A Meta-analysis of the Relationship Between Children's Physical Activity and Mental Health

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The present study was a comprehensive, quantitative synthesis of the literature examining the effects of physical activity on children's mental health outcomes. The final analysis included 73 published and unpublished studies, totaling 246 effect sizes. Various study and participant characteristics were coded to assess moderator effects, including type of physical activity, mental health outcome, gender, cognitive ability, mental status, and implementer of the physical activity, etc. Results demonstrated varying effects depending on the methodology of the examined study [i.e., correlational vs. randomized controlled trial (RCT)/non-RCT] and characteristics of the participants, although overall effects of physical activity on children's mental health were small but significant, indicating that on average physical activity led to improved mental health outcomes for all children.

Key words interventions; mental health; overweight; physical activity.

Introduction

Within the past decade, the US has seen a steady decline in the numbers of physically active children (Centers for Disease Control [CDC], 2008). Although children spend the majority of the day in classrooms, schools are increasingly under more pressure to meet high stakes testing standards. This pressure has created the push for more instructional time and less time devoted to physical activity (i.e., physical education or recess breaks; Burgeson, Weschler, Brener, Young, & Spain, 2001; Hardman, 2008). Moreover, technology has afforded children more opportunities to play video games, watch TV, or browse the Internet, activities that contribute to sedentary behaviors (Stevens, To, Stevenson, & Lochbaum, 2008). Parents also report having more concern about their children's safety in playing outside or using active means of transportation (i.e., biking, walking) on their way to school, further limiting the amount of children's physical activity (Stevens et al., 2008; World Health Organization [WHO], 2009).

When physical activity is restricted during school hours, children do not compensate for loss of physical activity after school, resulting in children who are incredibly sedentary throughout the majority of the day (Dale, Corbin, & Dale, 2000). The relationship between sedentary behaviors and prevalence of obesity has been well documented (CDC, 2008; Pate et al., 2002). For the first time in history, children have a shorter lifespan than their parents due to obesity-related diseases (Wang & Veugelers, 2008; WHO, 2009). Although, but one factor in a myriad of influences, the amount of physical activity children engage in is linked to their status of being overweight or obese (National Center for Health Statistics, 2009).

One critical relationship that has been examined in the literature has been the link between physical activity and mental health. Although the research in this area is scarce compared to studies examining the effects of physical activity on mental health in adults, there is a considerable need for this body of research. Approximately 20% of school-age children have a diagnosable mental health

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disorder and require psychological treatment (U.S. Public Health Service, 2000). However, the majority of children do not receive services to remediate their concerns (Thompson, 2005; U.S. Public Health Service, 2000). One subset of the childhood population that is particularly at risk for mental health disorders are those children classified as overweight or obese. It is well documented in the literature that children who are classified as overweight or obese have significantly more psychosocial problems than do children who are of typical weight (Farhat, Iannotti, & Simons-Morton, 2010). Yet, when studies examine the effects of physical activity on children's mental health, differential effects for children who are either overweight or obese are commonly not considered. Although physical activity interventions that have been used to build self-esteem and physical fitness in youth have exhibited promising results (Ekeland, Heian, & Hagen, 2005), it is unclear what the impact of physical activity has on the mental health of all children, including those who are considered overweight or obese.

In a meta-analysis of 16 randomized controlled studies, Larun and colleagues (Larun, Nordheim, Ekeland, Hagen, & Heian, 2006) investigated the effects of vigorous exercise interventions in preventing or reducing anxiety or depression in children and youth. Although depression and anxiety were the only outcome variables in this meta-analysis, results were in favor of exercise interventions in alleviating or preventing negative symptoms in children and youth (Larun et al., 2006). Although the 2006 meta-analysis by Larun and colleagues was a comprehensive synthesis of the literature with respect to the outcomes of anxiety and depression symptomology in youth, there are a number of other mental health concerns that affect school-aged populations. Attention-deficit hyperactivity disorder (ADHD) is typically a comorbid condition in children with such diagnoses as anxiety or depression, and there have been a handful of studies investigating the relationship between physical activity and mental health outcomes in children diagnosed with ADHD. In addition, self-esteem has been found to be an important buffer in the onset of childhood mental disorders (Ekeland et al., 2005); it is therefore imperative to consider the role of self-esteem in relation to physical activity and children's mental health. Including these studies in the meta-analysis would have provided researchers a more comprehensive picture of the relationship between physical fitness and mental health in children. Further, the 2006 meta-analysis excluded studies that were not randomized controlled clinical trials, leaving open the question as to whether effects have been found in other studies, including quasi-experimental and correlational designs. Last, Larun and colleagues (2006) excluded children who were classified as overweight or obese and therefore did not take into account children's health status. It is important to consider the differential effects physical activity may have on children's health status, especially considering the documented risk of overweight/obese children with increased psychosocial difficulties (Farhat et al., 2010).

Given the number of studies that were not included in the 2006 meta-analysis, as well as the multitude of other mental health concerns pervasive in youth not taken into account, this study attempted to fill the gap in examining the relationship between physical activity and children's mental health. Moreover, a comprehensive set of moderator variables were also examined. No meta-analysis to date has examined differential effects of moderator variables in the relationship of physical activity and mental health in children, although there is reason to believe that intervention effects of physical activity may differ depending on such moderators as gender (Kremers, Droomers, Van Lenthe, & Brug, 2007; Simen-Kapeu & Veugelers, 2010), age (Fedewa & Ahn, in press; Kremers et al., 2007), methodological design (Conn, 2010), and implementer (Stice, Shaw, & Marti, 2006), to name a few. Researchers have argued for the increased use of moderator analyses in examining outcomes of physical interventions in children given the multitude of differential relationships and mechanisms of behavior change in youth (Kremers et al., 2007). Thus, a number of moderator analyses were conducted to determine if child mental health outcomes were associated with various characteristics of samples, research methodology, or interventions. Therefore, the present meta-analysis addressed the following two questions:

1. What are the overall effects of physical activity on children's mental health?
2. Do the effects of physical activity on children's mental health vary depending on the intervention, sample, and study design characteristics? In particular, is physical activity more important for children who are classified as obese or overweight?.

Methods

The Search Process

The location of relevant studies in this research synthesis was as exhaustive as possible, and included both published and unpublished literature based on a manual as well as a computerized search of pertinent databases including PsychLit, PsychInfo, Dissertation Abstracts, MedLine, and ERIC. Key terms for literature searches included the words

"physical activity," "physical fitness," "physical exercise," "curricular activity," "exercise," "mental health," "anxiety," "depression," "dysthymia," "bipolar," "post-traumatic stress disorder," "attention deficit hyperactivity disorder," "eating disorder," "anorexia," "bulimia," "youth," "adolescents," and "children". As well as database resources, general search engines (e.g., Google) were employed with the above key terms to capture those studies that had not been included in the databases. Lastly, literature reviews, ancestry searches, and comprehensive analyses conducted in the area (i.e., Jorm, Allen, O'Donnell, Parslow, Purcell, & Morgan, 2006; Larun et al., 2006; Ortega, Ruiz, Castillo, & Sjostrom, 2008) were searched to include any additional bibliographic information. Results yielded over 150 references between 1960 and 2010.

Studies retrieved from the initial searches were screened using specific criteria: (a) studies had to investigate the effect or relationship of some type of physical activity and children's mental health (i.e., the dependent variable was a mental health outcome of some form); (b) target populations had to range from pre-school to high-school age (3–18 years); (c) no qualitative or conceptual studies were included; (d) data that have only been used once in a manuscript to avoid replication (i.e., studies that had published more than one article on the same participants were not included, as were studies that were done as unpublished theses and subsequently published); and (e) studies must have been reported in English. This process identified a total of 95 studies.

Out of 95 studies, 22 studies (a reference list of 22 excluded studies is available online as Supplementary Data) were excluded due to the following reasons: (a) 20 studies did not provide sufficient information (i.e., mean, standard deviation) for calculating effect size and (b) two studies used advanced data analysis techniques such as regression. Therefore, a total of 73 studies (a reference list of 73 included studies is available online as Supplementary Data) were included in the current research synthesis.

Coding of Studies

Based on a literature review, a systematic coding scheme was developed to identify salient features of each study. Specifically, variables with regard to (a) study design, (b) participant, (c) physical activity/exercise, and (d) mental health characteristics were independently coded and entered into the computer database for statistical analyses. Coding of these variables was mainly based on author's report. When no information was given by author(s), variables were coded as "not informed." The author and a graduate student independently coded and entered variables described above. All discrepancies were resolved upon discussion.

Study Design Characteristics

Study design was coded as (1) between-subject design (i.e., posttest-only-control group design), (2) within-subject design (i.e., pretest–posttest design), (3) mixed-design (i.e., pretest–posttest control group design), and (4) cross-sectional or correlational design. Based on the research questions being asked, the included studies were categorized into either (a) group comparison study examining the effect of physical activity interventions on mental health outcomes or (b) cross-sectional/correlational study examining the relationship between physical activity and mental health outcomes.

When comparison groups were used, the assignment methods that allocate subjects into comparison groups were categorized into the following areas: (a) random, (b) not random, and (c) not informed. Then, studies using random assignment were next categorized as randomized controlled trials (RCTs), which were compared to the rest of studies (i.e., non-RCTs). Study setting was coded as (1) school, (2) clinic, (3) after-school program, (4) research center, and (5) other. Last, other study characteristics such as publication type (i.e., published vs. unpublished) and study location (i.e., US vs. non-US) were coded.

Participant Characteristics

Participants were coded as (1) typical/typical inferred, (2) cognitively impaired, (3) learning disabled or children with academic delays, (4) children with ADHD, (5) children with Post-Traumatic Stress Disorder (PTSD), (6) children with emotional problems (e.g., anxiety, depression), (7) children with behavior problems (including children with conduct disorder), (8) children who had undergone cancer treatment, and (9) not informed. Participants were also coded as (1) typical, (2) fit, (3) mixed, and (4) not informed, depending on their physical fitness status. Other information including whether participants were diagnosed or not (i.e., Yes or No), mean age and gender (i.e., male, female, or mixed) were also coded.

Physical Activity Characteristics

Specific characteristics of physical activity were coded. First, the focus of physical activity was qualitatively collected and then categorized into (1) aerobic training, (2) resistance/strength/circuit training, (3) flexibility training, (4) regular PE program, (5) sport participation such as ski, football, and volleyball, (6) movement/motor skill training, (7) yoga (including meditation), (8) combined, and (9) not

informed. These categories were constructed based on the description provided by the authors of the study, as well as the features of the activity children were receiving. If two categories overlapped (i.e., if aerobic training and resistance training were both targeted for the intervention), then the study features were coded as a "combined" intervention. The exception to this coding scheme was for the category of PE intervention, as it was often unclear what the focus of the PE intervention focus was with respect to the type of physical activity. Thus, studies using PE programming as their physical activity intervention received a coding of "PE intervention," even if the PE intervention may have included aerobic training. The authors chose this coding framework to maintain consistency across studies, as the majority of PE programming interventions did not explicitly state the target of their physical activity. Second, total hours, frequency per week, intensity (i.e., light, moderate, intense, and mixed when different levels of intensity were involved), and unit (i.e., individual-based, small group with less than 10 subjects, medium group with subjects between 10 and 30, large group with more than 30 subjects, and whole class) of the physical activity were collected. Last, the administrator who led the physical activity (i.e., teacher/instructor, researcher, PE specialist, external instructor including after-school counselors, volunteers, after-school counselors, and recreational therapist) was also coded.

Mental Health Outcome Characteristics

Mental health outcome measures were categorized into depression/dejection, anxiety, global self-esteem, self-concept (including exercise self-concept, physical self-concept, academic self-concept, social self-concept, and family/home self-concept), distress/PTSD and emotional distress, psychological distress or a combination of multiple symptoms (e.g., depression and anxiety; emotional disturbance), suicidal ideation, ADHD, life satisfaction, somatic symptoms, problems in social functioning, conduct/behavioral problems, cognitive impairment, and psychosis.

Effect Size

Depending on the research questions and/or designs of the included study, the following two types of effect sizes (ESs) were computed in the current meta-analysis: one for comparison studies (d) and the other for correlational/cross-sectional studies (r). From the comparison studies, the standardized mean difference between treatment/intervention and control groups was computed. The group with no physical activity intervention was treated as a control group. When studies used a pretest–posttest control group design, d was computed using the formulas in Morris (2008). If no pretest was used, d was computed using the formula in Lipsey and Wilson (2001). When no sufficient statistics were reported, d was computed from the reported t or F statistics using the formulas outlined in Rosenthal (1994). Also, the odds ratio was converted to d using the formula presented in Borenstein (2009). From the correlational studies examining the association between physical activity and mental health outcome, the reported r was obtained. In addition, if comparison studies examined the relationship of physical activity level with mental health outcome, d-ESs were converted to r by the formulas shown in Rosenthal (1994).

Statistical Analyses

The statistical analyses were based on the methods proposed by Hedges and Olkin (1985) and also described in Cooper, Hedges, and Valentine (2009). Under the fixed-effect model, the computed effect-sizes were weighted by the inverse of its variance, and an overall homogeneity test of these effects (Q_{total}) was initially performed. When the fixed-effects model did not hold (or Q_{total} was significant), the random-effects model or mixed-effects model with predictors were applied. The random-effects model incorporated the additional uncertainty to the effect variances, which was estimated using the methods of moments. Further, the mixed-effects model with moderators (i.e., children's mental health outcomes) incorporated additional uncertainty within each level of categorical moderators, whose weights were computed for effect in each level of moderators. More details about random-effects or mixed-effects models with categorical moderators can be found in Raudenbush (2009).

Dependency

Studies often provided dependent effect sizes by using multiple measures of variables, which in turn violates the assumption of independence (Glesser & Olkin, 2009). For instance, Allison et al. (2005) used three mental health outcomes including psychological distress, problems in social functioning, and depression/anxiety. Such dependency issues can be handled in various ways (Becker, 2000).

In this meta-analysis, the issue of dependency was first handled by choosing effect sizes from the total score or averaging effect sizes from subtest scores if no total score was presented, rather than using a subtest score. Effect sizes were then grouped into subcategories of physical activity and mental health measures described above and thus they were no longer dependent within each subcategory for the computation of the overall effect sizes. The authors chose this method due to its simplicity and

feasibility as compared to multivariate methods, which require a full variance-covariance matrix of dependent effect sizes.

Results

Description of Studies

The included 73 studies yielded a total of 246 ESs. These included 182 *d*- and 64 *r*-ESs. Studies were published between 1974 and 2009 and most of the studies ($s = 55$) were conducted in the US, while the rest of them were from various countries including Brazil ($s = 1$), German ($s = 1$), Hungary ($s = 1$), South Africa ($s = 3$), Switzerland ($s = 1$), the UK ($s = 6$), China ($s = 2$), Canada ($s = 4$), and Australia ($s = 2$). Sample sizes used in the 73 studies ranged from 9 to 14,594 ($M = 484.13$, $SD = 1714.82$), including 14 to 502 ($M = 55.67$, $SD = 86.86$) from RCT ($s = 30$), 9 to 2,444 ($M = 192.85$, $SD = 502.27$) from non-RCT ($s = 24$), and 35 to 14,594 ($M = 1398.58$, $SD = 3441.39$) from correlational studies ($s = 19$). Participants' age ranged from 3.67 to 17.66 years ($M = 12.67$, $SD = 2.94$). In the majority of studies, children were typical in their mental, fitness, and diagnostic status (i.e., represented non-clinical populations).

Publication Bias

The current review included both unpublished and published studies. However, the Egger's regression tests (Sutton, 2009) were found to be significant for both effect sizes ($t(180) = -1.34$, $p < .01$ for *d*-ESs; $t(62) = -1.60$, $p = .02$ for *r*-ESs), indicating the presence of potential publication bias.

Comparison Studies

A total 182 *d*-effect sizes examining the intervention effect of the physical activity on children's mental outcomes were first analyzed. The significant *Q*-statistic of 1395.11 indicates that the included *d*-ES were heterogeneous. Further, the estimated *d*-ES under the random-effects model was −0.38 with a *SE* of 0.11, which was statistically significant. Such a significant but negative result indicates that physical activity has a moderate effect on alleviating children's negative mental health outcomes.

However, a statistically significant mean *d*-ES difference was found between RCT and non-RCT studies ($Q(1) = 65.58$, $p < .01$), showing significantly lower mean *d*-ES from RCT studies ($\bar{d} = -.30$, $SE = 0.06$) when compared to non-RCT studies ($\bar{d} = -.57$, $SE = 0.24$). Also, the statistically significant *Q* statistics suggested that *d*-ESs for both studies were statistically different ($Q(101) = 298.68$, $p < .01$for RCT; $Q(78) = 1030.80$, $p < .01$ for non-RCT). Thus, the following moderator analyses were performed separately for RCTs and non-RCT studies. Table I shows the results from the RCT and non-RCT studies.

Type of Mental Health Outcome

The intervention effect of the physical activity program significantly differed by type of mental health outcome for both RCT ($Q(11) = 133.67$, $p < .01$) and non-RCT studies ($Q(11) = 181.23$, $p < .01$). From RCT studies, the physical activity intervention was found to be effective for reducing depression ($\bar{d} = -.41$, $SE = 0.13$), anxiety ($\bar{d} = -.35$, $SE = 0.18$), psychological distress/PTSD ($\bar{d} = -.61$, $SE = 0.30$), and emotional disturbance ($\bar{d} = -.33$, $SE = 0.17$). It was also found that physical activity significantly enhanced children's self-esteem ($\bar{d} = .29$, $SE = 0.08$) and their self-concept ($\bar{d} = .16$, $SE = 0.10$). However, the treatment effect from non-RCT studies was significant only for increasing children's self-esteem ($\bar{d} = .78$, $SE = 0.28$).

Physical Activity Intervention

From both RCT and non-RCT studies, the estimated mean ESs were significantly different depending on the characteristics of the physical activity programs, including focus, intensity, intervention unit, total hours, frequency per week, and administrator of the physical activity intervention.

First, the mean *d*-ESs from RCT studies were statistically significant and largest when the intervention was focused exclusively on circuit training ($\bar{d} = -.72$, $SE = 0.29$), followed closely by the intervention with a combined physical activity focus ($\bar{d} = -.57$, $SE = 0.11$). These results indicate that interventions with a focus on circuit training or a combination of aerobic and resistance training significantly lowered children's mental health disturbances when compared to a control group with no physical activity. From non-RCT studies, the intervention with sport participation was the sole program that showed a statistically significant reduction on children's mental disturbance, compared to control groups with no physical activity ($\bar{d} = -1.06$, $SE = 0.27$).

Second, an intervention with an intense level of physical activity was found to be significant for reducing children's mental health disturbance from RCT studies ($\bar{d} = -.27$, $SE = 0.08$), although the largest and most significant intervention effect was found from RCT studies that did not indicate the intensity level of their physical activity intervention ($\bar{d} = -.41$, $SE = 0.10$). From non-RCT studies, a moderate intensity of physical activity

Table I. *Moderator Analyses for d-Effect Sizes*

	RCT studies				Non-RCT studies			
	k	*M*	*SE*	*Qwithin*	*K*	*M*	*SE*	*Qwithin*
Outcome	$Q(11) = 133.67^{**}$				$Q(11) = 182.23^{**}$			
Depression	14	−0.41**	0.13	32.19**	16	−1.14	0.71	94.19**
Anxiety	16	−0.35*	0.18	69.96**	9	−1.51	0.85	27.16**
Self-esteem	26	0.29**	0.08	60.71**	16	0.78**	0.28	163.25**
Distress/PTSD	5	−0.61*	0.30	13.83**	7	−1.42	1.15	36.01**
Emotional disturbance	4	−0.33*	0.17	7.10	5	−0.42	0.41	4.53
ADHD	5	−0.92	0.64	17.17**	2	0.31**	0.10	6.09*
Somatic symptom	3	0.35	0.21	1.14	4	−0.43	0.40	6.26
Social function problem	11	−0.26	0.15	27.48**	6	1.15	0.93	439.63**
Conduct problem	6	0.00	0.46	2.20	6	−0.12	0.63	48.99**
Cognitive problem	2	−0.50	0.66	6.54*	1	−0.82	2.77	-
Self-concept	9	0.16**	0.10	11.59	6	0.12	0.31	16.22**
Quality of life	2	0.15	0.09	0.04	1	0.79	0.9	-
PA focus	$Q(4) = 44.21^{**}$				$Q(6) = 145.22^{**}$			
Aerobic	30	−0.14	0.09	48.51*	48	−0.75	0.38	226.17**
Circuit/Strength	9	−0.72*	0.29	9.57	3	−0.32	0.33	1.16
Flexibility	34	−0.13	0.11	95.53**	10	−0.69	0.39	111.72**
Combined focus	29	−0.57**	0.11	100.86**	3	−0.27	0.37	46.55**
Sport participation	1	0.11	–	–	5	−1.06**	0.27	17.57**
Yoga/Meditation	–	–	–	–	1	−0.99	–	–
Not indicated	–	–	–	–	9	−0.32	0.27	482.46**
Intensity	$Q(4) = 32.96^{**}$				$Q(4) = 35.21^{**}$			
Light	5	−0.10	0.29	0.111	3	−0.34	0.40	5.82
Moderate	7	−0.18	0.17	3.018	3	−1.89*	0.90	7.97
Intense	26	−0.27**	0.08	36.35	23	−0.22	0.41	138.77**
Mixed	13	0.06	0.18	5.31	12	−1.44	0.87	36.61**
Not indicated	52	−0.41**	0.10	220.93**	38	−0.49	0.31	806.46**
Unit	$Q(4) = 22.69^{**}$				$Q(4) = 57.35^{**}$			
Individualized	–	–	–	–	7	−1.82**	0.65	17.01**
Small group (<10)	8	0.10	0.21	1.24	3	−0.50**	0.14	1.16
Medium group (10–30)	26	−0.13	0.08	33.69	6	−1.73	1.67	28.59**
Large group (>30)	14	−0.38	0.21	34.82**	–	–	–	–
Total class	16	−0.45**	0.11	41.32**	7	−0.25	1.39	33.01**
Not indicated	39	−0.39**	0.10	164.91**	56	−0.24	0.17	893.73**
Hours	$Q(2) = 24.46^{**}$				$Q(2) = 41.11^{**}$			
Less than 20 hr	53	−0.16**	0.04	53.69	25	−1.84**	0.59	117.20**
20–33 hr	31	−0.42**	0.13	125.61**	11	−0.28**	0.08	10.27
More than 33 hr	10	−0.55**	0.19	74.07**	17	0.09	0.43	109.27**
Frequency	$Q(6) = 60.73^{**}$				$Q(4) = 51.39^{**}$			
1	21	−0.57**	0.18	108.38**	10	−0.81*	0.48	103.85**
2	18	−0.37**	0.09	39.13**	1	−0.99	–	–
3	35	−0.09	0.08	58.00**	39	−0.60	0.46	197.99**
4	7	−0.61	0.43	7.8	3	−0.32	0.55	1.16
5	14	−0.30	0.16	5.58	–	–	–	–
7	1	−1.19	–	–	–	–	–	–
Not indicated	7	−0.39*	0.45	20.98**	26	−0.37	0.25	676.46**
Administrator	$Q(5) = 16.28^{**}$				$Q(5) = 47.19^{**}$			
Teacher	12	−0.36*	0.15	60.66**	48	−0.76*	0.35	226.17**
Researcher	37	−0.20**	0.08	45.71	3	−1.71**	0.65	1.16
PE specialist	9	−1.02**	0.33	15.8	10	−0.09	0.18	111.72**

(continued)

Table I. *Continued*

	RCT studies				Non-RCT studies			
	k	*M*	*SE*	*Qwithin*	*K*	*M*	*SE*	*Qwithin*
After-school counselor	7	−0.11	0.46	1.35	3	−0.08	0.53	46.55**
Not indicated	33	−0.41**	0.12	158.77**	5	−0.27	0.16	17.57**
Therapist	5	−0.10	0.29	0.11	1	0.02	–	–
Clinician	–	–	–	–	9	−0.82	0.78	482.46**
Gender	$Q(3) = 33.80$**				$Q(3) = 49.33$**			
Female	6	−0.41	0.43	7.60	23	−1.60*	0.66	245.34**
Male	34	−0.55**	0.11	119.79**	13	−0.04	0.28	476.73**
Mixed	63	−0.19**	0.07	137.48**	4	−0.39	0.22	238.25**
Not informed	–	–	–	–	2	0.00	0.07	–
Diagnostic status	$Q(1) = 59.19$**				$Q(1) = 25.23$**			
Yes	23	0.17	0.25	64.28**	30	−1.00	0.52	197.13**
No	80	0.07*	0.12	218.03**	49	0.64*	0.27	808.49**
Mental status	$Q(6) = 9.46$				$Q(6) = 84.03$**			
Normal	53	−0.29**	0.04	179.38**	48	−0.27**	0.11	788.97**
Cognitively impaired	–	–	–	–	2	−2.49*	1.42	18.63**
Learning disabled	20	−0.36**	0.07	61.01**	–	–	–	–
ADHD	6	−0.48	0.27	13.83*	1	−0.99	–	–
Emotionally disturbed	19	−0.11	0.13	17.61*	4	−0.37	0.20	3.02
PTSD	1	−1.27	–	–	11	−3.42**	1.17	65.71**
Children w/behavior Problem	1	0.11	–	–	2	−0.03	0.63	3.33
Not indicated	3	0.16	0.21	1.27	11	0.33	0.63	74.93**
Fitness status	$Q(1) = 0.07$				$Q(1) = 25.23$**			
Normal	67	−0.29**	0.04	197.13**	56	−0.23*	0.11	851.57**
Fit	36	−0.27**	0.05	808.49**	4	−0.06	0.26	0.71

Note. **$p < .01$; *$p < .05$.

showed a significant decrease on negative mental health outcomes ($\bar{d} = -1.89$, $SE = 0.90$), compared to control groups with no physical activity.

Third, the mean *d*-ES from RCT studies was negative and statistically significant for physical activity done in school with the entire classroom ($\bar{d} = -.45$, $SE = 0.11$). However, the mean *d*-ESs from non-RCT studies were statistically significant for individualized physical activity ($\bar{d} = -1.82$, $SE = 0.65$) or small group physical activity ($\bar{d} = -.50$, $SE = 0.14$). Post hoc tests comparing mean *d*-ESs from non-RCT studies indicated that the individualized physical activity program appeared to be the most effective for alleviating negative mental health outcomes ($M_{diff} = 1.32$, $p = .047$).

Fourth, the total hours of the physical activity intervention was categorized into three groups: (a) less than 20 hr, (b) 20–33 hr, and (c) more than 33 hr. These three categories were created based on the mean hours of the physical activity or physical education program (20 hr) and its standard deviation (13 hr). These hours were distributed over the length of the intervention, which varied by study design. For RCT studies, the average length of time for physical activity interventions was 11.1 weeks ($SD = 3.6$), while for non-RCT studies the mean length was 8.95 weeks ($SD = 4.5$). From RCT-studies, physical activity programs with more than 33 hr showed a statistically significant reduction in mental health disturbance ($\bar{d} = -.55$, $SE = 0.21$), followed by 20–33 hr of physical training ($\bar{d} = -.55$, $SE = 0.21$) and less than 20 hr physical activity ($\bar{d} = -.55$, $SE = 0.21$). From non-RCT studies, mean *d*-ESs showing an intervention effect with less than 20 hr ($\bar{d} = -1.84$, $SE = 0.59$) or 20–33 hr ($\bar{d} = -.28$, $SE = 0.08$) were significant.

Fifth, the mean *d*-ES from RCT studies was statistically significant when the physical activity program was provided once per week ($\bar{d} = -.57$, $SE = 0.18$) and twice per week ($\bar{d} = -.37$, $SE = 0.21$). From non-RCT studies, the intervention with physical activity provided once per week showed significantly more effect on decreasing negative mental health outcomes when compared to the control group ($\bar{d} = -.81$, $SE = 0.48$).

Last, mean *d*-ESs from RCT studies were significant when the physical activity program was administered by

the classroom teacher ($\bar{d} = -.36$, $SE = 0.15$), researcher ($\bar{d} = -.20$, $SE = 0.08$), or physical education specialist ($\bar{d} = -1.02$, $SE = 0.33$). From non-RCT studies, the significant treatment effect was found when physical activity intervention was administered by the classroom teacher ($\bar{d} = -.76$, $SE = 0.35$) and researcher ($\bar{d} = -1.71$, $SE = 0.65$), whose mean d-ESs were not statistical different ($M_{diff} = 0.95$, $p = .19$).

Participant Characteristics

From both RCT and non-RCT studies, significant mean differences were found by several participant characteristics including gender and diagnostic status. However, the intervention effect did not depend on age or whether participants were on a prescribed regimen of medication. A significant mean difference by children's mental health status and physical fitness status was found only from non-RCT studies, not from RCT studies.

First, both male and mixed-gender groups from RCT studies showed significant intervention effects, while only females from non-RCT studies showed significant intervention effects on alleviating negative mental outcomes. Second, it was found from both RCT and non-RCT studies that the physical activity programs were more effective in reducing negative mental health outcomes for children who were clinically diagnosed. Third, the overall means from non-RCT studies varied depending on children's cognitive and mental health status. In particular, the overall mean d-ES from the cognitively impaired and PTSD classified groups showed the largest effects. Post hoc analysis indicates that the overall mean d-ES for PTSD was significantly larger compared to typically developing children ($M_{diff} = -2.68$, $p < .05$). Fourth, the intervention effect was equally effective for children classified as overweight/obese and children who were of average weight.

Correlational Studies

A total of 64 r-ESs represents the relationship between children's level of physical activity and mental health. The significant Q statistics of 1040.02 indicates that the 64 r-ESs were statistically different. Under the random-effects model, the estimated average correlation was statistically significant, having a weighted mean of −0.06 with a SE of 0.02. The statistically significant and negative effect indicates that greater physical activity was related to a lesser likelihood of experiencing detrimental mental health outcomes. Table II shows the results from correlational/cross-sectional studies.

Type of Mental Outcome

The overall relationship between physical activity level and mental health differed depending on the type of mental health outcome ($Q(11) = 272.20$, $p < .01$). Of the 11 types of mental health outcomes, the level of physical activity showed significant relations to depression ($\bar{r} = -.14$, $SE = 0.04$) and self-concept ($\bar{r} = -.14$, $SE = 0.05$). Such results indicated that the level of physical activity had a significantly negative relationship with depression and significantly positive relationship to a child's self-concept.

Participant Characteristics

The mean r's varied by several participant characteristics including gender, cognitive status, and physical fitness

Table II. *Moderator Analyses for r-Effect sizes*

Study characteristics	K	M	SE	Qwithin	Study characteristics	k	M	SE	Qwithin
Outcome, $Q(10) = 540.32$**					Fitness status, $Q(3) = 286.81$**				
Depression	12	−0.14**	0.04	272.2**	Typical	23	0	0.05	37.20*
Anxiety	7	−0.09	0.06	22.85**	Fit	4	−0.02	0.02	0.29
Self-esteem	14	0.04	0.04	30.75**	Obese	35	−0.12**	0.04	174.61**
Distress/PTSD	5	−0.04	0.06	73.03**	Not indicated	2	−0.03	0.15	541.19**
Emotional mood	3	−0.09	0.08	18.15**	Mental status, $Q(2) = 87.79$**				
Somatic symptom	3	0.01	0.01	1.65	Typical	60	−0.07**	0.03	408.86**
Problem in social function	7	0.04	0.06	32.61**	Learning disabled	2	−0.04	0.05	2.27
Conduct problem	1	−0.19	0.14	—	Not indicated	2	−0.03	0.16	541.09**
Psychosis	2	0.01	0	0.01	Gender, $Q(2) = 43.46$**				
Self-concept	8	0.14**	0.05	52.6**	Girl	13	−0.13*	0.06	98.71**
Suicidal ideation	2	0.03	0.1	8.66**	Boy	6	−0.17*	0.09	31.72**
Diagnostic status, $Q(1) = 1.15$					Mixed	45	−0.03	0.03	866.13**
Yes	6	−0.03	0.09	11.81*					
No	58	−0.07**	0.03	1027.07**					

Note. **$p < .01$; *$p < .05$.

status, but they did not depend upon age or whether children were clinically diagnosed. First, both girls and boys showed significant mean *r*s between level of physical activity status and mental health. The magnitude of mean correlations for boys and girls were almost identical. Second, only children who were typically developing in their cognitive abilities showed a significant but negative relationship of physical activity to mental health. Third, the mean correlation between physical activity and mental health outcome for children classified as obese was found to be statistically significant. Finally, the relationship between physical activity and negative mental health outcomes was negative and significant for children who were not clinically diagnosed.

Other Study Characteristics

For both *d*- and *r*-ESs, statistical results from the moderator analyses using other study characteristics such as setting of the physical activity intervention and study location are available online as Supplementary Data.

Discussion

The current study examined the effect of children's physical activity on their mental health outcomes. Through a comprehensive synthesis of the literature, 73 studies yielding 246 effect sizes revealed a number of critical findings. Some of the findings varied depending on the methodological design of the included studies. RCT, non-RCT, and correlational results will be discussed, highlighting the significance and practical implications of these findings.

As predicted, increased levels of physical activity had significant effects in reducing depression, anxiety, psychological distress, and emotional disturbance in children. Both RCT and non-RCT studies also showed that physical activity increased children's levels of self-esteem. An overall effect size of −0.30 for RCT studies and −0.57 for non-RCT studies is consistent with meta-analytic reviews in adults, which have found effect sizes that range from 0.36 to 1.10 in both clinical and non-clinical populations (see Stathopoulou et al., 2006). These results mirror studies done with adult populations, as physical activity has shown significant benefits in lowering adult depression, anxiety, and overall psychological distress (Dixon, Mauzey, & Hall, 2003; Paluska & Schwenk, 2000). The 2006 meta-analysis using solely randomized controlled studies with children found similar results with respect to the small, but beneficial effects of physical activity on depression and anxiety (Larun et al., 2006).

One of the main purposes of this analysis was to evaluate whether physical activity exerted a unique effect for children who were classified as overweight or obese. Given that prior research has identified increased psychosocial distress among children classified as overweight or obese (Farhat et al., 2010), it was expected that physical activity may play an even more important role for this group of children. Both RCT and non-RCT studies, however, demonstrated equal effects for children who were obese/overweight and those who were of typical weight. In other words, both groups of children showed statistically significant effects on improved mental health, regardless of their weight/height ratio. This is a critical finding for clinicians working with children from all physical fitness backgrounds, as despite a child's body mass index, children appear to reap some clinical benefit from physical activity.

Although correlational studies also found a significant relationship between increased levels of physical activity and decreased levels of depression (as well as an enhanced self-concept), other mental health outcomes were not found to relate significantly to heightened levels of physical activity. Yet, one critique of correlational studies in this area is that they leave open the question as to whether the relationship between physical activity and mental health is simply an effect of negative affect on the child's motivation to engage in physical activity. The experimental studies have somewhat clarified this relationship and will likely provide a more accurate indicator of how much physical activity influences mental health outcomes in children. Given that depression, anxiety, psychological distress, emotional disturbance, and self-esteem were all positively affected through randomized-controlled designs in both children and adults across multiple studies, these findings can be interpreted as robust (Larun et al., 2006; Stathopoulou, Powers, Berry, & Smits, 2006).

As demonstrated in this analysis, the type of physical activity children received had varying effects on their mental health. RCT studies demonstrated the greatest effect with circuit training/strength training activities and mixed activity interventions, meaning a combination of aerobic and resistance training exercise. The more children engaged in these types of activities, the less adverse mental health issues they experienced. Results from aerobic exercise and resistance training can be found in numerous studies based on adult populations, as both types of activity have resulted in consistently beneficial effects for participants' mental health. Possible mechanisms include an increase in serotonin or other neurotransmitters associated with the "endorphin" effect in alleviating negative affect, although additional clinical studies are needed to specify

the precise neurological pathways that mediate the relationship between physical activity and mood on a physiological level (Stathopoulou et al., 2006).

Although there is a dearth of research in this area using child participants, the level of intensity of the intervention played a significant moderating effect in both RCT and non-RCT studies. Interventions designed with high levels of intensity had the greatest effect on children's mental health in RCT studies, while moderate-level activities exerted a greater effect for non-RCT studies. Again, there is a sparse research base in which to make sense of these findings, but in the only meta-analysis to date studying this relationship, Larun and colleagues found no difference between low and high intensity exercise when assessing effects on depression and anxiety (2006). However, multiple studies on adult populations suggest an overwhelming consensus in favor of high intensity exercise (Stathopoulou et al., 2006). Perhaps with the addition of RCT studies in the present analysis, this relationship was better discerned. As argued for adult populations, higher intensity exercise may enhance neurological, physiological and cognitive factors that mediate the relationship between activity and mood. Although more research is needed to confirm this hypothesis, perhaps similar mechanisms are at work in children (Shephard, 1996; Stathopoulou et al., 2006; Wiles, Jones, Haase, Lawlor, Macfarlane, & Lewis, 2008).

Curiously, interventions done approximately 1 to 2 days per week and for more than 33 hr (spanning the length of the intervention) were most effective in RCT studies. For non-RCT studies, interventions done approximately 1 day per week for no more than 20 hr were the most effective. That is, interventions that were done more than 3 days per week or for more than a total of 20 hr did not alleviate children's mental health ailments for non-RCT studies. Although this finding from RCT studies appears to contradict findings with the non-RCT studies, the seemingly low amount of hours could be explained by the relatively short duration of physical activity interventions used in the included studies. In other words, the average length of time for physical activity interventions was 8.95 weeks ($SD = 4.5$), ranging from 2 to 20 weeks for non-RCT studies. For RCT-studies, the length of the intervention phase was longer ($M = 11.1$ weeks, $SD = 3.6$). Thus, with a mean total of 20 hr for the non-RCT interventions, this would equate to approximately 2.2 hr per week of additional physical activity for children—around 44 min, 3 times per week. For a mean total of 33 hr for non-RCT studies, the average amount of physical activity would come to approximately 2.9 hr per week, or 58 min, 3 times per week. The differential mean intervention length across study designs likely affects the total of hours needed for significant results. A number of possibilities might explain this finding of children's need for fewer hours of total physical activity. First, it could be that since children already receive relatively short and sporadic bouts of physical activity throughout the week (i.e., recess or game play; see Dencker, Bugge, Hermansen & Andersen, 2010; Rowland, 1996) they may not require as much physical activity for an intervention to be effective in reducing negative mood. Another possibility concerns the dearth of studies that included these descriptors (frequency and duration of intervention) in their methodology. For example, there was only one effect size from which to code daily (5 days/week) physical activity for children. Without knowing this information, it was impossible to code for these features of dosage, and thus it is likely that an accurate assessment of the dose-response relationship could not be obtained, just as in the prior 2006 meta-analysis (Larun et al., 2006).

When designing physical activity interventions for children, this study showed that individualized- or class-wide interventions had the greatest effect on children's mental health. When the intervention was led by teachers, researchers, or PE specialists, children showed the significant reduction in mental health problems through physical activity in both RCT and non-RCT studies. This finding has practical applications, as children spend the majority of their waking hours in school. With many children unable to access mental health treatment through outpatient or clinical settings, schools are the one place where services are both mandated and free for children with diagnosed mental health ailments (Hoagwood & Johnson, 2003). Thus, schools have the potential to be a vehicle for improving children's mental health outcomes.

Gender was found to be a moderator in both RCT and non-RCT studies, although the findings were inconsistent. In RCT samples, males and mixed-gender groups showed the largest gains from physical activity with respect to their mental health outcomes. However, non-RCT studies showed that girls benefit more than boys do when it comes to the effects of physical activity on their mental health. Correlational studies demonstrated yet another finding and showed no differential effect by gender. The methodological design of each study likely plays a critical role in whether gender and age are found to be moderating factors in the relationship between physical activity and mental health. In other words, the differential findings between RCT, non-RCT, and correlational studies may help elucidate why the "gender difference" finding has been markedly inconsistent in this body of research (Wiles et al., 2008). Some authors have postulated that physical activity exerts a greater effect on females' mental health

outcomes due to their "feeling better" (i.e., higher self-esteem and self-concept) about their appearance and overall lack of physical activity compared to same-age male peers (Lagerburg, 2005). Other authors argue that girls and boys in fact are not affected differently, and that gender differences between activity levels and psychological well-being can be "smoothed out" over time (Parfitt & Eston, 2005). The present analysis, however, does show that when RCT studies are analyzed separately, males appear to reap larger psychological benefits from physical activity than do their female peers. Further research is needed to investigate the mechanisms behind these variations, perhaps using a mixed-methods design to assess both female and male children's perceptions of the benefits of physical activity (Loman, 2008).

Additional participant characteristics were found to moderate the relationship between physical activity and mental health outcome. For children who were diagnosed as cognitively impaired or emotionally disturbed, effect sizes from RCT studies were significantly greater compared to children who were typically developing and did not have an emotional disorder. In fact, the RCT studies used for analysis demonstrated an effect size that was five times as large for children with cognitive impairments and almost twice as large for students with emotional disturbance. Perhaps the severity of problems for these two groups of children enhanced the effect of physical activity on their mental health, just as children who were clinically diagnosed with a disorder or disability displayed higher levels of mental health benefit than those children in the general population without a clinical diagnosis. These findings are critical for clinicians and school-based practitioners, as it demonstrates the increased effectiveness of physical activity for children who display severe problem behaviors or clinical symptomology.

As with any study, there are limitations that must be addressed. First, regardless of both searching and including unpublished and published studies, slight publication bias existed for the current analysis, which might threaten the validity of research findings in the current meta-analysis. However, it should be pointed out that such problem reflects the way individual studies in the field are conducted and disseminated (Sutton, 2009). In spite of the potential validity threat due to publication bias, the current review at least can inform the possible presence of publication bias in the area and estimate the likely effect of bias based on the distribution of the effect sizes from the available studies. By taking into account this potential validity threat, the overall effect size between physical activity and children's mental health remained significant. Second, the majority of studies (69%) did not include children's ethnicity or socioeconomic status. Thus, these variables could not be included as potential moderators for the relationship between physical activity and child mental health outcomes. Yet researchers have demonstrated higher levels of obesity in racially, ethnically, and socioeconomically disadvantaged populations (Burton & VanHeest, 2007). It is likely that different relationships exist for these populations than for middle-class, Anglo-American groups. Future research in this area should include detailed descriptors of the included sample so that these relationships can be examined.

In summary, the present quantitative synthesis of the literature demonstrated a small to moderate effect of physical activity on children's mental health. Given that findings varied by methodological design, additional RCT-designed studies are warranted to replicate and confirm the current findings. The evidence from this meta-analysis adds to the current body of knowledge documenting the positive mental health effects of exercise in children, particularly for those children who exhibit a higher severity of symptomology. For practitioners, physical activity can thus be considered an effective component to already well-established treatments (e.g., cognitive-behavioral therapy) in the field. Clinicians, school-based professionals, and parents should encourage physical activity in children, not only for the physical health benefits, but for the positive mental health outcomes as well.

Supplementary Data

Supplementary data can be found at: http://www.jpepsy.oxfordjournals.org/.

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