walking speed on the standardised scale; −0.42, −0.20); 6% for chair rise time (4%, 8%; p<0.01, N = 17,215); and the OR of

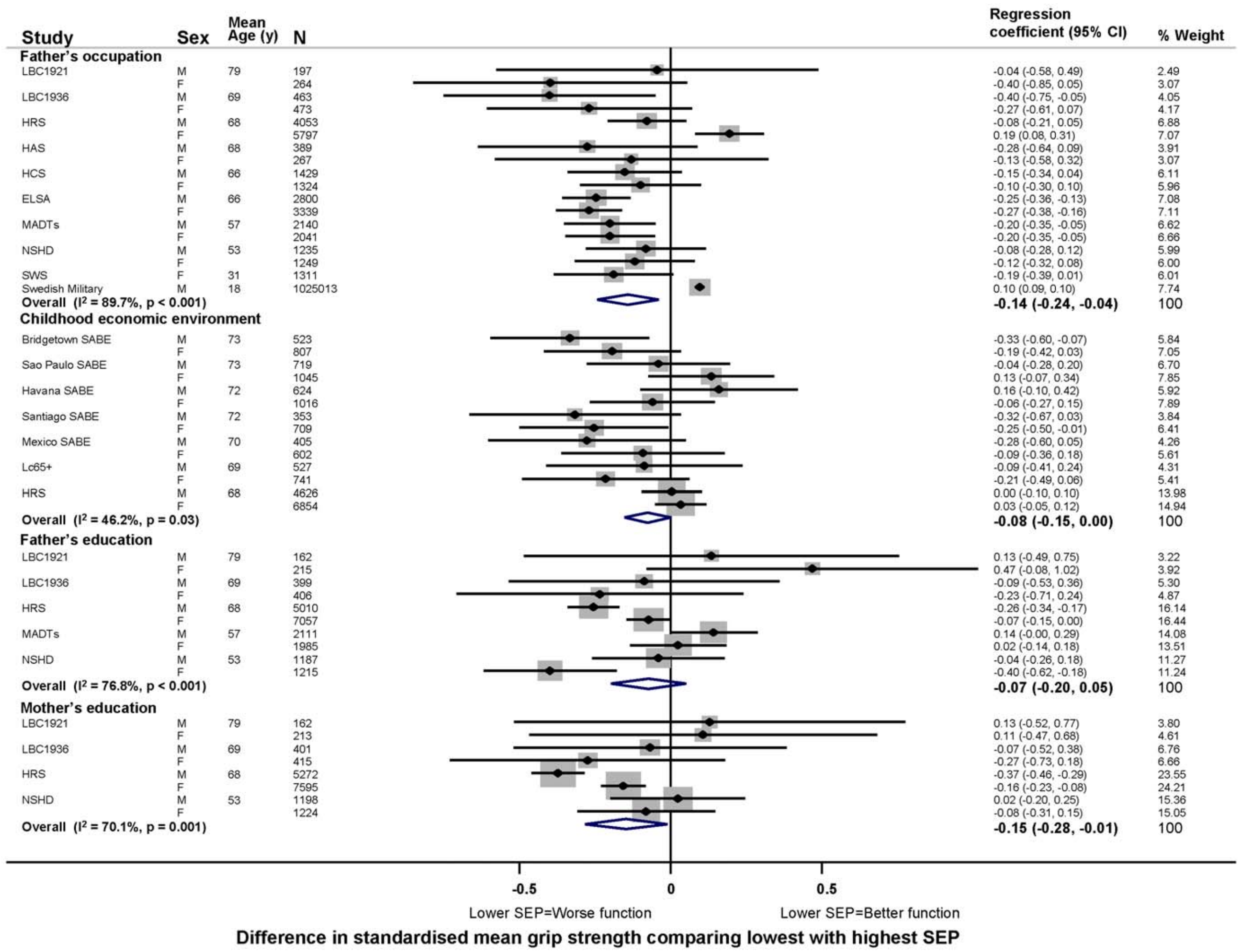

Figure 3. Age adjusted differences in mean standardised grip strength comparing lowest with highest childhood SEP. Footnotes: Please note that in the study of middle aged Danish twins (MADTs) major wage earner's occupation and education rather than father's occupation and education were assessed. Swedish 1969/70 Conscription Cohort was a subset of the study on the Swedish Military Service Conscription Register so has not been included in the meta-analysis. The results were: Swedish 1969/70 Conscription Cohort; 100% male; mean age 18.3 years; N = 42,365; the standardised estimate for father's occupation and grip strength was an increase of 0.24 SDs (95% CI: 0.21, 0.28). The abbreviations of study names for figures 3–6 are: ABC1921: Aberdeen Birth Cohort 1921; ABC1936: Aberdeen Birth Cohort 1936; Boyd Orr; CaPS: Caerphilly Prospective Study; ELSA: English Longitudinal Study of Ageing; HAS: Hertfordshire Aging Study; HCS: Hertfordshire Cohort Study; HRS: Health and Retirement Study; KLoSA: Korean Longitudinal Study of Ageing; LBC1921: Lothian Birth Cohort 1921; LBC1936: Lothian Birth Cohort 1936; Lc65+: Lausanne Cohort 65+; MADTs: The study of middle aged Danish twins; NSHD: MRC National Survey of Health and Development; PREHCO project: Puerto Rican Elderly Health Conditions project; SABE: Survey on Health and Wellbeing of Elders (conducted in: Bridgetown, Barbados; Havana, Cuba; Mexico City, Mexico; Santiago, Chile; Sao Paulo, Brazil); Swedish Military: Swedish Military Service Conscription Register; SWS: Southampton Women's Survey.
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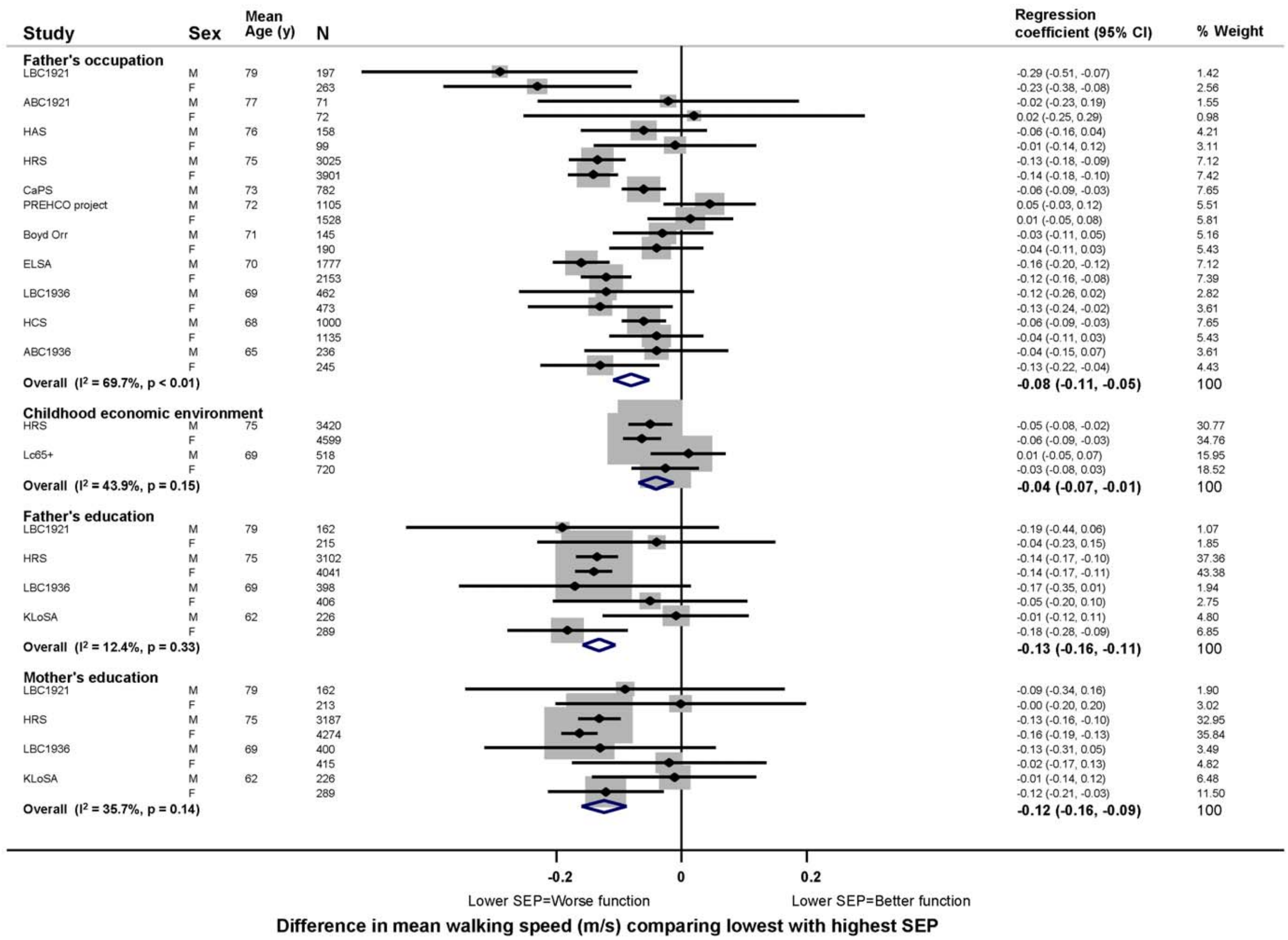

Figure 4. Age adjusted differences in mean walking speed (m/s) comparing lowest with highest childhood SEP.
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inability to balance for 5 s was 1.26 (1.02, 1.55; p = 0.03, N = 22,156).

Adult SEP and body size adjusted results

After adjustment for adult SEP, associations were attenuated substantially (i.e. by 50 to 75%) for all outcomes (Table 1). For grip strength and standing balance, further attenuation occurred after additional adjustment for body size whereby associations were consistent with chance (−0.02 SDs for grip strength; 95% CI -0.07, 0.04; p = 0.59 and OR of inability to balance for 5 s 1.02; 0.84, 1.24; p = 0.85) (Table 1). However, for walking speed and chair rise time despite substantial attenuation there was still evidence of modest associations with childhood SEP in fully adjusted models: −0.02 m/s for walking speed (−0.04, −0.001; p = 0.02) (−0.08 SDs for walking speed on the standardised scale; −0.15, −0.01; p = 0.03) and 3% for chair rise time (1%, 5%; p = 0.02) (Table 1).

Heterogeneity

There was evidence of substantial heterogeneity between studies in meta-analyses of grip strength $I^2 = 86.1\%$ (95% CI: 81.3, 89.7) and walking speed $I^2 = 72.1\%$ (58.4, 81.3) and moderate heterogeneity for chair rise time $I^2 = 33.6\%$ (0.0, 60.4) and standing balance $I^2 = 47.5\%$ (19.0, 66.0) (Table 1), with adjustment for adult SEP and body size reducing the heterogeneity between studies (Table 1). In stratified meta-analyses, there was no clear evidence that age or method of ascertaining SEP (pre-specified factors) explained the heterogeneity found (Table 2) and meta-regression analyses were not conducted on either of these factors because of limited power. In stratified meta-analyses for grip strength and standing balance, the associations found in age adjusted models were stronger in European studies than in studies from other parts of the world (Table 2). Meta-regression analyses provided further evidence of a difference in effect by study location for standing balance (OR for non-European compared to European = 0.58; 0.36, 0.94; p = 0.03) but there was no evidence of differences by location in meta-regression analyses of the other three outcomes (coefficients for non-European compared to European are: 0.05 SDs for grip strength; −0.12, 0.23, p = 0.51; 0.01 m/s for walking speed; −0.09, 0.12, p = 0.81; and 1% for chair rise time; −6%, 7%, p = 0.84). In most instances the removal of each individual study from the meta-analyses did not influence estimates of the level of heterogeneity or main findings greatly. The main findings remained the same even when the largest study (the Swedish Military Service Conscription Register, N = 1,025,013) which found an association in the opposite direction to most other studies for grip strength, was removed (results not shown) however the estimated level of heterogeneity between studies was lower when this study was removed with I^2 reduced from 86.1% to 58.7%. The funnel plots (data not shown) and Egger test showed no evidence of small-study bias for walking speed (p = 0.60), chair rise time

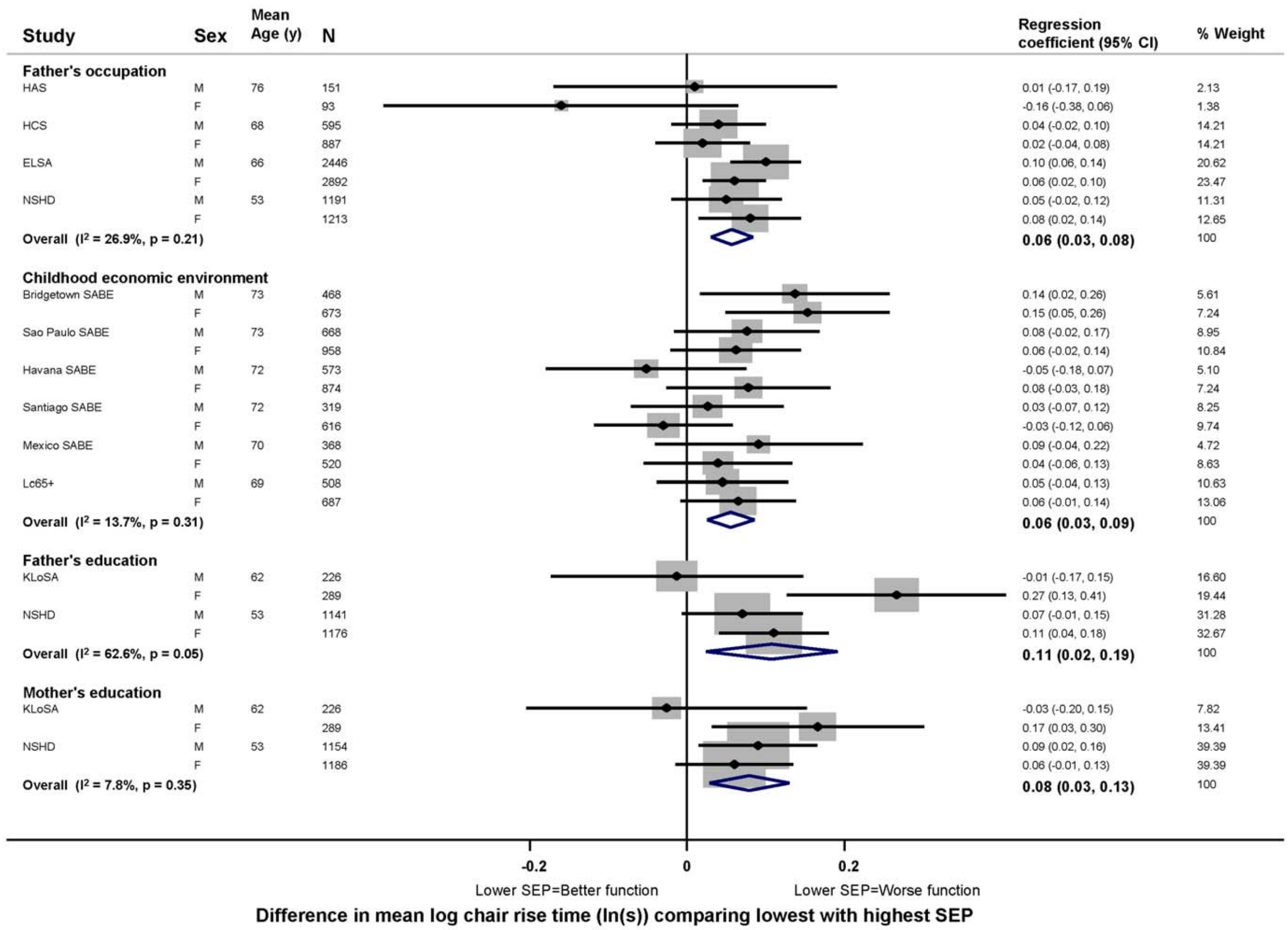

Figure 5. Age adjusted differences in mean chair rise time (ln(s)) comparing lowest with highest childhood SEP.
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($p = 0.54$) or standing balance ($p = 0.24$). However, for grip strength, the funnel plot was asymmetrical ($p < 0.001$) although on further investigation this asymmetry was found to be attributable to the inclusion of the Swedish Military Service Conscription Register and when this study was removed from the plot there was no longer evidence of bias ($p = 0.40$).

Discussion

We found modest associations between indicators of childhood SEP and objectively measured physical capability levels in adulthood. People with lower SEP in childhood were more likely to have weaker grip strength, walk more slowly and perform less well in tests of chair rising and standing balance in later adulthood than people with higher childhood SEP, after adjustment for age. The associations of childhood SEP with walking speed and chair rise time were maintained, despite attenuations in effect size, after adjustment for indicators of adult SEP and current body size. However, the results from meta-analyses should be interpreted with some caution as there was evidence of unexplained heterogeneity between studies.

Explanation of findings

Our finding of attenuations in effect size after adjustment for adult SEP suggests that associations between childhood SEP and physical capability levels could be partially explained by the tracking of SEP across life, with SEP in adulthood being a better predictor than childhood SEP. However, childhood SEP was measured by recall in all but two studies [39,70] and would be expected to be more prone to measurement error than adult SEP which could dilute the size of effects estimated for childhood SEP. Furthermore, adjusting for adult SEP and adult body size could be considered an over-adjustment, if these factors lie on the causal pathway.

The associations of childhood SEP with walking speed and chair rise performance were maintained after adjustment for adult SEP, suggesting that the accumulation of adverse exposures over a lifetime may be a better model of the associations than one which considers only adult factors. There are several potential pathways that may link childhood SEP to adult physical capability. For example nutrition, motor development, physical activity and fitness in early life are socioeconomically graded and track into adulthood and such factors as these and others including stress and inflammation should be investigated further in future work. However, although prenatal growth, indexed by birth weight, is consistently related to adult grip strength [25,44,71] and is socioeconomically graded, in adjusted analyses childhood SEP and grip strength were not associated suggesting that this is one pathway unlikely to explain the observed associations.

Possible sources of heterogeneity

Eleven of the nineteen studies included in this review are from the UK, in part because of the inclusion of the HALCyon cohorts.

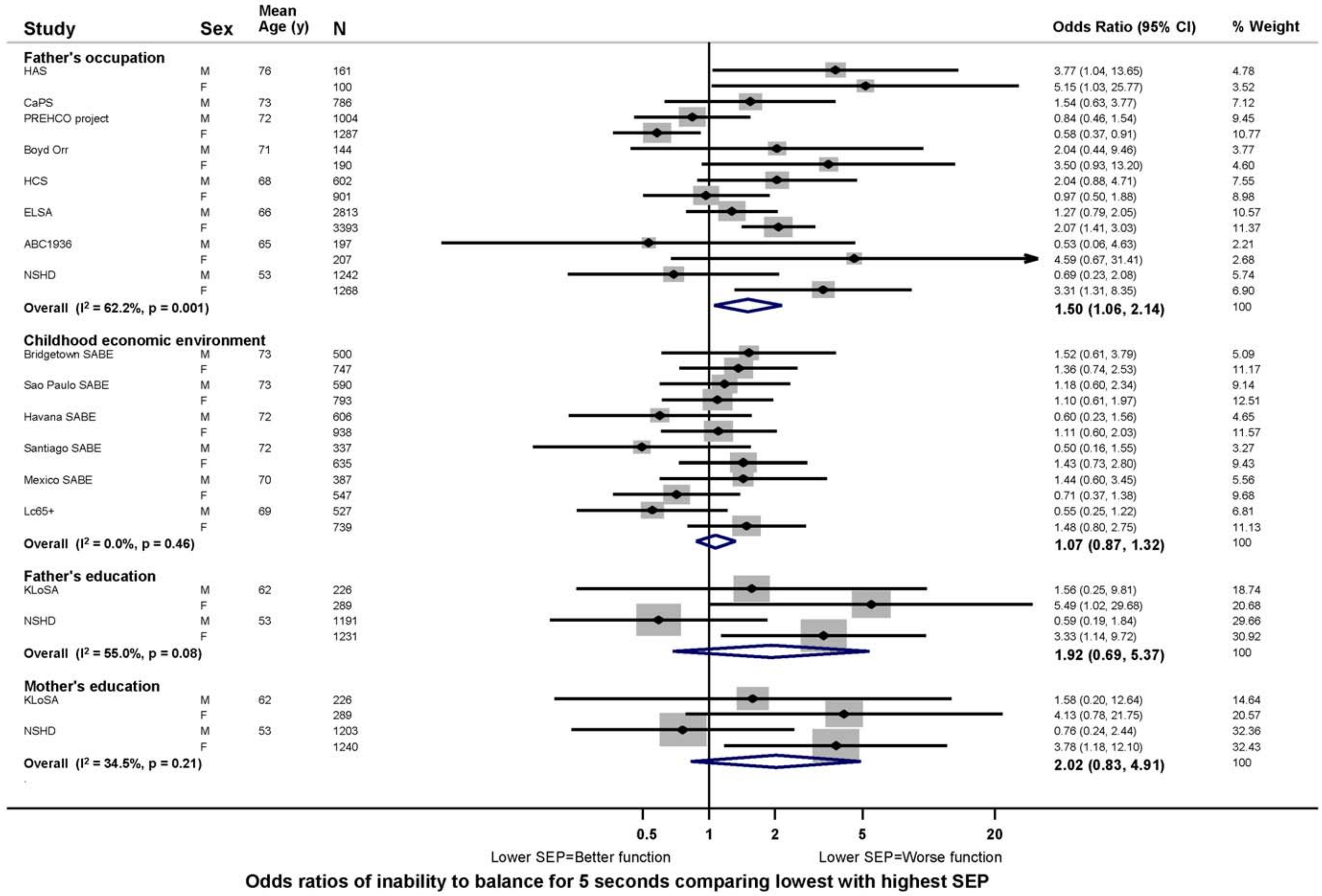

Figure 6. Age adjusted odds ratios of inability to balance for 5 seconds comparing lowest with highest childhood SEP.
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However, eligible studies have also been conducted in other European countries, [27,32,43,49] the USA, [46,48] Central and South America and the Caribbean [23] and Korea [53]. When comparing results by study location, most studies conducted in Europe used father's occupation as an indicator of SEP, whereas studies from other parts of the world used childhood economic environment or parental education. The differences found by study location may, therefore, be explained by differences in SEP indicator used.

There were differences between studies in the protocols followed for assessment of physical capability which could have contributed to the heterogeneity observed. A range of different handheld dynamometers [72] were used to measure grip strength (Table S1) with either the average or maximum value achieved over a set number of trials used in analyses. However, by using standardised regression coefficients in meta-analyses differences between studies in the types of dynamometer used were taken into account. Walking times were measured over different distances ranging from 8 feet (equivalent to 2.4 metres) [40] to 20 metres [43]. Walking and get up and go times were converted into speeds to ensure measures were more comparable across studies, despite differences in distance. However, participants may tackle a test differently depending on distance. Further, while in most studies participants were asked to walk at a normal pace, in a small number of studies [35,52] participants were asked to walk as fast as possible. For chair rises, all participants were asked to perform five, except for the NSHD, where times to complete five rises were estimated from times to complete ten rises using sex-specific conversion factors derived from ELSA participants of a similar age who undertook both five and ten chair rises. Standing balance was always measured with eyes open, but other differences in the tests existed. Times were dichotomised to make comparisons across studies possible, but the categorisation may have produced a weaker measure of true balance ability than would have been achieved using a continuous measure.

A further possibility is that the heterogeneity between studies is real. It is plausible that the associations of childhood socioeconomic position with physical capability vary by study context including geographical location and birth period, whereby SEP in early life may play a more important role in some contexts than others.

Strengths and limitations

Two main strengths of this systematic review are the inclusion of several objective measures of physical capability and the wide range of different studies. By following a strict protocol, testing *a priori* hypotheses and including many unpublished results, we hope to have minimised various sources of bias including selection and publication biases. A further strength is that by requesting that study authors perform their analyses in a standardised way, we have been able to limit the possibility that heterogeneity between studies is explained by variation in analytical methods, which may occur when using only published results.

There are also some potential limitations to this review. Firstly, ridit scores were used to model our main explanatory variables as it allows more valid comparisons of results across studies where the

Table 1. Overall summary estimates of effect for the associations between childhood SEP and physical capability from random effects meta-analyses using ridit scores and comparing lowest with highest SEP.

Model*	Regression coefficient†	95% CI	p-value	I^2	95% CI	p-value‡
Grip strength (sd score) (N = 1,061,855) (15 data points for men and 15 for women)						
1	−0.13	(−0.21, −0.06)	0.001	86.1%	(81.3, 89.7)	<0.001
2	−0.04	(−0.10, 0.02)	0.16	69.2%	(55.2, 78.8)	<0.001
3	−0.02	(−0.07, 0.04)	0.60	65.0%	(48.4, 76.2)	<0.001
Walking speed (m/s) (N = 20,770) (13 data points for men and 12 for women)						
1	−0.07	(−0.10, −0.05)	<0.001	72.1%	(58.4, 81.3)	<0.001
2	−0.02	(−0.04, −0.01)	0.004	23.6%	(0.0, 53.3)	0.14
3	−0.02	(−0.04, −0.001)	0.015	20.0%	(0.0, 51.1)	0.19
Chair rises (ln(s)) § (N = 17,215) (11 data points for men and 11 for women)						
1	0.06	(0.04, 0.08)	<0.001	33.6%	(0.0, 60.4)	0.06
2	0.03	(0.01, 0.05)	0.01	19.8%	(0.0, 52.2)	0.20
3	0.03	(0.01, 0.05)	0.02	28.0%	(0.0, 57.3)	0.11
Standing balance (N = 22,156) (15 data points for men and 14 for women)						
1	1.26	(1.02, 1.55)	0.03	47.5%	(19.0, 66.0)	0.003
2	1.06	(0.86, 1.30)	0.60	41.5%	(8.9, 62.5)	0.01
3	1.02	(0.84, 1.24)	0.85	34.7%	(0.0, 58.5)	0.04

* Model 1: Age adjusted; Model 2: Age and adult SEP adjusted; Model 3: Age, adult SEP and body size adjusted.
† Mean difference in standard deviation score of grip strength; Mean difference in walking speed (m/s); Mean difference in natural log transformation of chair rise time (ln(s)); Odds ratio of inability to balance for 5 s for standing balance comparing lowest versus highest SEP based on ridit scores.
‡ *p*-values from Cochran's *Q* statistic.
§ The regression coefficients for chair rise time can be multiplied by 100 to represent percentage change in time [60].
Note: These models include estimates from studies for father's occupation if available, childhood economic environment if not and father's education if neither other measure of childhood SEP available.
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distribution of childhood SEP varies; however, by using this method, we are assuming that the relationship of childhood SEP with physical capability is linear. While this seems to be a reasonable assumption as many associations between SEP and health outcomes are linear [73–75], in some cohorts this assumption may be violated and this would lead to an underestimation of the size of association between childhood SEP and physical capability. However, there was little evidence of non-linearity in the HALCyon cohorts when this was investigated (results not shown). Secondly, the study participants included in analyses were selected on the basis of the availability of the outcome variable. People who have difficulty undertaking the physical capability tests [76] are, therefore, often excluded from analyses. This is a particular problem in older study populations as non-participation in physical capability tests is often found to be higher in subjects who have fallen in the previous year, use a walking aid, or have impaired activities of daily living [77]. We did not account for non-participation in analyses, except when considering standing balance where those people unable to undertake the test were included in the group classified as unable to balance for at least five seconds, therefore associations between adverse childhood SEP and physical capability in adulthood may have been underestimated. Attrition of the original samples (through non-response and death) is another potential limitation and may account for some differences between study populations found. Another potential limitation is that some studies adjusted for adult height and weight, whereas other studies adjusted for BMI and this may not remove confounding effects of height on physical capability. In addition there are other potential confounding factors, such as medication use and health status, which have not been included in these analyses, as it was decided that requesting further adjustments may lead to inconsistencies in adjustments across studies, but which may play some part in explaining the associations found.

We were unable to explain all the heterogeneity between studies and we may have failed to identify subgroup effects due to lack of power. Further, although we specified possible sources of heterogeneity *a priori*, the effects of the characteristics we investigated were potentially confounded by each other and by other factors. By examining only a small range of indicators of childhood SEP and being able to include only one indicator per study in our final set of analyses we may not have appropriately captured the aspects of the childhood economic environment which are most important in relation to physical capability, however, the indicators used are those which are most frequently measured across studies.

Implications

This review demonstrates the impact of childhood SEP on physical capability levels in adulthood, which in turn are predictors of subsequent mortality in older community-dwelling populations [4]. To illustrate the potential impact of childhood SEP, we have used estimates from our previous meta-analysis [4] to predict how these associations translate into mortality differentials. A quartile change in walking speed is approximately one SD change (in terms of normal distributions). A quartile slower walking speed was associated with a mortality hazard ratio (HR) of 1.38 [4]. Our age adjusted estimate comparing the lowest with the highest childhood SEP was −0.31 SDs for walking speed. A 0.31 SD slower walking speed would be expected to have a HR of 1.11

Table 2. Overall age adjusted summary estimates of effect for the associations between childhood SEP and physical capability from random effects meta-analyses using ridit scores and comparing lowest with highest SEP stratified by age, method of ascertaining SEP and location.

Stratification		No. of data points M; F	Total N	Regression coefficient†	95% CI	p-value	I^2	p-value‡
Grip strength (sd score)								
Age group (y)	<60	3;3	1,032,989	−0.11	(−0.27, 0.05)	0.18	89.1%	<0.001
	60+	12;12	28,866	−0.14	(−0.22, −0.06)	0.001	64.8%	<0.001
Ascertainment of SEP	Prospective	1;1	2,484	−0.10	(−0.24, 0.04)	0.16	0.0%	0.79
	Retrospective	14;14	1,059,371	−0.14	(−0.22, −0.05)	0.001	86.6%	<0.001
Location	Europe	9;9	1,045,202	−0.17	(−0.29, −0.06)	0.003	89.4%	<0.001
	Other	6;6	16,653	−0.08	(−0.19, 0.04)	0.19	68.8%	<0.001
Walking speed (m/s)								
Age group (y)	<60	0;0	0	N/A				
	60+	13;12	20,770	−0.08	(−0.10, −0.05)	<0.001	72.1%	<0.001
Ascertainment of SEP	Prospective	1;1	335	−0.04	(−0.09, 0.02)	0.21	0.0%	0.86
	Retrospective	12;11	20,435	−0.08	(−0.11, −0.05)	<0.001	73.6%	<0.001
Location	Europe	10;9	10,696	−0.07	(−0.10, −0.05)	<0.001	61.4%	<0.001
	Other	3;3	10,074	−0.07	(−0.14, 0.001)	0.05	86.5%	<0.001
Chair rises (ln(s)) §								
Age group (y)	<60	1;1	2,404	0.07	(0.02, 0.11)	0.007	0.0%	0.54
	60+	10;10	14,811	0.06	(0.03, 0.08)	<0.001	39.1%	0.04
Ascertainment of SEP	Prospective	1;1	2,404	0.07	(0.02, 0.11)	0.007	0.0%	0.54
	Retrospective	10;10	14,811	0.06	(0.03, 0.08)	<0.001	39.1%	0.04
Location	Europe	5;5	10,663	0.06	(0.04, 0.08)	<0.001	7.4%	0.37
	Other	6;6	6,552	0.07	(0.02, 0.11)	0.003	49.7%	0.03
Standing balance								
Age group (y)	<60	1;1	2,510	1.56	(0.34, 7.23)	0.57	78.0%	0.03
	60+	14;13	19,646	1.24	(1.00, 1.52)	0.05	45.6%	0.01
Ascertainment of SEP	Prospective	2;2	2,844	2.00	(0.90, 4.45)	0.09	44.2%	0.15
	Retrospective	13;12	19,312	1.20	(0.97, 1.48)	0.09	46.5%	0.01
Location	Europe	8;7	13,270	1.60	(1.18, 2.15)	0.002	41.8%	0.05
	Other	7;7	8,886	1.00	(0.80, 1.26)	1.00	25.2%	0.18

† Mean difference in standard deviation score of grip strength; Mean difference in walking speed (m/s); Mean difference in natural log transformation of chair rise time (ln(s)); Odds ratio of inability to balance for 5 s for standing balance comparing lowest versus highest SEP based on ridit scores.
‡ *p*-values from Cochran's *Q* statistic.
§ The regression coefficients for chair rise time can be multiplied by 100 to represent percentage change in time [60]
M: Male; F: Female.
Note: These models include estimates from studies for father's occupation if available, childhood economic environment if not and father's education if neither other measure of childhood SEP available.
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i.e. an 11% increased hazard of death for those who are most deprived in childhood compared to those who are least deprived. The assumption of a linear quartile change representing an SD change is confirmed by the ilSIRENTE study [78], which considered walking speed as a continuous measure and was not included in the pooled estimate for the meta-analysis [4]. It should also be noted that the impact of these effects on physical dependency, quality of life, medical and social care are likely to be far greater. For example, life expectancy in the UK for people living in the poorest neighbourhoods is seven years shorter than for people living in the richest neighbourhoods but the difference in disability-free life expectancy is even more marked at seventeen years [16]. Thus people in poorer areas die sooner and spend more of their shorter lives with a disability [16]. Analyses of US Civil War veterans suggest that recent declines in disability rates were a continuation of declines in both chronic disease and disability occurring over the past century due to improved nutrition, sanitation, and education [79] which is consistent with our finding of a role for SEP in explaining variation in physical capability levels. If future improvements in life expectancy are to be matched with compression of morbidity [19], then policy makers must tackle the underlying causes behind social inequalities across the life course as well as implementing effective interventions for current older people.

Conclusion

This systematic review provides evidence of modest associations between childhood SEP and physical capability levels in adulthood, although considerable heterogeneity between studies was observed. When considering methods of improving the physical capability levels of future populations of older adults, it is necessary to consider the long-term impact of childhood socioeconomic position and the role of socioeconomically graded risk factors in early life.

Supporting Information

Table S1 Characteristics of studies included in the review.
(DOC)

Appendix S1 Search strategy for systematic review of published literature on the association between childhood socioeconomic position and physical capability.
(DOC)

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Author Contributions

Conceived and designed the experiments: KB RC RMM DK YBS RH. Analyzed the data: KB RC SH TH HI SJ KN MO FR J. Spagnoli J. Starr BEA MVZ. Wrote the paper: KB RC. Literature review and data extraction: KB RC. Acquisition of data: KB RC RMM DK AAS BEA AB KC SC CC JC LC IJD PD SE JG AJG DG SH TH HI SJ KN MO AP FR BS J. Spagnoli J. Starr AS HS PT DW LJW MVZ YBS RH. Interpretation of results: YBS KB RC RH DK RMM. Critical revision and approval of the manuscript: KB RC RMM DK AAS BEA AB KC SC CC JC LC IJD PD SE JG AJG DG SH TH HI SJ KN MO AP FR BS J. Spagnoli J. Starr AS HS PT DW LJW MVZ YBS RH.

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