Title

Domain-specific physical activity and mental health: A meta-analysis.

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Abstract

Context: The mental health benefits of physical activity are well established. However, less is known about whether the relationship between physical activity and mental health is consistent across different life domains. It is important to understand how context may influence the relationship between physical activity and mental health so that interventions and policy guidelines can be tailored to maximise positive effects.

Evidence acqisition: In 2015, systematic searches of four databases identified 13,435 records, of which 98 studies met the inclusion criteria.

Evidence synthesis: Included studies were published between 1988 and 2015 and had a combined sample size of 648,726. Of the 98 studies included, 93 examined leisure-time physical activity, 14 examined work-related physical activity, 15 examined transport physical activity, 16 examined household physical activity, 3 examined school sport, and 3 examined physical education. Multi-level meta-analyses showed that leisure-time physical activity (r = .13) and transport physical activity (r = .13) both have a positive association with mental health. Leisure-time PA (r = -.11) and school sport (r = -.09) both have an inverse association with mental ill-health. However, physical activity is not consistently associated with lower mental ill-health across domains as work-related physical activity is positively associated with mental ill-health (r = .09). Household physical activity and participation in physical education had no relationship with mental health or mental ill-health.

Conclusions: The domain in which physical activity occurs influences the relationship between physical activity and mental health and should, therefore, be considered when developing interventions, treatment programs, and policy guidelines.

Context

Mental ill-health accounts for a substantial proportion of the burden of disease worldwide.[1-3] Individuals with mental ill-health may experience low self-esteem, struggle to maintain interpersonal relationships, and have a higher risk of communicable and non-communicable diseases than those not experiencing mental ill-health.[1,4] Mental health, however, is a positive state of well-being where individuals realize their potential, experience positive emotions, and are able to cope with stress, maintain interpersonal relationships, work productively, and contribute to their community.[5]

Systematic reviews have shown that physical activity (PA) is associated with greater mental health,[6] and a reduced risk of mental ill-health, specifically depression and anxiety.[7,8] However, many of the studies included in these reviews measured total weekly PA. Given that PA is defined as any muscular movement that expends energy, PA can take place during leisure-time, work, or school, as a method of transportation, or while carrying out household chores.[9] As the reasons for participation are likely to vary between these different PA domains (i.e., areas of life which present opportunities for PA), it is possible that the outcomes experienced are also different.[10,11]

A literature review that compared total PA (i.e., all PA undertaken in a given time regardless of life domain) to leisure-time PA reported that leisure-time PA was more consistently and strongly associated with reduced depression.[12] Further, a number of individual studies have shown that leisure-time PA has a stronger relationship with mental health and mental ill-health, compared to work-related PA, transport PA, and household PA.[13-15] In order to understand how to optimally use PA to promote mental health and prevent mental ill-health, an understanding of the relationships within specific PA domains is required. Therefore, the

primary purpose of this study was to synthesise study results and provide meta-analytic evidence of the relationships between domain-specific PA and mental health and mental ill-health. The secondary purpose was to conduct moderated meta-analyses to explore factors that may contribute to variation. The final purpose was to identify gaps in the literature regarding PA domains that have not been investigated extensively.

Evidence Acquisition

The methods detailed below were conducted in accordance with the 'Preferred Reporting Items for Systematic Reviews and Meta-Analysis' (PRISMA) statement.[16]

Inclusion and Exclusion Criteria

Studies eligible for this review met the following inclusion criteria: a) a quantitative assessment of PA within at least one specified domain (e.g., leisure-time, work, physical education, active commuting, or household or domestic duties), unless an experimental study was carried out within a specific domain then no domain specific measure of PA was required, b) a quantitative assessment of at least one mental health outcome variable (i.e., mental health, mental wellbeing, psychological wellbeing, subjective wellbeing, life satisfaction, positive affect, negative affect, depression, anxiety, stress, or psychological distress), c) a quantitative assessment of the relationship between PA in a specified domain and mental health, d) a cross sectional, longitudinal, or experimental design, and e) full text, peer reviewed journal articles.

With regards to the mental health related search terms, all studies measuring mental health, mental wellbeing, and psychological wellbeing were included.[17] Further, positive affect and

life satisfaction are two core components of mental wellbeing and were also included.[18] Mental ill-health is defined as a broad term encompassing mental health disorders and preclinical mental health problems.[19-22] Internalising disorders are the largest cluster of mental disorders within the DSM-V and are responsible for a large portion of the burden of disease attributable to mental ill-health.[2,23-25] Internalising disorders reflect the tendency to express mental distress inwards emotionally, and include unipolar depression and anxiety disorders.[23,26] As such, mental ill-health in this review refers to symptoms of internalising mental disorders (i.e., depression and anxiety) and mental health problems (i.e., psychological distress, stress, negative affect).

Studies were excluded if they: a) included participants from special populations (e.g., participants who were physically frail), b) only measured total PA or did not specify the domain in which PA was measured, c) measured sedentary behaviour but not levels of PA, d) measured mental health specifically in terms of a particular setting or circumstance (e.g., job strain), e) solely reported qualitative data, or f) were published in languages other than English.

Search Strategy

Systematic searches were conducted in February 2015 in four databases: Scopus, PubMed, PsychINFO, and SPORTDiscus. Searches involved keywords from three main groups, including physical activity terms, mental health-related terms, and domain specific terms. The search was not restricted by publication date or study design, but included exclusion terms to reduce the number of irrelevant records identified. The full search strategy can be found in Table S1. Search results were then exported into Endnote reference manager software and removed duplicates.

Study Selection

Two reviewers independently assessed the title and abstract of each study and records recommended for exclusion by both reviewers were excluded. The same two reviewers then independently screened the full text of the remaining studies recommending each for inclusion or exclusion. Discrepancies were resolved by discussion between the two reviewers, along with a third reviewer, until consensus was reached. Finally, the reference lists of all included studies were checked for any relevant articles not returned in the search results.

Data Extraction

A researcher extracted data from each article into a predefined data extraction form. Data items included: authors, year of publication, study design, sample (size, age, sex, and country), measures of PA and mental health or mental ill-health, method of data analysis, and statistical results. A second reviewer cross-checked the extracted data for accuracy and all discrepancies were discussed and resolved.

Statistical Analysis

Correlation effect sizes were either extracted, or calculated from the results of each individual study.[27,28] Next, internal consistency scores (e.g., Cronbach's α) were used to correct each correlation for attenuation.[29,30] When this information was missing, an internal consistency score reported in similar literature was used. If an internal consistency score was not obtainable, or the study used a single item measure, a conservative score of .70 was used.[31] Finally, because *r* becomes more skewed as the value moves away from zero, all *r* were

converted to Fisher's adjusted *Z* scale (z), which is almost normally distributed.[27,28] The variance (v) and standard error (SE) of each effct size were then calculated.[27]

Two random-effects meta-analyses (i.e., one for mental health and one for mental ill-health) were conducted in late 2015. In order to account for dependent effect sizes (i.e., multiple effect sizes within a single study), the metaSEM package in R, version 3.2.2, was used to conduct three-level meta-analyses using structural equation modelling, where multiple effect sizes (Level 2) are clustered within studies (Level 3).[32 33] The weighted average effect sizes (r) and 95% CIs have been reported for each. In line with Cohen's guideline for interpreting the strength of correlations (r), a correlation of .1 was interpreted as weak, .3 moderate, and .5 strong.[34]

The I^2 statistic indicates the percentage of the total variation in effect sizes that is due to genuine differences between the individual study results as opposed to chance.[35] However, as I^2 increases rapidly towards 100% as the number of participants within the primary studies increases, I^2 is interpreted as possible heterogeneity that may be relevant.[36] According to Cochrane's overlapping criteria, an I^2 statistic between 0% and 40 % may not be important, 30% to 60% may represent moderate heterogeneity, 50% to 90% may represent substantial heterogeneity, and >75% considerable heterogeneity.[37]

Next, mixed-effects meta-analyses were conducted as they extend the random-effects meta-analyses by including fixed and random components within the one model in order to test study characteristics as potential predictors.[33] Study characteristics tested as potential moderators included PA domain, the specific mental health outcomes, age, sex, study design,

type of PA measure, and risk of bias. Age was categorised as children (1-9 years), adolescents (10-19 years), adults (20-64 years), and older adults (65+ years).[38,39] For each mixed-effects meta-analysis the regression coefficient (β) is reported, demonstrating whether the moderator is a positive or negative predictor of the effect size. The R^2 which demonstrates the proportion of heterogeneity explained by the moderator variable is also reported.[32] The *p* value for an omnibus ANOVA test demonstrating whether the mixed-effects model was significantly different from the random-effects model is also shown in Table 1 and Table 2. When the mixed-effects meta-analysis was significantly different, the effect size and 95% CI within each sub-group were included.

Rosenthal's fail-safe *N* was calculated to indicate the number of unpublished studies with a mean effect of zero required to cause the meta-analysis effect to become non significant ($p > .05$).[40] A larger fail-safe *N*, relative to the number of included studies, suggests that unpublished studies not included in the review would be unlikely to overturn the effect reported.[40] In order to assess the risk of bias across studies, Egger's regression asymmetry tests were conducted on the two overall meta-analyses (i.e., mental health and mental-ill health). However, it was not appropriate to conduct Egger's tests for the meta-analyses on each PA domain as ≥10 studies are required to distinguish chance from real asymmetry.[37,41]

Risk of Bias of Individual Studies

Six criterion were adapted from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[42] and the Consolidated Standards of Reporting Trials (CONSORT) statement to assess risk of bias of individual studies.[43] The criteria used was similar to that used in previous meta-analyses.[44,45] Two reviewers independently assigned a 1 (present and explicitly explained) or a 0 (absent or inadequately described) to each included

study on each criterion: a) random selection of schools/and or participants (sampling procedures were appropriate and adequately described, including randomisation process for experimental studies), b) participant eligibility criteria stated and adequate description of study sample, c) valid assessment of PA participation including adherence to a PA program if no direct measure of PA was included, d) valid assessment of mental health or mental ill-health, e) covariates adjusted for in analyses relating to PA and mental health (e.g., sex and age), f) power calculation reported and the study was adequately powered to detect hypothesised relationships. Next, percentage agreement and Cohen's kappa coefficient[46] were calculated and discrepancies were discussed until 100% agreement was reached.

Evidence Synthesis

As shown in Figure 1, the literature search yielded 13,435 studies. Following title and abstract screening, 373 full-text articles were retrieved and reviewed. Ninety-eight studies met the inclusion criteria and at least one suitable effect size could be calculated for all but one study.[47]

Study Characteristics

Study characteristics are presented in Table S2. Publication dates ranged from 1988-2015, with 66% being published in the last 5 years. Studies were mostly observational (98%), as experimental studies predominantly conduct interventions in laboratory settings rather than a specific life domain. The observational studies were mostly cross-sectional (76%), the sample sizes ranged from 19 to 106,319, with a total sample size of 648,726, and the majority of studies (76%) sampled adults. The majority of studies measured leisure-time PA (95%) – 13% measured work-related PA, 14% measured transport PA, 15% measured household PA,

3% measured school sport, and 3% measured physical education. Table S3 shows the number of studies measuring each mental health variable within each PA domain by age. Finally, all studies in this review exclusively utilised self-report measures of PA such as reporting PA participation over the previous days, weeks, or months.

Effect Sizes, Heterogeneity, and Moderator Analyses

Figure 2 highlights the effect size and 95% CI for each PA domain for mental health and mental ill-health and full results of the moderated meta-analyses are presented in Table 1 and Table 2.

Physical activity has a weak negative association with mental ill-health (r = -.09, 95% CI = -.13, -.04, $p < .001$). Overall, PA domain significantly moderates the strength of the relationship between PA and mental ill-health ($p < .001$) and explains 46% of the variance. In comparison to leisure-time PA, school sport is not significantly different (β = -.04, $p >.05$), whereas work-related PA (β = .19, $p < .001$), transport PA (β = .07, $p < .05$), household PA (β = .11, $p < .001$), and physical education (β = .07, $p < .05$) are all positive predictors of the effect size.

Leisure-time PA has a weak inverse association with mental ill-health and large heterogeneity is evident. Table 1 shows that the outcome measured is a significant predictor of strength, accounting for 36% of the variance. This result is due to a stronger negative association between leisure-time PA and depression (r = -.16), compared to other mental ill-health measures (r = -.03 to -.09). School sport is also significantly associated with mental ill-health, however, the effect (r = -.09) is slightly smaller than leisure-time (r = -.11). In contrast, work-

related PA has a weak positive association with mental ill-health and age is a significant predictor (p = .03) as the association is larger among adults (r = .10) than adolescents (r = .01), but this only explains 13% of the variance.Transport PA, household PA, and physical education have no significant association with mental ill-health.

Overall, PA in the included studies has a weak positive association with mental health (r = .11, 95% CI = .07 to .17, p < .001). Physical activity domain does not significantly moderate the relationship between PA and mental health (p = .59), as work-related PA (β = -.03), household PA (β = -.03), school sport (β = -.03), and physical education (β = -.03) are all non-significant (p > .05) negative predictor coefficients, compared to leisure-time. Nevertheless, the effect sizes varied between domains.

Leisure-time PA has a weak positive association with mental health and the effect size is not significantly moderated by the mental health outcome, sex, age, study design, PA measure, or risk of bias. Transport PA also has a weak positive association with mental health, but the CI is much wider when compared to leisure-time PA. The purpose of the trip (e.g., walking to work, walking during leisure-time) is the only significant moderator (p = .01) and explains majority of the variation in effect sizes (R^2 = 76%). More specifically, active travel to and from work has a stronger relationship with mental health (r = .28) than active travel where the purpose was not identified or where all active trips were measured together (r = .05). While work-related PA is positively associated with mental health, heterogeinety is high and the relationship is not significant. Further, age is a significant moderator (p = .002) and explains 89% of the variance, as work-related PA is only positively associated with mental health in the one study examining adults >65 years (r = .37). Household PA, school sport, and physical education are not significantly associated with mental health.

Risk of Bias

Initial agreement between the two reviewers was 90% and the kappa coefficient ($\kappa = .81$) indicated strong agreement.[48] Upon discussion 100% agreement was achieved. Nineteen percent of studies have a high risk of bias and 59% have a moderate risk of bias, while only 18% have a low risk of bias. The complete results for risk of bias within studies are shown in Table S4. Non-significant Egger's test results for the mental health ($t = 1.6121$, $p = .11$) and mental ill-health meta-analyses ($t = 0.0925$, $p = .93$) revealed low asymmetry, suggesting low risk of bias across studies.

Discussion

The key message from this meta-analysis is that PA is not consistently associated with mental health or mental ill-health across different life domains. In fact, life domain significantly moderates the relationship between PA and mental ill-health. This is an important finding given the increased focus on lifestyle physical activity (e.g., standing desks and parking further from destinations to encourage active travel) in recent years and the existence of PA guidelines that encourage individuals to participate in PA in various domains.[49] While lifestyle PA outside leisure-time may improve people's physical health, such behaviours may not benefit mental health.[50] Promoting PA specifically during leisure-time, compared to other PA domains, may be most beneficial in terms of mental health promotion and the prevention of mental ill-health. However, it is also possible that individuals with poor mental health choose to participate in less leisure-time PA, whereas the same does not occur for other domains such as household PA. Age, sex, types of measurements, and study design explain little heterogeneity. As such, it is possible that other factors are causing some of the variation

between domains and within domains, and the results of the current review highlight the need to understand the source of this variation.

Evidence supports a number of psychosocial mechanisms that explain the effect of PA on mental health; however, there is little understanding as to whether these mechanisms play the same role in different PA domains.[22] For example, PA enhances self-efficacy and exposes individuals to challenges that offer opportunities to develop confidence and a sense of mastery.[51,52] Domains such as work-related PA and household PA may consist primarily of walking, and given the simplicity of that activity, PA in these domains appears likely to offer fewer opportunities to experience a sense of mastery than PA during leisure-time.[53] Alternatively, the social interaction hypothesis suggests that participating in PA with other people may influence mental health outcomes.[54] Transport PA may or may not be conducted with other people and so it is possible that social interaction explains some of the variance within this domain. The distraction hypothesis suggests that PA diverts individuals' attention from stressful life events which leads to improved mental wellbeing.[55] Perhaps, leisure-time PA provides a distraction from stress, but PA during domains such as work do not; indeed, work itself may be a source of stress.

Another potentially important factor is motivation. Leisure-time PA is often a chosen activity in which individuals are likely to participate due to enjoyment or perceived benefits.[56,57] Choosing to participate for enjoyment is central to autonomous motivation.[58] Alternatively, work-related PA is likely to be viewed as a compulsory task and may be enforced by another person or only carried out for the purpose of receiving an external reward (i.e., pay).[13] If an activity is undertaken due to such factors, motivation is controlled.[58] Self-determination theory posits that behaviours which are undertaken due to autonomous motivation are more

likely to be associated with the satisfaction of psychological needs (i.e., autonomy, competence, and relatedness), and that wellbeing is enhanced when an individual's psychological needs are satisfied.[59] As such, autonomously motivated behaviours are expected to yield more positive psychological outcomes than behaviours undertaken due to controlled motivation.[58,60,61] Further, evidence also shows that exercise involving choice is associated with increased positive affect and enjoyment, compared to exercise with no choice.[62-64]

Self-determined motivation may also explain some of the variation within each PA domain.[17] While transport PA is positively associated with mental health among adults, no such relationship was found for adolescents. It is possible that this finding reflects the mental health benefits experienced when adults personally choose to walk to work because it is enjoyable or important, while young people who are forced to walk to school do not experience the same benefit. Furthermore, Asztalos reported that transport PA was associated with increased stress among blue collar workers but not among white collar workers. [13] Financial factors may force some blue collar workers to bicycle to work (i.e., controlled motivation), while white collar workers may be more likely to own a car, yet autonomously choose to walk or ride due to health benefits or enjoyment. [13] However, the role of autonomous motivation in the relationship between PA and mental health has not yet been explored.

Increasing PA during work is not likely to be worthwhile in terms of reducing the prevalence of mental ill-health, as individuals with occupations that involve higher amounts of PA, such as blue collar jobs, are more likely to experience mental ill-health. This finding suggests that PA is not automatically associated with greater mental health and reduced mental ill-health,

and that contextual factors are crucial to such relationships. It is possible that work-related PA does not provide a distraction from stress or provide opportunities for improved self-esteem, thereby not improving mental health. However, it is also possible that people with poorer mental health have limited occupational opportunities and secure employment in lower paid physically active jobs. Interestingly, work-related PA was positively associated with mental health as well as mental ill-health. While this result is plausible given that mental health and mental ill-health are not always negatively correlated,[65] it demonstrates that work-related PA is associated with mental health for some people and mental ill-health for others. This finding highlights the need for more extensive investigations of work-related PA in order to determine when it may beneficial, as opposed to detrimental.

This review provides the first meta-analytic evidence of the relationships between PA undertaken in different life domains, and mental health and mental ill-health. Consequently, it provides the most comprehensive evidence showing that leisure-time PA is likely to be the an optimal domain to promote mental health and prevent mental ill-health. The number of studies and, therefore, the total combined sample size, are both strengths of this study, as is the range of outcomes included. Nevertheless, some limitations should also be noted. Firstly, 98% of the included studies were observational, the majority of which were cross-sectional. As cross sectional studies cannot infer causality, the study designs of the included studies are a limitation.[66] As such, well designed experimental studies are needed to improve understanding of the causal relationships in different domains. Secondly, all 98 studies in this review utilised self-report measures of PA. This is a limitation of the current review and highlights the need for objective measures of domain-specific PA. While objectively measuring PA within specific domains is challenging and costly, advancements in technology have made it increasingly possible as Global Positioning Systems and wearable cameras have been used to measure PA within specific life domains.[67-72]

The small number of studies included for work-related PA, transport PA, household PA, school sport, and physical education, in comparison to leisure-time, is also a limitation as a number of moderator analyses within these domains could not be conducted due to insufficient studies. Additionally, Sallis' guideline for interpreting systematic review results states that evidence is inconclusive if less than four studies are included.[73] While school sport was inversely associated with mental ill-health, only two studies were included. Furthermore, while no relationship between physical education and mental health or mental ill-health was identified, there is not enough evidence at this stage to conclude that physical education is not associated with mental health. This lack of evidence warrants further investigation of these two domains. Additionally, heterogeneity remained high in majority of the sub-group meta-analyses suggesting that variation in the effect sizes was not consistently due to age, sex, study design, measures used, or risk of bias. Not identifying the source of this variation is a limitation of the current study. As such, other factors (e.g., motivation and social interaction) need to be explored. Finally, studies included in this review measured the relationship between habitual PA and mental health. As it is possible that PA in some domains has an immediate effect on mood following exercise, despite not providing longer-term benefits, future studies need to explore acute effects of domain-specific PA.

Conclusion

Despite the well accepted relationship between PA and mental health, this review concludes that the relationship varies between different PA domains. Gaining knowledge of the specific factors that mediate or moderate these relationships could lead to the development of contextually tailored interventions and PA guidelines, and improve the effectiveness of PA as a prevention and treatment method. Nevertheless, the results of this meta-analyses indicate

that, compared to other PA domains, promoting PA during leisure-time is likely to be the most effective method of preventing mental ill-health.

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RLW led the design of the study, completed all searches, screening, and data collection, performed the statistical analyses, and led the writing of the manuscript. MB completed all screening of studies, cross-checked the data extraction, and helped draft the manuscript. PP participated in the statistical analyses and helped to draft the manuscript. DL was involved in the design of the study and helped draft the manuscript. TAB was involved in the design of the study and reviewed the manuscript. CL participated in the design of the study, was involved in the statistical analyses, and helped to draft the manuscript. All authors read and approved the final manuscript.

Table 1

Domain Specific PA and Mental ill-health Meta-Analyses and Moderator Analyses

	k	**Number of ES**	***r***	**95% CI**	I^2	**Fail-safe *N***	**Predictor coefficient *β***	**ANOVA *p* value**	R^2
Leisure-time PA	70	116	**-.11*** **	-.16, -.06	99.04%	7,717			
Outcome								.007	36%
Psychological distress	17	23	-.03	-.10, .04	99.50%		n/a		
Perceived stress	10	12	-.09	-.19, .01	98.33%		-.06		
Life dissatisfaction	1	1	-.09	-.27, .10	n/a		-.06		
Negative affect	8	13	-.08	-.08, .01	97.03%		-.04		
Depression	42	58	**-.16*** **	-.21, -.10	98.51%		**-.13*** **		
Anxiety	7	9	-.06	-.15, .02	96.11%		-.04		
Age								.08	11%
Sex								.13	6%
Study design								.34	0%
Type of PA measure								.46	13%
Risk of bias								.21	3%
Work-related PA	9	14	**.09** **	.03, .15	95.89%	79			
Outcome								.13	28%
Age								.03	13%
Adolescents	1	2	.01	-.15, .17	n/a		-.09		
Adults	8	12	.10	.04, .16	95.89%		n/a		
Sex								.55	15%
Type of PA measure								.13	69%
Risk of bias								.16	25%
Transport-related PA	7	15	-.02	-.05, .01	73.03%				
Outcome								.51	12%
Age								.59	9%
Sex								.42	3%
Purpose of trip								.51	47%
Type of PA measure								.99	5%
Risk of bias								.93	30%
Household PA	11	16	.02	-.04, .08	92.75%				
Outcome								.05	8%
Psychological distress	2	2	-.06	-.21, .09	92.93%		n/a		
Perceived stress	3	4	.01	-.10, .12	80.73%		.10		
Depression	8	10	.04	-.04, .12	83.53%		.12		
Age								.87	2%
Sex								.99	0%

Type of PA measure								.26	37%
Risk of bias								.65	11%
School sport	2	3	**-.09*** **	-.11, .-07	61.37%	26			
Outcome								.12	0%
Study design								.85	0%
Type of PA measure								1.0	0%
Risk of bias								.85	0%
Physical education	2	3	-.02	-.11, .08	97.70%				
Outcome								.002	100%
Negative affect	1	2	**-.08** **	-.14, -.03	n/a		n/a		
Depression	1	1	.05	-.09, .19	n/a		.14		
Type of PA measure								.09	100%
Risk of bias								.002	100%
Total score /6							.72		

Note: Bolface indicates statistical significance (*p<0.05, **p<0.01, ***p<0.001.
β, standardised regression coefficient; ES, effect sizes; I^2, I^2 statistic indicating proportion of variation due to heterogeneity; *k*, number of studies; PA, physical activity; *r*, correlation effect size; R^2, proportion of heterogeneity that can be explained by the moderator variable

Table 2

Domain Specific PA and Mental Health Meta-Analyses and Moderator Analyses

	k	**# ES**	***r***	**95% CI**	I^2	**Fail-safe *N***	**Predictor coefficient *β***	**ANOVA *p* value**	R^2
Leisure-time PA	33	58	**.13*** **	.08, .18	99.59%	1, 931			
Outcome								.46	16%
Age								.96	2%
Sex								.50	14%
Study design								.65	1%
Type of PA measure								.58	34%
Risk of bias								.94	
Work-related PA	5	6	.10	-.02, .22	89.13%				
Outcome								.10	67%
Age								.002	89%
Adults	3	3	.02	-.09, .12	76.50%		n/a		
Older adults	1	1	**.37*** **	.17, .54	n/a		**.36*** **		
Sex								.70	9%
Study design								.80	1%
Type of PA measure								.03	95%
Duration	1	1	-.03	-.12, .06	n/a		-.09		
Frequency	1	1	**.40*** **	.26, .54	n/a		**.34*** **		
MET-hr/week	4	4	**.06***	.01, .11	75.38%		n/a		
Risk of bias								.32	20%
Transport-related PA	7	11	**.13***	.02, .23	99.01%	37			
Outcome								.37	27%
Age								.44	21%
Sex								.70	10%
Purpose of trip								.01	76%
Not specified, or includes all travel	5	9	.05	-.02, .12	86.80%		n/a		
To work	2	2	**.28*** **	.19, .38	70.28%		**.24*** **		
Type of PA measure								.03	76%
Duration	1	1	**.48*** **	.28, .68	n/a		**.46*** **		
Frequency	1	1	**.27***	.04, .50	n/a		.25		
MET-hr/week	3	4	.02	-.09, .13	90.71%		n/n		
Binary	2	5	**.17***	.03, .30	99.53%		.15		
Risk of bias								.15	27%
Household PA	4	7	.04	-.02, .09	97.56%				
Outcome								.03	100%
Mental health	1	2	.00	.09, .17	n/a		n/a		

Mental wellbeing	2	4	.01	-.04, .06	98.62%	**-.12****		
Life satisfaction	1	1	-.01	-.06, .08	n/a	**-.14****		
Sex							.20	84%
Study design							.06	24%
Type of PA measure							.46	69%
Risk of bias							.25	5%
School sport	2	5	-.04	-.29, .23	99.78%			
Outcome							.36	15%
Sex							.13	55%
Study design							.36	15%
Physical education	2	10	.05	-.02, .13	96.27%			
Sex							1.0	0%
Type of PA measure							.77	2%

Note: Bolface indicates statistical significance (*p<0.05, **p<0.01, ***p<0.001).
β, standardised regression coefficient; ES, effect sizes; I^2, I^2 statistic indicating proportion of variation due to heterogeneity; *k*, number of studies; PA, physical activity; *r*, correlation effect size; R^2, proportion of heterogeneity that can be explained by the moderator variable

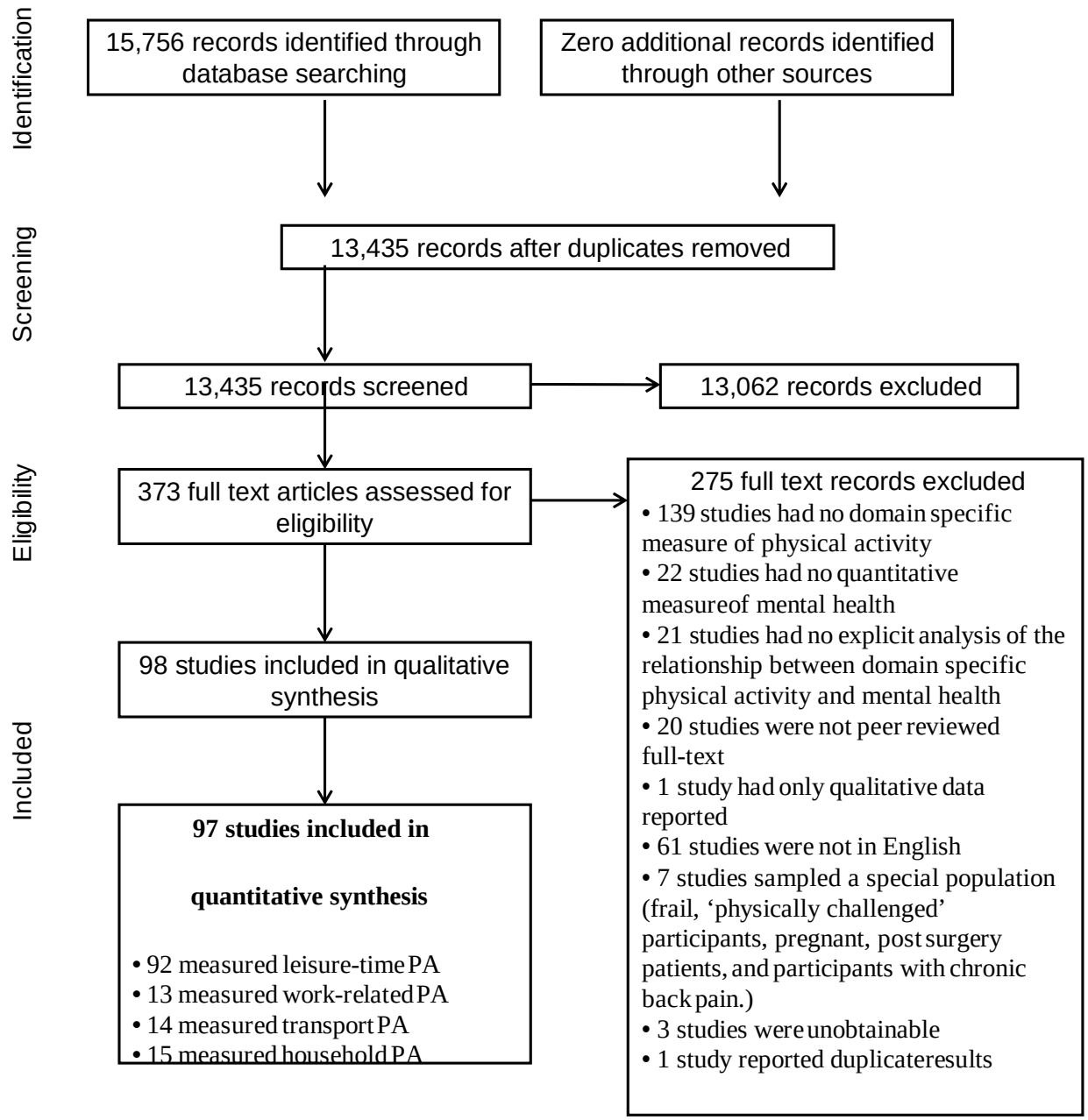

Figure 1. Flow diagram of articles throughout the systematic review. PA = physical activity.

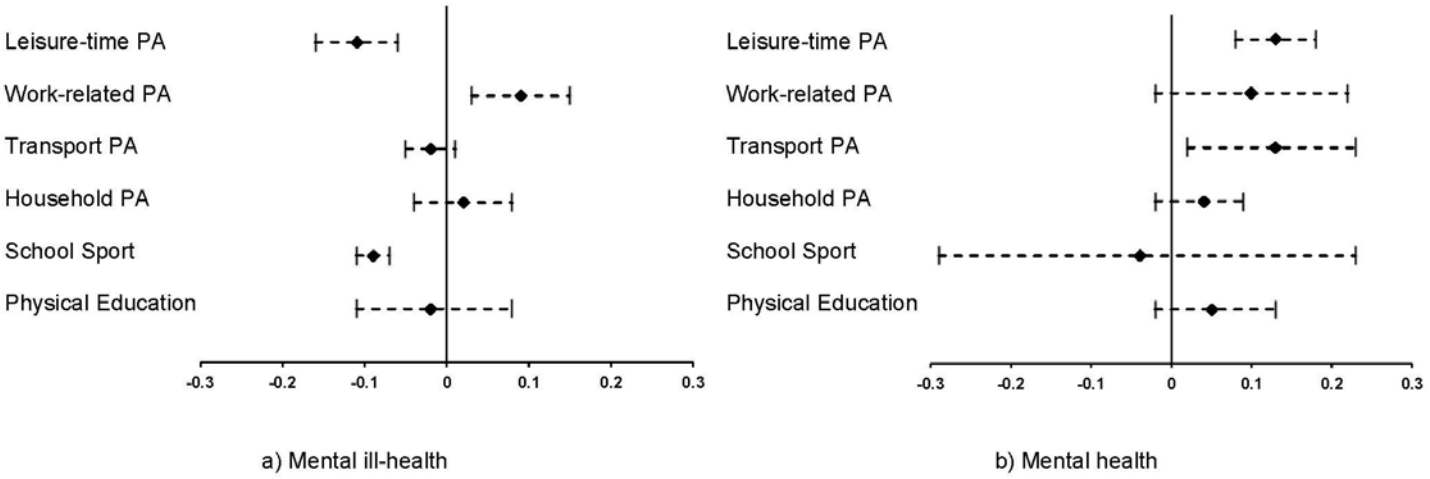

Figure 2. Correlation and 95% CI within specific PA domains for mental health and mental ill-health. PA = physical activity.

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Supplementary Text and Tables

Table S1.

Full list of search terms.

Physical Activity Keywords	Mental Health Keywords	Domain Specific Keywords		Excluded Terms		
"physical activit*"	"mental health"	domain*	domestic	Femur	Arousal	Ankle
"physical inactivity"	"mental well*being"	"types of"	housework	Patella	"heat stress"	Resistance
exercise	"psychological well*being"	"leisure time"	household	Knee	Ventricular	Rheumatology
sport*	"subjective well*being"	"leisure-time"	PE	Hip	"stress test*"	Lumbar
walking	"life satisfaction"	Sport*	P.E.	Lung	Renal	Gait
	"positive affect"	travel	"physical education"	Lactate	Heart	Rats
	"negative affect"	commut*	Occupation*	Contraction	Injur*	Metaboli*
	"mental illness"	transport*		Serum	Cardiovascular	Sclerosis
	"mental disorder*"	Transport-related		"Cartilage stress"	Diabetes	Stroke
	depress*	cycling		"Oxidative stress"	Trauma*	Dementia
	anxiety	walking		Cancer	Muscle	Biomechanics
	stress	work		Performance	Spin*	Ergonomics
	"psychological distress"	work-related		Horses	Arthritis	
				"Stress urinary incontinence"		

Full search extracted from Scopus

((TITLE-ABS-KEY (**commut***) OR TITLE-ABS-KEY (**"leisure time"**) OR TITLE-ABS-KEY (**"leisure-time"**) OR TITLE-ABS-KEY (**"types of"**) OR TITLE-ABS-KEY (**domain***) OR TITLE-ABS-KEY (**work**) OR TITLE-ABS-KEY (**occupation***) OR TITLE-ABS-KEY (**travel**) OR TITLE-ABS-KEY (**housework**) OR TITLE-ABS-KEY (**sport***) OR TITLE-ABS-KEY (**transport***) OR TITLE-ABS-KEY (**cycling**) OR TITLE-ABS-KEY (**domestic**) OR TITLE-ABS-KEY (**work-related**) OR TITLE-ABS-KEY (**transport-related**) OR TITLE-ABS-KEY (**pe**) OR TITLE-ABS-KEY (**p.e.**) OR TITLE-ABS-KEY (**"physical education"**) OR TITLE-ABS-KEY (**household**)) AND SUBJAREA (**mult** OR **medi** OR **nurs** OR **vete** OR **dent** OR **heal** OR **mult** OR **arts** OR **busi** OR **deci** OR **econ** OR **psyc** OR **soci**)) AND ((TITLE-ABS-KEY (**"mental health"**) OR TITLE-ABS-KEY (**"mental well*being"**) OR TITLE-ABS-KEY (**"psychological well*being"**) OR TITLE-ABS-KEY (**"subjective well*being"**) OR TITLE-ABS-KEY (**"life satisfaction"**) OR TITLE-ABS-KEY (**"positive affect"**) OR TITLE-ABS-KEY (**"negative affect"**) OR TITLE-ABS-KEY (**"mental illness"**) OR TITLE-ABS-KEY (**"mental disorder*"**) OR TITLE-ABS-KEY (**depress***) OR TITLE-ABS-KEY (**anxiety**) OR TITLE-ABS-KEY (**stress**) OR TITLE-ABS-KEY (**"psychological distress"**)) AND SUBJAREA (**mult** OR **medi** OR **nurs** OR **vete** OR **dent** OR **heal** OR **mult** OR **arts** OR **busi** OR **deci** OR **econ** OR **psyc** OR **soci**)) AND ((TITLE-ABS-KEY (**"physical activit*"**) OR TITLE-ABS-KEY (**"physical inactivity"**) OR TITLE-ABS-KEY (**exercise**) OR TITLE-ABS-KEY (**sport***) OR TITLE-ABS-KEY (**walking**)) AND SUBJAREA (**mult** OR **medi** OR **nurs** OR **vete** OR **dent** OR **heal** OR **mult** OR **arts** OR **busi** OR **deci** OR **econ** OR **psyc** OR **soci**)) AND NOT TITLE-ABS-KEY (**femur**) AND NOT TITLE-ABS-KEY (**patella**) AND NOT TITLE-ABS-KEY (**knee**) AND NOT TITLE-ABS-KEY (**hip**) AND NOT TITLE-ABS-KEY (**lung**) AND NOT TITLE-ABS-KEY (**lactate**) AND NOT TITLE-ABS-KEY (**contraction**) AND NOT TITLE-ABS-KEY (**serum**) AND NOT TITLE-ABS-KEY (**performance**) AND NOT TITLE-ABS-KEY (**"heat stress"**) AND NOT TITLE-ABS-KEY (**arousal**) AND NOT TITLE-ABS-KEY (**"stress urinary incontinence"**) AND NOT TITLE-ABS-KEY (**"cartilage stress"**) AND NOT TITLE-ABS-KEY (**renal**) AND NOT TITLE-ABS-KEY (**"oxidative stress"**) AND NOT TITLE-ABS-KEY (**"stress test*"**) AND NOT TITLE-ABS-KEY (**ventricular**) AND NOT TITLE-ABS-KEY (**heart**) AND NOT TITLE-ABS-KEY (**injur***) AND NOT TITLE-ABS-KEY (**diabetes**) AND NOT TITLE-ABS-KEY (**muscle**) AND NOT TITLE-ABS-KEY (**spine**) AND NOT TITLE-ABS-KEY (**arthritis**) AND NOT TITLE-ABS-KEY (**trauma***) AND NOT TITLE-ABS-KEY (**ankle**) AND NOT TITLE-ABS-KEY (**sclerosis**) AND NOT TITLE-ABS-KEY (**stroke**) AND NOT TITLE-ABS-KEY (**metaboli***) AND NOT TITLE-ABS-KEY (**dementia**) AND NOT TITLE-ABS-KEY (**biomechanics**) AND NOT TITLE-ABS-KEY (**ergonomics**) AND NOT TITLE-ABS-KEY (**resistance**) AND NOT TITLE-ABS-KEY (**rheumatology**) AND NOT TITLE-ABS-KEY (**lumbar**) AND NOT TITLE-ABS-KEY (**gait**) AND NOT TITLE-ABS-KEY)

Table S2.

Summary of studies included in the systematic review.

Author	Study Design	Country	Sample	Age (years)	Physical Activity Domain	Physical Activity Measure	Mental Health Measure
Aldana (1996)	Cross-sectional	United States	32,229 adults (57% female)	M = 37.3	Leisure time	1985 National Health Interview Survey	Strain Questionnaire
Armstrong (2004)	Experimental	Australia	19 adults (100% female)	Mo. = 30	Leisure time	n/a	Edinburgh Postnatal Depression Scale
Asztalos (2009)	Cross-sectional	Belgium	1,919 adults (47% female)	R = 20 - 65	Leisure time, Transport, Household	Flemish Physical Activity Computerized Questionnaire	GHQ12, Perceived Stress Scale
Balboa-Castillo, (2011)	Longitudinal	Spain	1,097 older aged (52% female)	M = 70.3 ± 5.6	Leisure time	Nurses' Health Study and the Health Professionals' Follow-up Study.	Spanish version of the SF-36
Barrington (2012)	Cross-sectional	United States	621 adults (57% female)	R = 18 - 65	Leisure time	Two items from the Godin Leisure-Time Exercise Questionniare, one item from the IPAQ	Perceived Stress Scale-10
Bernaards (2006)	Longitudinal	Netherlands	1,747 adults (sex not reported)	Not reported	Leisure time	Frequency of PA	Dutch Version of the CES-D
Bertheussen (2011)	Cross-sectional	Norway	4,500 middle and older aged adults (56% female)	M = 53.1 ± 15	Leisure time	The number of times the participant exercised last week.	SF-8 Health Survey
Binsinger (2006)	Longitudinal	France	1,791 adolescents (53% female)	M = 11.1 ± 0.5	Leisure time	Do you do an extra curricular sport? Hours per week?	State-Trait Anxiety Inventory
Birkeland (2009)	Longitudinal	Norway	924 adolescents (45% female)	R = 13 - 23	Leisure time	One item	Seven item inventory
Bogaert (2014)	Cross-sectional	Belgium	1,066 adults (68% female)	M = 40.3 ± 9.7	Leisure time, Work, Transport, Household	IPAQ	SF-36
Borges (2013)	Cross-sectional	Brazil	1,656 older aged (64% female)	R = 60+	Leisure time	IPAQ	Geriatric Depression Scale
Branco (2014)	Cross-sectional	Brazil	1,953 young adults (55% female)	R = 18 - 35	Leisure time	IPAQ	Mini International Neuropsychiatric Interview 5.0 (MINI)
Brooks (2014)	Cross-sectional	England	4,404 adolescents (sex not reported)	Year 7, 9, and 11	Leisure time	Frequency and duration of vigorous exercise undertaken during leisure-time.	From the Health Behaviour in School-Aged Children World Health Organisation study
Brunes (2013)	Cross-sectional	Norway	38,743 adults (56% female)	M = 51.2 (females) M = 55.1 (males)	Leisure time	Frequency, duration, and intensity of weekly leisure-time PA over last 12 months. Self-report job rated as sedentary, frequent walking, frequent lifting, or heavy manual labor.	Hospital Anxiety and Depression Scale
Brunes (2014)	Longitudinal	Norway	23,991 adults (53% female)	M = 51.2 (females) M = 55.1 (males)	Leisure time	Frequency, duration, and intensity of weekly leisure-time PA over last 12 months.	Hospital Anxiety and Depression Scale – Anxiety Subscale

Bűltmann (2002)	Longitudinal	Netherlands	7,208 adults (25% female)	R = 18 - 65	Leisure time	One item	GHQ12
Bustamante (2013)	Cross-sectional	United States	174 middle and older aged adults (74% female)	M = 65.97 ± 9.12	Leisure time, Household	40-item Community Healthy Activities Model Program for Seniors (CHAMPS) PA questionnaire	CES-D
Buttery (2014)	Cross-sectional	Germany	39,001 adults (56% female)	M = 48.1	Leisure time	One item	Health Related Quality of Life - 4, Self-reported depression diagnosis
Cerin (2009)	Longitudinal	Australia	2,194 adults (64% female)	M = 46.3 ± 12.0	Leisure time, Work, Transport, Household	IPAQ	SF-12
Chen (2012)	Cross-sectional	Taiwan	2,727 older aged (51% female)	R = 65+	Leisure time	Frequency and duration of sport.	10-item Chinese version of the CES-D
Chi (2015)	Longitudinal	Taiwan	2,630 middle and older aged adults (53% female)	R = 53+	Leisure time	Frequency, duration, and intensity of Leisure Time Physical Activity	CES-D
Choi (2008)	Cross-sectional	United States	188 adults (100% female)	M = 41 ± 10.96	Leisure time	IPAQ-Long Version	20-item Korean version of the CES-D
Craike (2010)	Cross-sectional	Australia	4,702 adults (100% female)	M = 34.6 ± 5.23	Leisure time	One item	"How difficult do you feel your life is at the moment?", Kessler Psychological Distress Scale
Desha (2007)	Cross-sectional	United States	727 adolescents (51% female)	M = 15.26	Leisure time	The Sport Involvement Index	Hovac's Children's Depression Inventory
Doerksen (2014)	Longitudinal	United Sates	33 adults (42% female)	R = 15+	Leisure time	Leisure Activity Scale	Satisfaction with Life Scale, Perceived Stress Scale, CES-D, Kuppens Affect Scale, State-Trait Anxiety Inventory
Dupuis (1995)	Cross-sectional	Canada	743 middle and older aged adults (58% female)	R = 55+	Leisure time	Frequency, duration, and intensity of participation in physically active leisure activities.	CES-D Bradburn Affect Scale
Eime (2014)	Cross-sectional	Australia	793 adults (100% female)	R = 18+	Leisure time	Duration of PA during previous week.	SF-36 , Life Satisfaction Score
Feuerhahn (2014)	Cross-sectional	Germany	126 adults (68% female)	M = 3778 ± 10.24	Leisure time	Exercise Diary	PANAS
Fisher (2004)	Experimental	United States	582 older aged adults (59% female)	R = 65+	Leisure time	3 items about neighborhood activity level.	SF-12
Fløtnes (2011)	Longitudinal	Norway	2,000 adolescents (52% female)	R = 13 - 19	Leisure time	Frequency, duration, and intensity of training, and type of activity.	Hopkins Symptom Check List-5 (SCL-5)
Giacobbi Jr (2007)	Cross-sectional	United States	59 young adults (37% female)	M = 21.56 ± 1.94	Leisure time	Leisure-time Exercise Questionnaire (LTEQ)	PANAS
Goldfield (2011)	Cross-sectional	United States	1,259 adolescents (59% female)	M = 14.8 ± 1.8	Leisure time	The Godin Leisure-Time Exercise Questionnaire	CDI, Multidimensional Anxiety Scale for Children (MASC-10)
Griffiths (2010)	Cross-sectional	United Kingdom	13,470 children (49% female)	M = 5.2	Leisure time	One item	Strengths and Difficulties Questionnaire (SDQ)
Hamer (2009)	Longitudinal	England	4,323 middle and older aged adults (52% female)	M = 63.4 ± 9.7	Leisure time	Frequency and intensity of physical activities during leisure time.	CES-D

Hamer (2009)	Cross-sectional	Scotland	19,842 adults (54% female)	M = 45.2 ± 15.5	Leisure time, Household	Frequency of participation in ≥20mins of leisure-time PA. Frequency and duration of household PA.	GHQ12
Herman (2015)	Cross-sectional	Canada	7,725 adolescents (49% female)	R = 12 - 17	Leisure time	Adaptation of Minnesota Leisure Time Physical Activity Questionnaire	"Would you say your mental health in general is excellent, very good, good, fair, or poor?"
Humphreys (2013)	Cross-sectional	United Kingdom	989 adults (68% female)	R = 16+	Leisure time, Work, Transport	Recent Physical Activity Questionnaire, 7 day travel to work recall	SF-8
Hyde (2011)	Cross-sectional	United States	190 young adults (66% female)	M = 19.3 ± 2.8	Leisure time	The Godin Leisure-Time Exercise Questionnaire	20 items measuring four components of affect
Im (2014)	Cross-sectional	United States	542 middle aged adults (100% female)	M = 49.04 ± 6.05	Leisure time, Work, Household	Kaiser Physical Activity Survey	Depression Index for Midlife Women
Inal (2007)	Cross-sectional	Instanbul	133 older aged adults (36% female)	M = 73.9 ± 8	Leisure time	Items addressing frequency and duration	Life Satisfaction Index
Iwasaki (2001)	Cross-sectional	Canada	17,626 (sex not reported)	R = 12+ years	Leisure time	Physically active leisure index	Mental Distress Scale and Depression Scale
Jewett (2014)	Longitudinal	Canada	853 young adults (54% female)	M = 20.4	School sport	One item	One item for mental health, one item for stress, Major Depression Inventory
Joseph (2014)	Cross-sectional	United States	590 young adults (48% female)	M = 20.4 ± 1.7	Leisure time	The Godin Leisure-Time Exercise Questionnaire	Satisfaction with Life Scale, Bradburn Affect Balance Scale
Jurakić (2010)	Cross-sectional	Croatia	989 adolescents and adults (51% female)	Not reported	Leisure time, Work, Transport, Household	IPAQ	SF-36
Kilpatrick (2013)	Cross-sectional	Australia	3,367 adults (72% female)	M = 46.2	Leisure time	IPAQ	Kessler Psychological Distress Scale
Kim (2014)	Cross-sectional	United States	1,708 middle and older aged adults (61% female)	M = 67.88 ± 11.17	Leisure time	4 items related to the frequency of participation	5 items were borrowed from an existing study for life satisfaction, the degree of experiencing 7 descriptive adjectives.
Korniloff (2012)	Cross-sectional	Finland	927 older aged adults (50% female)	R = 65 - 74	Leisure time	Frequency of physical activities in leisure-time at different ages.	BDI-21
Kremer (2014)	Cross-sectional	Australia	8,256 adolescents (52% female)	M = 11.5 ± 0.8	Leisure time, School sport, Physical education	Frequency of after school and weekend sport. The number of sports teams played on at school. Number of days per week attended physical education.	Short Mood and Feelings Questionnaire
Ku (2009)	Longitudinal	Taiwan	2,831 middle and older aged adults (46% female)	R = 50 - 89 (baseline)	Leisure time	"Do you usually engage in any type of leisure-time PA?"	10-item Chinese version of CES-D
Kull (2012)	Cross-sectional	Estonia	956 adults (100% female)	R = 18 - 50	Leisure time, Work, Transport	Global Physical Activity Questionnaire	BDI-21
Kwag (2011)	Cross-sectional	United States	163 older aged adults	M = 81.84 ±7.05	Household	Participation in lawn or yard work, gardening, or	Perceived Stress Scale

			(73% female)			heavy housework such as vacuuming.	Geriatric Depression Scale
Lee (2012)	Cross-sectional	United States	624 older aged adults (72% female)	M = 77.35	Leisure time, Household	Physical Activity Level	CES-D
Lin (2008)	Cross-sectional	United States	528 adults (46% female)	M = 45.4 ± 11.3	Leisure time, Work, , Household	3 day 24 hour recall	BDI-21
Lutz (2007)	Longitudinal	United States	203 adults (31% female)	M = 43.61 ± 9.79	Leisure time	Leisure-time Exercise Questionnaire	Percieved Stress Scale
Malabo (2007)	Cross-sectional	South Africa	293 adults (48% female)	M = 25.9 ± 4.20	Leisure time	The Physical Activity Index	Satisfaction with Life Scale, GHQ12, The Affectometer 2
Martins (2013)	Cross-sectional	Brazil	506 adults (100% male)	M = 29 ± 9.77	Leisure time, Transport	Baecke Questionnaire, Travel mode binary variable	Brazilian version of the GHQ-12
McKercher (2009)	Cross-sectional	Australia	1,995 young adults (52% female)	M = 31.4 ± 2.6 (females) M = 31.6 ± 2.6 (males)	Leisure time, Work	IPAQ	Composite International Diagnostic Interview
McKercher (2013)	Cross-sectional	Australia	1,995 adults (52% female)	M = 31.5 ± 2.6	Leisure time	IPAQ	DSM-IV Criteria for Major Depression
McKercher (2012)	Cross-sectional	Australia	6,070 adolescents (50% female)	R = 9 - 15	Transport, Physical education	Self-report duration and frequency of walking and cycling to and from school and physical education.	Negative Affect Scale of the Affect Balance Scale
Molarius (2009)	Cross-sectional	Sweden	34,645 adults (53% female)	R = 18 - 84	Leisure time	"How much do you exercise physically in your leisure time?"	One item: severity of anxiety or depression.
Moore (1999)	Cross-sectional	United States	146 middle and older aged adults (76% female)	M = 56.6 ± 6.6	Leisure time	Minnesota Leisure Time Physical Activity Questionnaire	BDI
Motl (2004)	Longitudinal	United States	4,594 adolescents (49% female)	M = 12.7 ± 0.4	Leisure time	“Do you get some regular physical activity outside of school?”	CES-D
Mouchacca (2013)	Longitudinal	Australia	1,382 adults (100% female)	M = 35.7 ± 7.7	Leisure time	IPAQ-Long Version	Perceived Stress Scale
Mouton (2000)	Cross-sectional	United States	210 older aged adults (61% female)	M = 72.12 ± 6.32	Leisure time	Minnesota Leisure Time Physical Activity Questionnaire	Geriatric Depression Scale
Mutrie (2007)	Cross-sectional	Scotland	1,742 adults (55% female)	Three age cohorts: approximately 24, 44, and 64	Leisure time, Work, Household	Amount and intensity of PA during leisure-time, work, and housework.	Hospital Anxiety and Depression Scale
Nakamura (2014)	Cross-sectional	Brazil	1,001 adults (58% female)	M = 46 ±17 (females) M = 43 ± 16 (males)	Leisure time	IPAQ-Long Version	SF-36
Ohta (2007)	Cross-sectional	Japan	670 adults (36% female)	R = 18 - 60 years	Leisure time, Transport	State the weekly hours of leisure-time exercise engaged in. Frequency and duration of walking and bicycling.	GHQ12
Pagán (2014)	Longitudinal	Germany	53,819 adults (sex not reported	R = 16+	Leisure time	"How often do you take part in active sports?"	“How satisfied are you with life, all things considered?”
Pasco(2011)	Cross-sectional	Australia	547 older aged adults (44% female)	R = 65 – 80	Leisure time	Subjects reported participation in habitual LT physical activity throughout the prior year.	The Structured Clinical Interview for DSM-IV Criteria for Major Depression Research

							Version, Non-patient edition
Pastor (2003)	Cross-sectional	Spain	1,038 adolescents (51% female)	M = 16.31 ± 0.92	Leisure time	Frequency of sport participation not at school.	Two items: Frequency of feeling nervous and depressed.
Pedisic (2015)	Cross-sectional	Croatia	1,163 young adults (62% female)	M = 21.5 ± 1.8	Leisure time, work, Transport, Household	IPAQ-Long Version	Satisfaction with Life Scale
Peeters (2014)	Cross-sectional	Australia	25,596 adults (100% female)	3 age cohorts: M = 27.6 ± 1.5 , M = 52.2 ± 1.5, M = 78.2 ± 1.5	Leisure time, Household	Modified version of the Active Australia Questionnaire	SF-36
Petronyte (2009)	Cross-sectional	20 European countries	106,319 adolescents (51% female)	R = 11 - 15	Leisure time	Amount of exercise during free time.	Health Behavior in School-aged Children symptom checklist.
Pickett (2012)	Cross-sectional	United Kingdom	164 adults (64% female)	M = 30	Leisure time	Leisure Time Exercise Questionnaire	BDI-II, PANAS
Purakom (2014)	Cross-sectional	Thailand	226 older aged adults (76% female)	M = 68.41 ± 6.42	Leisure time, Work, Transport	Global Physical Activity Questionnaire	Mental Health Indicator short version 2007 (TMHI-15)
Rocha (2012)	Cross-sectional	Brazil	3,597 adults (71% female)	R = 15+	Leisure time	Frequency and intensity of PA during last month.	Self-Reporting Questionnaire (SRQ-20)
Sabiston (2013)	Longitudinal	Canada	860 adolescents (54% female)	M = 12.7 ± 0.5 (baseline), M = 20.4 ± 0.7 (last cycle)	Leisure time	The number of organized sports teams involved in during the last year.	"A validated depressive symptom scale"
Sanchez-Villegas (2008)	Longitudinal	Spain	10,381 adults (sex not reported)	Not reported	Leisure time	Leisure Time Physical Activity questionnaire collecting information about 17 activities.	Self-reported physician diagnosis of depression, anxiety, or stress, or the use of antidepressants or tranquilizers.
Sanchez-Villegas (2012)	Longitudinal	Spain	4,206 adults (sex not reported)	Not reported	Leisure time	Leisure Time Physical Activity questionnaire collecting information about 17 activities.	Spanish version of the SF-3
Sasidharan (2006)	Cross-sectional	United States	774 middle and older aged adults (sex not reported)	R = 50+	Leisure time	How many hours a day did you spend walking?	Single item from the Satisfaction with Life Scale, single item from the adapted Daily Hassles Scale
Schnohr (2005)	Cross-sectional	Denmark	12,028 adults (54% female)	R = 20 - 79	Leisure time	Frequency and intensity of PA.	Do you feel stressed? How often do you feel stressed? How satisfied have you been with your life within the last year?
Serrano-Sanchez (2013)	Cross-sectional	Spain	246 older aged adults (100% male)	R = 65+	Leisure time	Frequency and duration of PA and sport club affiliation.	10-item CES-D
Sieverdes (2012)	Cross-sectional	United States	9,580 adults (100% male)	M = 48.9 ± 9.7	Leisure time	Type, frequency, and duration of leisure-time PA.	10-item CES-D
Stephens (1988)	Cross-sectional	Canada	23,791 adults (sex not reported)	R = 15+	Leisure time	Frequency and duration of leisure-time PA.	General Well-Being Schedule, CES-D, Bradburn's Affect Balance Scale, Health Opinion Survey
Surkan (2005)	Cross-sectional	United States	409 adults (59% female)	R = 18+	Leisure time	Non-work related physical activity in the past 30 days?	Two items from the Health Related Quality of Life Scale, a question

							about satisfaction with life
Tessier (2005)	Longitudinal	France	3,891 adults (58% female)	M = 51.8 ± 6.1	Leisure time	Modifiable Activity Questionnaire	SF-36
Teychenne (2008)	Cross-sectional	Australia	1,501 adults (100% female)	M = 42 R = 18 - 65	Leisure time, Work, Transport, Household	IPAQ	30-item GHQ
Teychenne (2010)	Cross-sectional	Australia	3,645 adults (100% female)	R = 18 - 45	Leisure time, Work, Transport, Household	IPAQ	CES-D
Teychenne (2014)	Cross-sectional	Australia	4,065 adults (100% female)	R = 18 - 45	Leisure time	IPAQ-Long Version	10 item CES-D
Thøgersen-Ntoumani (2005)	Cross-sectional	United Kingdom	312 adults (35% female)	M = 34.11 ± 8.07	Leisure time	Baecke Habitual Physical Activity Questionnaire	Satisfaction with Life Scale
Valois (2004)	Cross-sectional	United States	4,758 adolescents (53% female)	Grade 9 - 12 Students	Leisure time, Transport, School sport	One item for leisure-time, The number of sports teams played on at school. Frequency of physical education, Self-report minutes spent exercising during physical education.	Students' Life Satisfaction Scale
Vuillemin (2007)	Cross-sectional	France	5,654 adults (59% female)	M = 47.6 ± 6.5 (females), M = 25.1 ± 4.6 (males)	Leisure time	Modifiable Activity Questionnaire	SF-36
Wang (2011)	Longitudinal	Canada	17,276 adolescents and adults (52% female)	R = 12+	Leisure time	Modified version of the Minnesota Leisure Time Physical Activity Questionnaire	Composite International Diagnostic Interview - Short Form
Wendel-Vos (2004)	Longitudinal	Netherlands	1,871 adults (53% female)	M = 43.3 ± 9.3 (females), M = 44.1 ± 9.2 (males)	Leisure time	Duration of leisure-time PA.	Health Related Quality of Life
Winjndaele (2007)	Cross-sectional	Belgium	2,616 adults (45% female)	M = 47.8 ± 12.3 (females), M = 49.3 ± 13.0 (males)	Leisure time, Transport, Household	Flemish Physical Activity Computerized Questionnaire	Perceived Stress Scale
Yang (2012)	Longitudinal	Finland	935 adults (51% female)	M = 38.4 ± 5.06 (females) M = 37.9 ± 4.97 (males)	Leisure time	Frequency and intensity of PA.	Modified version of the BDI
Zullig (2011)	Cross-sectional	United States	245 adolescents (55% female)	Year 7 and 18	Physical education	Frequency of physical education attendance.	One item

Note: For brevity only the first author is listed.

BDI, Beck Depression Inventory; CES-D, Center for Epidemiological Studies Depression Scale; GHQ, General Health Questionnaire; IPAQ, International Physical Activity Questionnaire; M, mean; Mo, Mode; PA, physical activity; PANAS, Positive and Negative Affect Scale; R, range; SF, Short Form Health Survey

Table S3.

Mental health variables measured within each PA domain.

	Positive Mental Health				Mental ill-health					
	Mental Health	**Mental Wellbeing**	**Life Satisfaction**	**Positive Affect**	**Mental ill-health**	**Stress**	**Life Dissatisfaction**	**Negative Affect**	**Depression**	**Anxiety**
Leisure-time PA	**Older Adults** n = 3,798 (k = 3) **Adults** n =22,970 (k = 8) **Adolescents** n = 8,726 (k = 2)	**Adults** n = 36,478 (k = 6)	**Adults** n = 7.695 (k = 9) **Adolescents** n =62,981 (k = 3)	**Adults** n = 49,204 (k = 9)	**Adults** n = 151,278 (k = 13) **Adolescents** n = 108,989 (k = 3) **Children** n = 13,476 (k = 1)	**Adults** n = 57,700 (k = 10)	**Adults** n = 12,028 (k = 1)	**Adults** n = 47,496 (k = 8)	**Older Adults** n = 10,033 (k = 9) **Adults** n = 141,175 (k = 26) **Adolescents** n = 17,953 (k = 7)	**Adults** n = 64,214 (k = 5) Adolescents n = 3,050 (k = 2)
Work-related PA	**Older Adults** n = 226 (k = 1) **Adults** n =2,055 (k = 2)	**Adults** n = 3,183 (k = 2)	**Adults** n = 1,750 (k = 1)		**Adults** n = 506 (k = 1)				**Adults** n = 47,910 (k = 7) **Adolescents** n = 1,742 (k = 1)	**Adults** n = 38,743 (k = 1)
Transport PA	**Older Adults** n = 226 (k = 1) **Adults** n =2,055 (k = 2)	**Adults** n = 21,168 (k = 3)	**Adults** n = 1,750 (k = 1) **Adolescents** n = 4,758 (k = 1)		**Adults** n = 1,919 (k =1) Adolescents n = 670 (k = 1)	**Adults** n = 4,535 (k = 2)		**Adolescents** n = 6,070 (k = 1)	**Adults** n = 6,102 (k = 3)	
Household PA	**Adults** n = 2,055 (k = 2)	**Adults** n = 27,793 (k = 2)	**Adults** n = 1,750 (k = 1)		**Adults** n = 21,761 (k = 2)	**Older Adults** n = 163 (k = 1) **Adults** n = 4,535 (k = 2)			**Older Adults** n = 961 (k = 3) **Adults** n = 6,216 (k = 4) **Adolescents** n = 1,742 (k = 1)	
School Sport	**Adolescents** n = 853 (k = 1)		**Adolescents** n = 4,758 (k = 1)			**Adolescents** n = 853 (k = 1)			**Adolescents** n = 8,700 (k = 2)	
Physical Education			**Adolescents** n = 5,003 (k = 2)					**Adolescents** n = 6,070 (k = 1)	**Adolescents** n = 7,847 (k = 1)	

Note: Blank cells indicate that no study examined the relationship between that particular physical activity domain and mental health variable. PA, physical activity

1 Table S4.

2 *Risk of bias of included studies.*

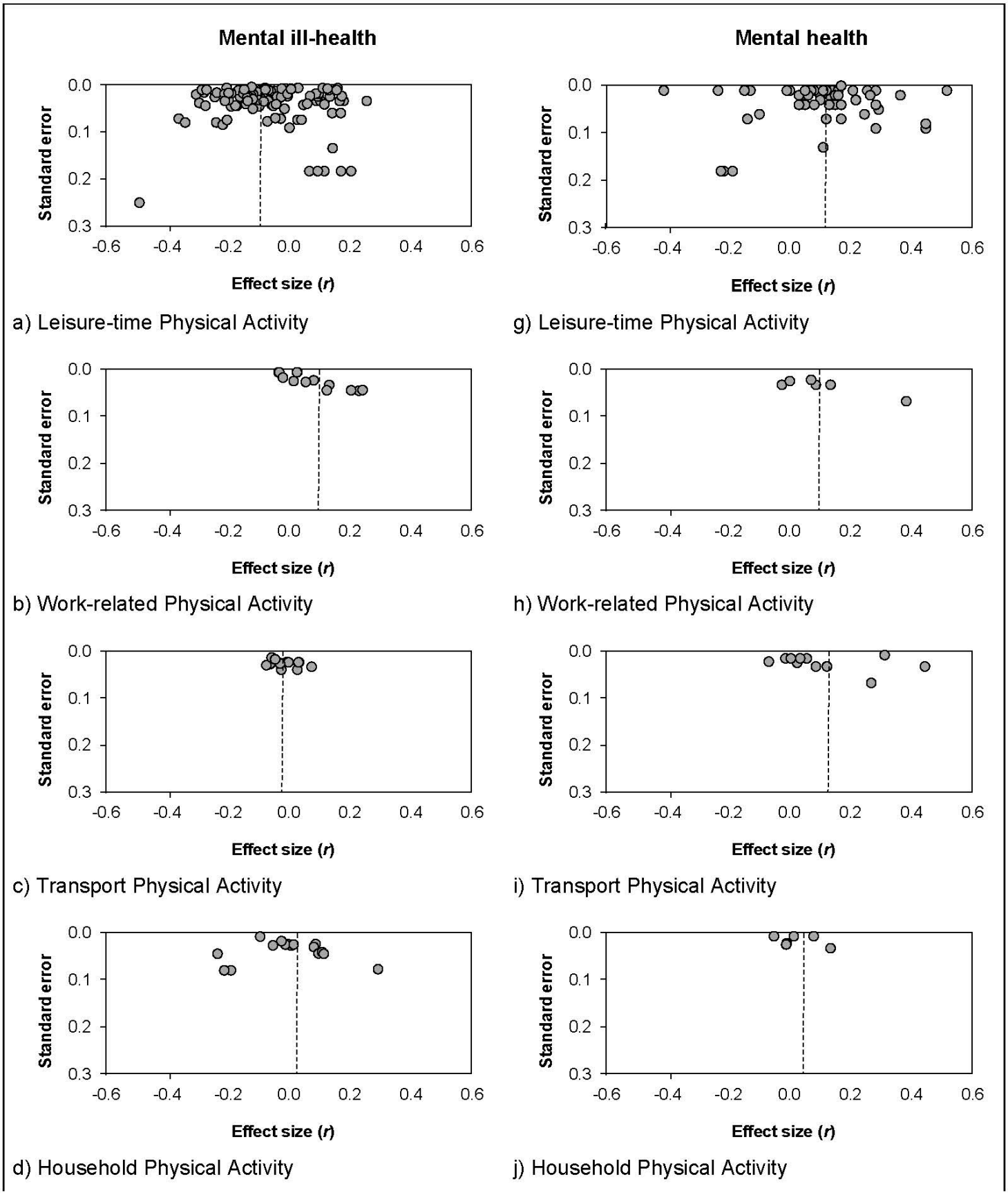
Author	Random selection of schools or participants	Eligibility criteria stated and study sample described	Valid assessment of physical activity	Valid assessment of mental health or mental ill-health	Covariates adjusted for in analyses	Power calculation reported and study adequately powered.	Risk of Bias Score /6
Aldana (1996)	0	1	0	1	1	0	3
Armstrong (2004)	1	0	1	1	0	1	4
Asztalos (2009)	1	1	1	1	1	0	5
Balboa-Castillo (2011)	1	1	1	1	1	0	5
Barrington (2012)	1	1	0	1	1	0	4
Bernaards (2006)	0	0	0	1	0	0	1
Bertheussen (2011)	1	1	1	1	1	0	5
Binsinger (2006)	0	1	0	1	0	0	2
Birkeland (2009)	0	1	1	1	1	0	4
Bogaert (2014)	1	1	1	1	1	0	5
Borges (2013)	0	0	1	1	1	0	3
Branco (2014)	1	1	1	1	1	0	5
Brooks (2014)	1	0	1	0	0	0	2
Brunes (2013)	0	1	1	1	1	0	4
Brunes (2014)	0	1	1	1	1	0	4
Bűltmann (2002)	0	1	0	1	1	0	3
Bustamante (2013)	0	1	1	1	0	0	3
Buttery (2014)	1	1	0	1	0	0	3
Cerin (2009)	1	1	1	1	1	0	5
Chen (2012)	0	1	1	1	1	0	4
Chi (2015)	0	1	0	1	0	0	2
Choi (2008)	0	1	1	1	1	0	4
Craike (2010)	1	1	0	1	1	0	4
Desha (2007)	0	1	0	1	1	0	3
Doerksen (2014)	0	0	0	1	0	0	1
Dupuis (1995)	0	1	0	1	0	0	2
Eime (2014)	0	1	0	1	1	1	4
Feuerhahn (2014)	0	1	0	1	1	0	3
Fisher (2004)	1	1	1	1	0	1	5
Fløtnes (2011)	0	1	1	1	1	0	4
Giacobbi Jr (2007)	0	1	1	1	0	0	3
Goldfield (2011)	0	1	1	1	1	0	4
Griffiths (2010)	0	1	0	1	1	0	3

Hamer (2009)	0	1	1	1	1	0	4
Hamer (2009)	1	1	1	1	1	0	5
Herman (2015)	0	1	0	0	1	0	2
Humphreys (2013)	0	1	1	1	1	0	4
Hyde (2011)	0	1	1	1	0	0	3
Im (2014)	0	1	1	1	0	1	4
Inal (2007)	0	1	0	1	0	0	2
Iwasaki (2001)	0	0	0	0	1	0	1
Jewett (2014)	0	1	0	1	1	0	3
Joseph (2014)	0	1	1	1	0	0	3
Jurakić (2010)	1	0	1	1	1	0	4
Kilpatrick (2013)	0	1	1	1	1	0	4
Kim (2014)	0	1	0	0	0	0	1
Korniloff (2012)	1	1	0	1	1	0	4
Kremer (2014)	1	1	1	1	1	0	5
Ku (2009)	1	1	0	1	1	0	4
Kull (2012)	1	1	1	1	0	0	4
Kwag (2011)	0	1	1	1	0	0	3
Lee (2012)	0	1	0	1	1	0	3
Lin (2008)	0	1	1	1	1	0	4
Lutz (2007)	0	1	1	1	1	0	4
Malabo (2007)	0	1	0	1	0	0	2
Martin (2014)	0	1	0	1	1	0	3
Martins (2013)	0	1	1	1	1	0	4
McKercher (2009)	0	1	1	1	1	0	4
McKercher (2013)	1	1	1	1	1	0	5
McKercher (2012)	1	1	0	1	1	0	4
Molarius (2009)	1	1	0	0	1	0	3
Moore (1999)	0	1	1	1	1	0	4
Motl (2004)	1	1	1	1	1	0	5
Mouchacca (2013)	1	1	1	1	1	0	5
Mouton (2000)	0	1	1	1	0	0	3
Mutrie (2007)	1	1	0	1	1	0	4
Nakamura (2014)	1	1	1	1	1	0	5
Ohta (2007)	0	1	1	1	1	0	4
Pagán (2014)	0	0	0	0	0	0	0
Pasco (2011)	1	1	1	1	0	0	4
Pastor (2003)	1	1	0	0	0	0	2
Pedisic (2015)	1	1	1	1	1	1	6
Peeters (2014)	1	1	1	1	1	1	6
Petronyte (2009)	0	1	0	1	1	0	3
Pickett (2012)	0	1	0	1	1	0	3
Purakom (2014)	0	1	1	1	1	0	4

Rocha (2012)	0	1	0	1	1	1	4
Sabiston (2013)	0	1	0	1	1	0	3
Sanchez-Villegas (2008)	0	0	1	0	1	0	2
Sanchez-Villegas (2012)	0	0	1	1	1	0	3
Sasidharan (2006)	0	0	0	0	0	0	0
Schnohr (2005)	1	1	0	0	1	0	3
Serrano-Sanchez (2013)	1	1	0	1	0	0	3
Sieverdes (2012)	0	1	1	1	1	0	4
Stephens (1988)	0	0	0	1	1	0	2
Surkan (2005)	0	1	0	0	1	0	2
Tessier (2005)	0	1	1	1	1	1	5
Teychenne (2008)	1	1	1	1	1	0	5
Teychenne (2010)	1	1	1	1	1	0	5
Teychenne (2014)	1	1	1	1	1	0	5
Thøgersen-Ntoumani (2005)	0	1	1	1	0	0	3
Valois (2004)	1	0	0	1	1	0	3
Vuillemin (2007)	1	1	0	1	1	0	4
Wang (2011)	1	1	0	1	1	0	4
Wendel-Vos (2004)	1	1	1	1	1	0	5
Winjndaele (2007)	1	1	1	1	0	0	4
Yang (2012)	1	1	1	1	1	0	5
Zullig (2011)	0	1	1	0	1	0	3

Note: For brevity only the first author is listed.

1, present and explicitly explained; 0, absent or inadequately discussed



a) Leisure-time Physical Activity

g) Leisure-time Physical Activity

b) Work-related Physical Activity

h) Work-related Physical Activity

c) Transport Physical Activity

i) Transport Physical Activity

d) Household Physical Activity

j) Household Physical Activity

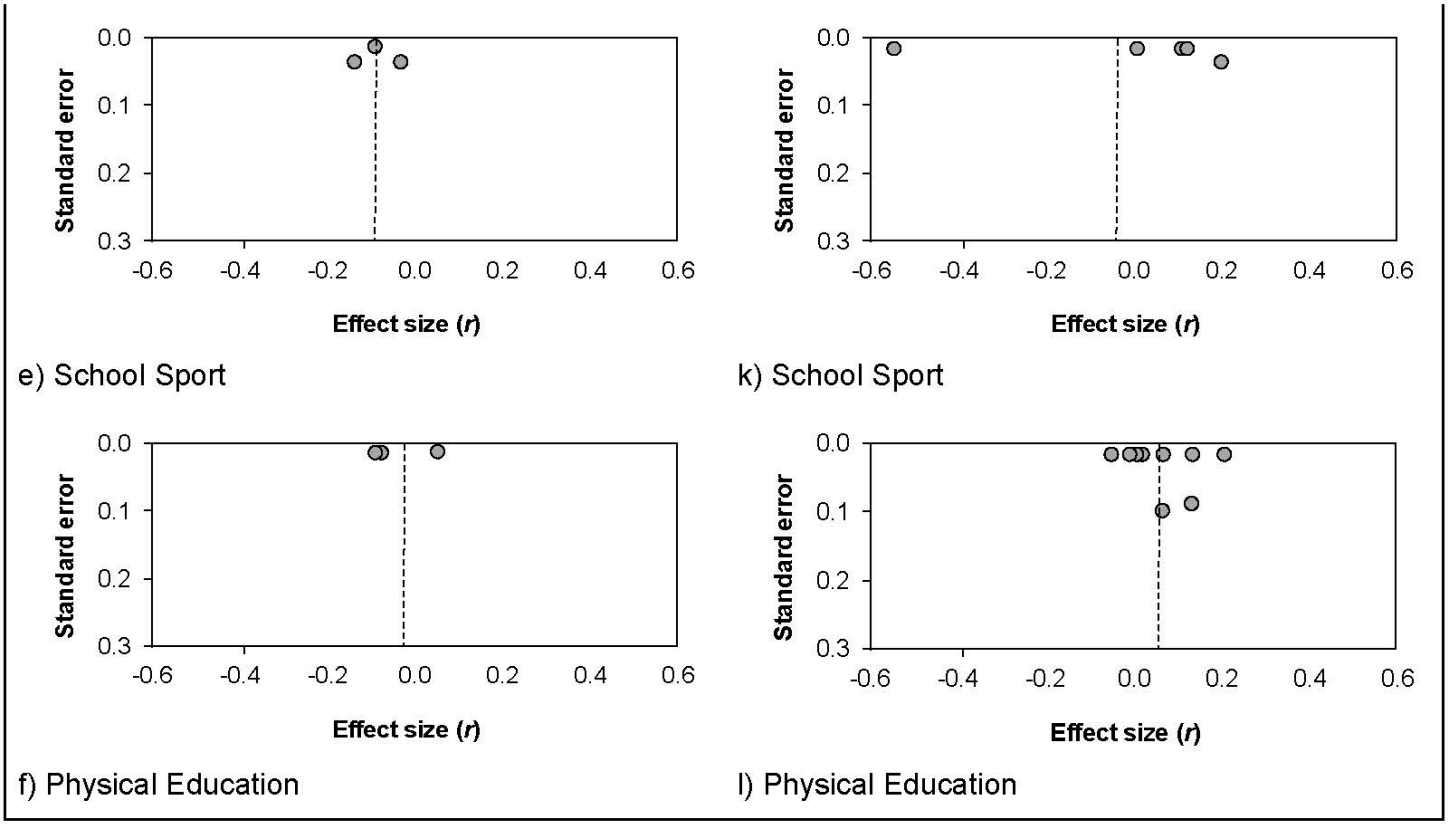


Figure S1. Individual study effect size estimates.