Physical Activity and the Prevention of Depression

A Systematic Review of Prospective Studies

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Context: Given its high prevalence and impact on quality of life, more research is needed in identifying factors that may prevent depression. This review examined whether physical activity (PA) is protective against the onset of depression.

Evidence acquisition: A comprehensive search was conducted up until December 2012 in the following databases: MEDLINE, Embase, PubMed, PsycINFO, SPORTDiscus, and Cochrane Database of Systematic Reviews. Data were analyzed between July 2012 and February 2013. Articles were chosen for the review if the study used a prospective-based, longitudinal design and examined relationships between PA and depression over at least two time intervals. A formal quality assessment for each study also was conducted independently by the two reviewers.

Evidence synthesis: The initial search yielded a total of 6363 citations. After a thorough selection process, 30 studies were included for analyses. Among these, 25 studies demonstrated that baseline PA was negatively associated with a risk of subsequent depression. The majority of these studies were of high methodologic quality, providing consistent evidence that PA may prevent future depression. There is promising evidence that any level of PA, including low levels (e.g., walking <150 minutes/weeks), can prevent future depression.

Conclusions: From a population health perspective, promoting PA may serve as a valuable mental health promotion strategy in reducing the risk of developing depression.
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Context

The WHO has predicted that depression will make one of the greatest contributions to overall global disease burden by the year 2020.[1] This prediction is alarming when considering depression's severity in causing disability.[2] Depression is commonly associated with high morbidity and mortality rates, via increased risk of suicide and major implications to brain and somatic functioning.[3–5] Fortunately, the realm of physical activity (PA) shows promising evidence that PA can treat depression which could avoid the physiologic side effects and costs associated with prescribed antidepressants.[6–9] However, with the high prevalence of depression worldwide and its burden on well-being and the healthcare system, intuitively, it would make more sense from a population health perspective to shift focus toward preventing the onset of depression.

However, in terms of evidence, this focus is narrowed, possibly due to the rigorous study designs required. For example, prospective studies that involve large cohorts and measure levels of PA and depression at two or more time periods are needed. Much of the research designs investigating this relationship have entailed cross-sectional methodologies.[10] These designs limit causal inferences regarding the temporal relationship between PA and depression.

In contrast, longitudinal studies have the potential to offer additional insights by uncovering the direction of relationships. This was one of Bradford Hill's[11] main criteria for judging if a causal link exists between two variables. Specifically, Hill explained that prospective-based studies have the strength to examine the temporal sequence between two variables, which may explain whether baseline levels of PA contribute to the primary prevention of depression at follow-up. Assessing prospective evidence is then important in making a stronger

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case for a causal link between PA and depression. Thus, from a public health and research perspective, it is of great importance to systematically review prospective studies that examine the protective influence PA has on depression.

The last review to examine a preventive relationship between PA and depression was conducted in 2008.[10] Although this review included broader observational (cross-sectional and longitudinal) and interventional (non-RCT and RCT) studies, they concluded based on 13 longitudinal studies that even relatively low doses of PA may protect against depression. Extending the review of Teychenne and colleagues,[10] the overall goal of the current review was to provide an update with a more explicit focus on longitudinal studies while additionally providing study quality assessments. Specifically, the primary objective of this review was to determine if baseline PA levels (i.e., aerobic PA) can prevent follow-up depression. A secondary objective was to examine the dose of PA needed to protect against depression. In addition, a related objective was to examine whether fluctuating levels of PA over time can affect the risk of subsequent depression.

In examining studies of the longitudinal association between PA and depression, it is inevitable to come across a range of criteria for assessing depression and variations in terminology that describe outcomes, such as clinical depression, a major depressive episode, or depressive symptoms. For the purpose of this review, the term "depression" is used for consistency to denote studies where (1) a cut-off score on a self-report measure has been used to assess for depressive symptoms with the assumption that being over the threshold may be more indicative of depression; or (2) depression has been ascertained through more-direct measures, such as a physician diagnosis. Collectively, this allows for interpretation to be potentially more clinically meaningful in contrast to the use of continuous measures, with which significant relationships may be better defined as a transitory negative affect.[12]

Evidence Acquisition

To conduct this systematic review, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[13] were followed to ensure that methodologic steps were addressed in completing a comprehensive search.

Peer Review Literature Search Strategy

To find studies examining the prospective relationship between PA and depression, the following databases were searched with assistance by two professional librarians for English-language, original research articles published in peer-review journals from January 1976 to December 2012: Medline, Embase, PubMed, PsycINFO, SPORTDiscus, and Cochrane. Reference lists of relevant studies and literature reviews were further examined, as well as links to "related articles" in electronic databases. Table 1 provides a detailed outline of the terms used in the current comprehensive search.

Table 1. Outline of search terms used for systematic review regarding physical activity and depression

Concept	MeSH terms	Other terms
Physical activity	Physical activity Exercise Physical fitness Sports Leisure activities	Walk* Run* Physical inactive* Habitual
Depression	Depression Depressive disorders Major depressive disorders	Mild dep* Moderate dep* Severe dep* Major dep*
Study design	Longitudinal studies Follow-up studies Prospective studies Cohort studies	
Association	Association Risk factors	Protect* Prevent* Relation* Causal* Onset

Note: MeSH is the U.S. National Library of Medicine's controlled vocabulary used for indexing articles for MEDLINE/PubMed. MeSH terminology provides a consistent way to retrieve information that may use different terminology for the same concepts.
*Denotes that the search term will look for any word with the given letter combination plus any combination of letters following the original combination.
MeSH, medical subject heading search terms

Inclusion/Exclusion Criteria

Articles were chosen for the systematic review if the studies met the following inclusion criteria: (1) employed a prospective-based, longitudinal design; (2) examined relationships between PA and depression over at least two time intervals; (3) identified PA as the exposure variable and depression as the outcome variable; (4) defined depression using depression threshold cut-off scores on self-report scales or using more-direct measures of depression such as a physician's diagnosis or hospital discharge records. Studies were excluded from analysis if they (1) were cross-sectional or experimental; (2) were not specific to depression; (3) did not assign a cut-off criteria to assess categoric depression; or (4) included depressed individuals at baseline.

Selection Process/Data Extraction

Initially, all titles and abstracts retrieved through the search engines were scanned, in order to identify articles relevant to the review. Potential articles were then appraised based on the eligibility criteria. The following characteristics were extracted from each study: (1) study design (i.e., author, geographic location,

age, gender, follow-up period, sample size, measurement of PA and depression including reported depression cut-off scores, and statistical analysis); (2) study findings (i.e., odds of developing depression, changes in PA and relationship to depression, covariates accounted for). Appendixes A and B (available online at www.ajpmonline.org) provide study details for all included articles.

Data Analysis

A formal quality assessment for each study was conducted independently using the Critical Appraisal Skills Programme (CASP)[14] for prospective studies. This protocol has been utilized by other systematic reviews examining similar longitudinal relationships.[15] The CASP appraises both internal and external validity by addressing four methodologic issues: (1) selection bias; (2) PA measurement bias; (3) depression measure bias; and (4) accounted confounding variables. Each issue was assessed and assigned a score based on the scoring system described by Barnett et al.[15] The assigned scores were tallied, giving each study a composite score ranging from 0 to 4, with each score representing a quality level: 0 or 1, low; 2, modest; and 3 or 4, high (Table 2). A harvest plot was used to concurrently quantify the number of studies finding a protective role of PA on depression, and to visually capture the study quality and sample size of each preventive and null finding (Figure 2). Data were analyzed between July 2012 and February 2013.

Evidence Synthesis

Study Identification and Selection

The initial search yielded a total of 6363 citations: 2111 in Embase, 1762 in MEDLINE, 1004 in PubMed, 693 in Cochrane, 684 in PsycINFO, and 109 in SPORTDiscus. All abstracts were screened, and 90 studies were found to be potentially eligible for inclusion. After a thorough selection process (Figure 1), 30 studies were included for analyses. A total of 60 studies were excluded (experimental or cross-sectional in design [n=17]; not specific to depression [n=12]; had no cut-off criteria score to assess depression [n=20]; were review articles [n=7]; did not exclude individuals with depression at baseline [n=4]).

Study Characteristics

All studies comprised nonclinical community samples of women/girls and/or men/boys ranging in age from 11 years to 100 years. Twenty studies examined associations for both genders; five were female only; four were male only. The majority of studies were conducted in North America (n=14) and Europe (n=13). The follow-up period was 1–27 years. Relative to those using subjective PA measures of aerobic activity, only one study objectively measured PA via ergometer cycling.[16] The majority of studies assessed depression through well-validated measures such as the Center for Epidemiologic Studies Depression Scale (CESD); several other studies used DSM-IV. Six studies measured depression more directly, via physician diagnosis (n=3); hospital discharge register (n=2); or use of antidepressants (n=1).

Number of Preventive Findings

A total of 25 of the 30 studies found a significant, inverse relationship between baseline PA and follow-up depression (Figure 2), suggesting that PA is preventive in the onset of depression.[16–23,25–29,31–34,36,37,39–43,45] Only five[24,30,35,38,44] of the included studies found no relationship between PA and subsequent depression, and four[23,25,34,43] studies found that women, and not men, who participated in PA were less likely to report depression at follow-up. Among the studies that found a protective role, the majority were considered to be of modest (n=6) or high (n=17) methodologic quality. In contrast, three studies that revealed null effects were of modest quality, with an additional study being categorized as low and high quality.

Amount of Physical Activity Required to Prevent Depression

Of the 30 studies included in this review, seven studies,[19,21,29,34,37,40,45] five of which are of high quality, measured PA in terms of minutes per week. Using binomial analysis, the investigations revealed that engaging in <150 minutes/week and >150 minutes/week were associated with a 8%–63%[19,21,29] and 19%–27%[19,21,37] decreased risk of future depression, respectively. The following high-quality studies revealed that being physically active for >240 minutes/week[21,29] and 420 minutes/week[45] also were protective against subsequent depression.

Two other studies[33,42] with high methodologic quality examined the daily amount of PA and its association to future depression. Lucas and colleagues[33] found that as little as 10–29 minutes (RR=0.90) of daily PA was preventive in the onset of depression. Their results additionally indicated that higher levels of daily PA (60–90 minutes/day, RR=0.84; >90 minutes/day, RR=0.80) were significantly associated with decreased risk of developing depression. Van Gool et al.'s[42] findings also demonstrated that engaging in PA for >30 minutes/day reduced the odds of subsequent depression by 48%.

Four studies[29,33,39,45] provided sufficient information regarding the relationship between walking and depression. All but one of these studies[45] indicated that walking was protective against future depression. Two high-quality studies[29,39] found that even "low" walking levels

Table 2. Study quality assessments of prospective studies examining physical activity and depression

Study	Selection bias	Measurement bias: Physical activity measure	Measurement bias: Depression measure	Confounding variables	Overall (0–4)[a]
Aberg (2012)[16]	N	N	N	Y	3
Augestad (2008)[17]	Y	N	N	N	3
Backmand (2003)[18]	Y	Y	N	N	2
Ball (2009)[19]	N	N	N	N	4
Bernaards (2006)[20]	Y	Y	N	Y	1
Brown (2005)[21]	N	N	N	N	4
Camacho (1991)[22]	N	Y	N	N	3
Carroll (2010)[23]	N	Y	N	N	3
Cooper-Patrick (1997)[24]	Y	N	Y	Y	1
Farmer (1988)[25]	N	Y	N	Y	2
Galligos-Corrillo (2012)[26]	N	N	N	N	4
Hamer (2009)[27]	N	N	N	N	4
Jerstad (2010)[28]	Y	N	N	Y	2
Jonsdottie (2010)[29]	N	N	N	Y	3
Kritz-Silverstein (2001)[30]	Y	N	N	N	3
Ku (2009)[31]	N	Y	N	N	3
Lampinen (2000)[32]	N	Y	N	Y	2
Lucas (2011)[33]	N	N	N	N	4
Mickkelsen (2010)[34]	N	Y	N	N	3
Mobily (1996)[35]	Y	Y	N	N	2
Morgan (1998)[36]	N	Y	N	N	3
Paffenbarger (1994)[37]	Y	Y	N	Y	1
Rothon (2010)[38]	N	Y	N	Y	2
Smith (2010)[39]	Y	N	N	N	3
Strawbridge (2002)[40]	N	Y	Y	N	2
Sund (2011)[41]	N	Y	N	Y	2
Van Gool (2006)[42]	N	Y	N	N	3
Wang (2011)[43]	N	Y	N	N	3
Weyerer (1992)[44]	N	Y	N	Y	2
Wise (2006)[45]	Y	N	N	N	3

[a]0 and 1 indicate low quality; 2 indicates modest quality; 3 and 4 indicate high quality.
N, no; Y, yes

were associated with a decreased risk of depression of up to nearly 60%. Another high-quality study[33] concluded that even walking at an average pace of <20 minutes/day and >40 minutes/day was protective against depression of up to 6% and 17%, respectively. In another context of PA dosage, one high-quality study[31] showed that being physically active less than twice per week was associated with an increased risk (OR=1.34) of developing depression. However, two other studies of low[20] and high[27] quality revealed that being active one to two times/week or more than once per week was associated with a decreased risk of depression of up to 40%.

Increasing/Decreasing Physical Activity Over Time and Risk of Depression

Eleven[19,21–23,27,31,32,38,42,43,45] of the 30 studies in this review provided information examining the change in PA levels over time and its association with depression. Only two of these studies, of low[38] and high quality,[31] showed no significant associations between changes in PA and depression. Four high-quality studies[22,23,27,45] concluded that reducing PA over time increases the risk of developing depression relative to remaining active or increasing activity levels. One study of modest methodologic quality[32] found a large effect, noting that individuals who reduced PA over time were more than ten times more likely to develop depression. Conversely, three high-quality studies[19,21,45] revealed that subjects who increased PA over time were at a reduced risk of subsequent depression, and two high-quality studies[42,45] showed that subjects who maintained their levels of PA were at a lower risk of depression relative to those who were inactive throughout.

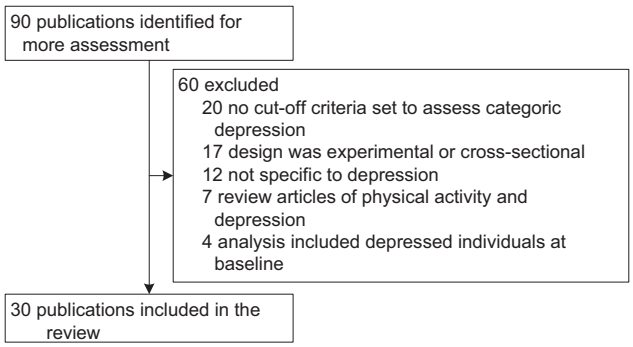

Figure 1. Flow diagram of selected studies

Discussion

The primary objective of this review was to determine if PA (i.e., aerobic PA) can prevent future depression. Promising scientific evidence (25 of 30 studies) demonstrates that baseline PA is negatively associated with a risk of subsequent depression. The majority of these studies were of high methodologic quality, providing a solid indication that PA may prevent future depression. A few studies in the review concluded that the protective effect of PA on depression is specific to women and girls.[23,25,34,43] These studies postulate that psychological factors may explain these findings because women may benefit more from the social aspects of PA than men.[46,47] This lends support to the findings in the Wang et al. study,[43] which showed that decreased activity levels were found to be associated with subsequent depression for divorced women.

Although many of the prospective studies suggest that PA may prevent future depression, five of the 30 studies revealed null findings,[24,30,35,38,44] although only one was considered to be of high quality.[30] Two[30,35] of these five focused their investigation among older adults. The lack of findings within this subgroup may reflect their age and lower levels of depression reported in relation to other cohorts.[48,49] Additionally, four of the five studies measured only the frequency of PA and not other components of PA, such as intensity. For example, studies reported by Weyerer et al.[44] and Mobily et al.[35] measured only the frequency of the participants' walking habits; Kritz-Silverstein et al.[30] dichotomously (i.e., yes/no) measured if participants engaged in strenuous exercise; and Cooper-Patrick et al.[24] assessed the frequency of exercising to a sweat. Thus, the resulting lack of precision in estimating PA dosage might explain the null finding in these studies. Reflecting the low to modest quality scores, a few of the studies that revealed null effects also failed to control for significant covariates that would yield nonsignificant relationships between PA and depression. For instance, three studies did not account for the covariates of BMI[24,38] and SES[24,30] in their statistical analysis, both of which have been found to be linked with depression.[50,51] Some studies possessed methodologic flaws that also would limit significant findings, such as weakness in power because of small sample size[24,30] and less than optimal measures of depression[38] compared to the high psychometric properties of the CESD and DSM-IV.

The secondary objective of this review was to examine the amount of PA required to prevent depression. In relation to current PA guidelines for adults, set by the Canadian Society for Exercise Psychology (CSEP; 150 minutes of moderate–vigorous PA per week), three high-quality studies[19,21,29] that measured PA in terms of minutes per week found that engaging in less than this amount was associated with a decreased risk of developing depression. For example, Jonsdottie and colleagues[29] reported that subjects engaging in PA (e.g., gardening/walking) for 120 minutes week were at a 63% reduced risk of developing future depression relative to those who were sedentary. Although the other two studies[19,21] found a smaller effect, it is still promising from a public health

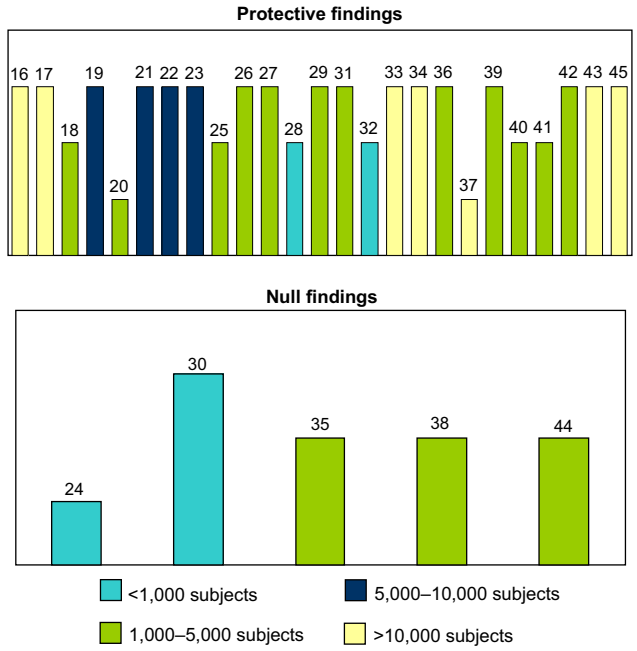

Figure 2. Harvest plot of the protective role physical activity has on depression

Note: Study quality scores are reflected by the height of the bar (short=0 or 1; medium=2; tall=3 or 4). Numbers shown above bars refer to study citations from Appendixes A and B (available online at www.ajpmonline.org).

perspective that even low amounts of PA per week can protect against depression.

In line with these findings, three studies[29,33,39] additionally found that walking was associated with a decreased risk of depression. Lucas and colleagues'[33] high-quality study showed that walking <20 minutes/day, and >40 minutes/day at an "average pace," could decrease risk of depression by 6% and 17%, respectively. Together, these results support the notion that <150 minutes/week of PA can prevent depression, although the required intensity of these minutes is less clear. Further, everyday activities such as walking appear to confer a benefit.

Other studies that measured PA in terms of minutes per week revealed that >150 minutes,[19,21] 240 minutes,[21,29] and 420 minutes[45] also were associated with a decreased risk of depression. Five studies in this review did find that increasing either intensity,[29,37] duration,[33] frequency,[31] or volume[41] is associated with a decrease in odds of developing depression. However, given the heterogeneity in PA measurement, a clear dose–response relationship between PA and reduced depression is not readily apparent. Future research should standardize PA measurement and use validated instruments to capture components of frequency, intensity, type, and duration.

An additional objective of this review was to examine the associations between fluctuating levels of PA over time and depression at follow-up. Although the majority of studies did not address this relationship, nearly all that did were of high quality and found the following: reducing PA over time increases the risk of developing depression relative to remaining active or increasing activity levels[22,23,27,45]; increasing PA over time reduces the risk of subsequent depression[19,21,45]; and maintaining levels of PA lowers the risk of depression relative to being inactive throughout.[42,45] Overall, these studies suggest that in order to further help prevent depression, individuals should sustain their activity levels over time and that despite an individual's history of inactivity, the initiation of PA may prevent depression.

Methodologic Issues/Future Research

Through a comprehensive search process with study quality assessments, this review provides a strong indication that PA can decrease the risk of developing depression. An inevitable question that arises from the general public relates to how this protective effect occurs. It is likely that no single mechanism explains such a preventive effect. Rather, a range of physiologic, biochemical, and psychosocial mechanisms most likely operate in concert, with the precise combination being unique.[52]

Given the self-report nature of the studies reviewed, one focus for future research might be the examination of potential psychosocial factors that may mediate the relationship between PA participation and depression. For example, Cairney et al.[53] examined whether changes in PA are associated with changes in distress during a 6-year period among older adults, and whether this association was mediated by changes in global self-esteem, mastery, and physical health status. They found that changes in global self-esteem and mastery accounted for half of the explained variance of PA on psychological distress. This study provides an example of how future epidemiologic studies also may be able to examine a range of theoretically informed, mediating variables subject to the availability of suitable self-report questions or other linking data sets.

Despite consistency in the literature regarding a protective function of PA, some caution is required given that there may be a number of covariates, such as genetic variations,[54] that predict both PA and depression and may not have been fully accounted for in the reviewed studies. Another methodologic weakness of the reviewed studies was the use of various self-report measures for PA and depression. Although it may not be feasible to objectively measure PA and carry out depression-based diagnostic interviews in large cohorts, such self-report measures are prone to bias (e.g., recall, social desirability) and are more focused on PA behavior as opposed to energy expenditure. This bias may exaggerate or conceal the true associations between PA and depression.

Additionally, the use of inconsistent self-report measures of PA between studies limits the ability to examine dose–response relationships between PA and depression. To aid comparison, future studies should capture various components of PA (e.g., frequency, duration, intensity) to compare and make inferences reflecting national PA guidelines. Researchers also could explore the relationships between types (e.g., aerobic versus strength training) and domains (e.g., occupational, household) of PA and the prevention of depression.

Similarly, the use of various subjective and direct measures of depression limits comparability between studies because of the use of different criteria for defining depression. In terms of subjective measures, there were inconsistencies in cut-off scores to indicate depressive symptomology. Even within the same depression scales, studies used different cut-off thresholds to indicate

depression. For example, the cut-off score for "significant" depressive symptomatology using the CESD is typically 16.[55] Although four studies used this cut-off,[25,26,42,45] other studies using the same measure, and sometimes different versions of the CESD, utilized lower threshold cut-offs that may have led to significant findings.

This inconsistency in classifying depression does have implications for interstudy comparisons, as well as for estimations of whether symptoms are clinically meaningful. Notably, six studies used a more direct measure that diagnosed individuals with depression: a physician,[33,37,44] a hospital discharge register,[16,34] or antidepressant use.[39] All but one of these studies[44] suggested that lack of PA was predictive of depression at follow-up. With limited but promising evidence, more investigation is required to elucidate the relationship between PA and *clinical* depression by using more direct measures (e.g., structured clinical interviews, use of antidepressants, use of hospital discharge register).

Strengths and Limitations

A main strength of this review is that it is the first to examine solely the prospective relationship between PA and depression. This review included a formal quality evaluation of the studies. The review was conducted comprehensively, which identified pertinent scholarly articles from various databases to be screened, appraised, and synthesized. A strict inclusion criterion was used to include only large, prospective-based studies that excluded individuals with depression at baseline. However, this review did not include gray research literature such as research reports, conference papers, and PhD dissertations, or studies not reported in English. The positive findings may thus be a consequence of publication bias.

Conclusion

The evidence is sufficient to conclude that PA may prevent depression. Twenty-five of the 30 studies showed that baseline PA is inversely related to follow-up depression, and the majority of these studies were of high methodologic quality. The prospective evidence reviewed here also adds weight to a causal relationship between PA and reductions in depression.[12] There is promising evidence that any level of PA, including low levels, can prevent future depression. At the least, current guidelines for PA, established for physical health benefits, appear equally appropriate for preventing depression.

Several studies in this review also suggested that to protect against future depression, individuals who are currently active should sustain their PA habits and those who have a history of inactivity should initiate a physically active lifestyle. From a health promotion perspective, this review suggests that promoting any level of PA could be an important strategy for the prevention of future depression, which could alleviate the burden of disease and treatment. As such, the population-level promotion of PA should be seen as a strategy for promoting population mental health in addition to physical health.

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Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.amepre.2013.08.001.

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