THE EFFECTIVENESS OF PHYSICAL ACTIVITY INTERVENTIONS ON YOUNG INDIVIDUALS WITH AUTISM SPECTRUM DISORDER: A META-ANALYSIS

By

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Abstract

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Objective: The purpose of the study is to examine the efficacy of physical activity interventions and practices on psychomotor, cognitive, or affective outcomes on young individuals diagnosed with Autism Spectrum Disorder (ASD).

Methods: Standard meta-analytical procedures determining inclusion criteria, literature searches in electronic databases, coding procedures, and statistical methods were used to identify and synthesize articles retained for analysis. Cohen's *d* (1988) will be utilized in order to interpret effect sizes and quantify research findings. The impact was assessed using coding procedures that categorize independent variables.

Results: A total of 23 independent samples (N=896) were utilized in this analysis. Results from meta-analyses indicated an overall high-moderate effect (g=0.761). Several outcomes indicated a moderate-to-high effect ($g \geq 0.5$). Moderator analyses were conducted to explain variance between groups; while no significant differences were found between groups, several trends were discovered within groups in which experimental groups outperformed control groups.

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INTRODUCTION

Physical activity is a crucial component in one's everyday life, and it is suggested that children and adolescents (ages 2-to-19 years of age) participate in at least 60 minutes of physical activity per day (Centers for Disease Control and Prevention [CDC], 2016; U.S. Department of Health and Human Services, 1996). Physical activity allows the human body to develop and strengthen across five components of physical fitness; muscular strength, muscular endurance, cardiorespiratory endurance, flexibility, and body composition (Caspersen, Powell, & Christenson, 1985). Working to improve or maintain these factors within everyday life allows the human body to prevent life-threatening diseases and conditions, such as cardiovascular disease, diabetes, hypertension, and obesity (CDC, 2016). In the United States, approximately 17 percent of children and adolescents in the United States are classified as obese (CDC, 2016; Finkelstein, Nickel, Barnes, & Suma, 2010).

Individuals with Autism Spectrum Disorder (ASD) are at an even greater risk for becoming obese and developing cardiovascular disease than the general population (McCoy, Jakicic, & Gibbs, 2016). This is unsurprising when one considers that individuals with ASD have been shown to be less active than their typically developing counterparts (Cai & Kornspan, 2012), and have higher body fat percentages (Maïano , 2011; Rimmer, Braddock, & Fujiura, 1993). Several factors contribute to inactivity among this population: (i) fine and gross motor skills required to participate in more traditional sports or physical activities, (ii) negative social interactions such as bullying or

negative social comparisons, (iii) differences in sensory processing of external stimuli such as auditory or tactile stimuli, and (iv) exclusion from activity (Finkelstein, Nickel, Barnes, & Suma, 2010; Healy, Msetfi, & Gallagher, 2013). Children with ASD were found to have an overall 35.7 % prevalence of being at-risk-for-overweight and a prevalence of overweight conditions at 19% (Curtin, Bandini, Perrin, Tybor, & Must, 2005). In comparison to their typically developing (TD) peers, further studies have shown that young individuals with ASD are more likely to be obese than their TD peers (Gillette et al., 2015).

Autism Spectrum Disorder

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Autism Spectrum Disorder (ASD) is a neurodevelopmental condition developed in the early stages of life, most typically diagnosed within the first three years of an individuals life, and is characterized with deficits in social reciprocity (e.g. interpersonal communication, reading emotions, and showing empathy) and repetitive behaviors (American Psychiatric Association, 2000). While recent research suggests that ASD is a genetically linked condition, there is still very little evidence for a valid bio-marker or biological test that reveals a genetic link to ASD (Lord, Cook, Leventhal, & Amaral, 2013); research has also shown that ASD is four times more likely to occur in males than females, and increased parental age can also increase the risk for occurrence of ASD (Grether, Anderson, Croen, Smith, & Windham, 2009; Lord et al., 2013). ASD is also characterized as a heterogeneous condition, meaning that different cases in different individuals relate to the same core domains of the condition, while the specific behaviors

of the individuals are different. These behaviors also change over time, meaning an individual who performs a specific behavior as a child might move on to a different behavior or fascination as they increase in age (Lord, Cook, Leventhal, & Amaral, 2000).

Physical activity and autism

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Research examining physical activity levels in young individuals with ASD has shown that this population tends to engage in less moderate-to-vigorous physical activity (MVPA) than their TD peers (McCoy et al., 2016). Self-reported measures from parental interviews have indicated that their children with ASD participated in significantly fewer types of physical activities than their TD peers, as well as spent less time annually participating in these physical activities compared to their TD peers (Bandini et al., 2013). Researchers have found age to be a determinant factor in a child with ASD's activity level, and older children with ASD are significantly more inactive than their younger peers; further research supports the notion that physical activity participation significantly decreases across the adolescent years for children with ASD (MacDonald, Esposito, & Ulrich, 2011; Memari et al., 2013). Recent studies have revealed that participants with ASD had lower scores on all physical fitness outcomes (excluding body composition) when compared to their TD peers, and group-dependent relationships were associated with improved PA profiles and levels (Pan et al., 2016). Research also indicates that external regulation is necessary for facilitating physical activity participation in youth with ASD in inclusive settings (Pan, Tsai, Chu, & Hsieh, 2011a). An observational study conducted by Boddy, Downs, Knowles, Fairclough (2015)

revealed that in a sample of 70 young individuals with ASD, 23% of the individuals spent enough time in physical activity to actually benefit their physical health.

Barriers to physical activity. Several themes have emerged in the literature as potential barriers to physical activity amongst children and adolescents with ASD. Many child-reported barriers have been noted in previous research, such as challenges in physical fitness, physical ability, sensory issues, fear of injury, negative peer interactions such as (lack of) camaraderie or initiation of friendship, social comparison, bullying, exclusion by the teacher, the difficulty of the task, requesting to be excluded, and a lack of understanding of the disability (Ayvazoglu, Kozub, Butera, & Murray, 2015; Healy, Msetfi, & Gallagher, 2013). Obrusnikova and Cavalier (2011) have reported several intrapersonal (e.g. preferences to video games or computers), interpersonal (e.g. lack of peers to participate with or parents not having time), and physical (e.g. inclement weather or unsafe equipment) barriers to physical activity; recent studies also indicate that young individuals with ASD tend to prefer engaging in screen time rather than engaging in moderate-to-vigorous physical activity (Healy, Haegele, Grenier, & Garcia, 2016). Children with ASD also experience barriers related to cognitive and affective deficits as well; past research indicates that young individuals with ASD display more deviation from self-regulatory behavior (i.e. attention, adaptability, object orientation, and persistence) (Bieberich & Morgan, 2004).

Several barriers to engage in physical activity have been reported by parents as well. Parents of children with ASD believe that community-based recreation programs are pertinent to their child's overall well-being, but studies have shown that parents feel

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they are in constant struggle for accessible opportunities to engage in these activities (Schleien, Miller, Walton, & Pruett, 2014). Recent research utilizing parental report measures have indicated that children with ASD displayed significant impairments in self-regulation, leading to decreased school and peer engagements (Jahromi, Bryce, & Swanson, 2013).

Motor development

Research indicates that motor skill deficits are often present and persistent in school-aged children with ASD, and previous studies conducted suggest that lapses in gross motor coordination and development are a characteristic feature of ASD (Staples & Reid, 2010). A previous meta-analysis (Fournier et al., 2010) examining the prevalence of motor coordination deficits between children with and without ASD determined there to be a significant standardized mean difference effect equal to 1.20 ($SE = 0.144$; $p < 0.0001$; $Z = 10.49$). More specifically, findings from previous research indicated that in a sample of 15 children with ASD, 73% of the population displayed fundamental skill delays, qualifying them for the *poor* or *very poor* classifications on the Test of Gross Motor Development version 2 (TGMD-II) (Berkeley, Zittel, Pitney, & Nichols, 2001; Ulrich, 2000). Recent studies have found that object-control skill ability was a major predictor of condition severity in children with ASD ($p<.05$) (MacDonald, Lord, & Ulrich, 2013). In order to address the issues of physical activity and deficits in motor development at a young age, adapted physical education programs create an adaptive and inclusive curriculum utilizing methods that accommodate for the abilities of students with

ASD and develop motor skills by promoting a transfer of learning to everyday life skills (Little, Sideris, Ausderau, & Baranek, 2014).

Statement of the Problem & Purpose

A study conducted by Sandt and Frey (2005) did reveal that children with ASD were more active during school hours compared to after-school hours, suggesting that school-time physical activity may be an optimal time slot for physical activity participation for children with ASD. Participation in fulfilling physical activity addresses three separate domains of development established by David Bloom and colleagues (Bloom, 2006); these domains consist of the psychomotor (i.e. physical movement, coordination, and use of the motor-skill), cognitive (i.e. knowledge or development of intellectual skills), and affective domains (i.e. feelings, values, appreciation, enthusiasms, motivations, and attitudes). Research suggests that the MVPA participation in children with ASD is heavily dependent on the content, physical environment, and instructor or practitioner-related characteristics (Pan, Tsai, & Hsieh, 2011b).

Similar meta-analyses have been conducted on the topic of physical exercise interventions on individuals with ASD (Sam, Chow, & Tong, 2015; Sowa & Meulenbroek, 2012), however they do not investigate what specific characteristics of the exercise interventions contribute to their effectiveness and only research conducted up to the year 2013 has been analyzed; therefore, the purpose of this study is to determine the effectiveness of physical activity interventions on the development of the psychomotor, cognitive, and affective domains in young individuals diagnosed with Autism Spectrum

Disorder (ASD). The secondary purpose of this study is to analyze the specific characteristics of these interventions (e.g. type of intervention, environment, duration, etc.) in order to further understand why an intervention may or may not be effective. In analyzing these practices and methods of physical activity, it is the hope of authors to give a variety of practitioners (e.g. physical educators, recreation leaders, etc.) tools to utilize in order to aid young individuals with ASD in their development of cooperation and physical activity skills for life-long physical fitness.

METHODS

Search Strategy

Search strategies for this study were developed around several keywords determined by the author. The main keywords utilized in the article searches included the following: autism spectrum disorder, physical education, physical activity, adapted physical education, adapted physical activity, and evidence based practices. Combinations of these keywords were inserted into searches on several academic journal databases; these databases include SPORTDiscus, ERIC, PsychINFO, PubMed/Medline, Child Development and Adolescent Studies, and PsychARTICLES.

Inclusion and Exclusion Criteria

Several inclusion criteria were implemented to determine which articles the author would save during an initial screening. The inclusion criteria for this study were as follows: (i) the study took place in a physical education (PE), physical activity (PA), or sport (S) setting; (ii) the participants of the study were aged from two to twenty-two (2-22) years of age; (iii) the study implemented a method or intervention in a PE, PA, or S setting; (iv) the study included a quantifiable outcome measure; (v) the population of the study was determined to have a disability of ASD; (vi) the study was written in the English language; (vii) the study was published after the year 1970.

Definitions of settings

To define the settings extracted from included studies, a physical education (PE) settings will be determined as activity taking place in an educational setting during school hours. Sport (S) settings will be determined as traditional team or individual, organized, sport-specific gameplay settings that occur outside of educational settings. Physical Activity (PA) settings will be determined as activity taking place outside of an educational setting or a sport-specific based setting (e.g. recreational activities such as walking, hiking, playing at a playground).

Identification of Relevant Studies

In order to determine whether articles saved from the initial searches were relevant, a X stage screening process was implemented. In stage 1, the author conducted an initial search via search engines utilizing a list of keywords developed for this analysis. If the title appeared relevant to the context of the study, the author saved the citation of the article to a citation program (EndNote X7); after completing the initial screening, the author ran a command in the citation program to remove all duplicates. In stage 2, the author screened the abstracts of articles saved to the citation database; if the abstract did not provide sufficient data or appeared to be unavailable, it was excluded from the study. In stage 3, the author retrieved the remaining articles in full-text form for further screening; if the articles did not meet inclusion criteria, they were excluded from the study.

Data Extraction

Information extracted from each article included study design (i.e. experimental or quasi-experimental), duration, setting (i.e. physical activity, physical education, or sport setting), type of training held by practitioners, outcomes measured (i.e. psychomotor, cognitive, or affective), level (i.e. degree of autism), age range, gender, country, support (i.e. whether parental support was reported in study protocol), location (i.e. rural vs. urban area), environment (i.e. physical activity, physical education, or sport setting), sample size, and measurement tool (i.e. objective or self-report).

Outliers and Publication Bias

Outliers

Outliers are studies in which findings lie within two standard deviations above or below the overall mean effect of the meta-analysis. Studies deemed as outliers will be found to result in relative residual scores (z-scores) outside the ninety-fifth percentile of the mean effect score (z score $\geq \pm 1.96$). Sensitivity analyses will be utilized in order to examine the impact of retention/removal of outliers and their influence on the overall effect score (Greenhouse & Ivengar, 1994).

Publication bias

In order to assess publication bias, three phases of control will be applied: (i) the author will conduct a comprehensive search of the literature, searching for both published and unpublished research articles relevant to the study; (ii) the author will make an observational analysis utilizing a ‘Funnel Plot’ method (i.e. visual representation of

symmetry of studies) to determine if the funnel plot is either symmetrical or asymmetrical (Duval & Tweedie, 2000a, 2000b); (iii) if the funnel plot is found asymmetrical, application of the "Trim and Fill" procedure, calculation of a 'Fail-Safe N' estimate, and inspection of funnel plots will be utilized by the author (Duval & Tweedie, 2000a; Pearson et al., 2014; Rosenthal, 1979).

Effect Size Calculations

Comprehensive Meta-Analysis (CMA) version-2 software will be utilized to make effect size calculations (Borenstein, Hedges, Higgins, & Rothstein, 2005). In order for these calculations to be made, data such as mean (M), sample size (N), standard deviation (SD), or F, t, r, or p-values will be extracted from each study (Rosenthal, 1994). The association between each physical activity intervention or method and the three learning outcomes (i.e. psychomotor, cognitive, and affective) in young individuals with ASD will be calculated utilizing a random-effects meta-analysis (Pearson et al., 2014). The studies will be used as the unit of analysis (Borenstein, Hedges, Higgins, & Rothstein, 2009). Cohen's criteria for small (> .20), moderate (> .50), and large (>.80) effect sizes was used to aid the interpretation of results (Pearson et al., 2014).

Heterogeneity of Variance

Due to the difference of study qualities expected in this review, there will be an assumption of variance of true effect size between studies. Between-study heterogeneity will be quantified using the Q-value, tau-squared (τ^2), and I-squared (I^2) statistics.

Moderator analyses will be conducted to examine associations between physical activity interventions and learning domain outcomes (i.e. psychomotor, cognitive, and affective) and the influence of selected demographic and methodological characteristics, such as age group. Analyses will be performed using Comprehensive Meta-Analysis (version-2) software (Pearson et al., 2014).

RESULTS

The main purpose of the current study was to determine the overall effectiveness across multiple outcomes of physical activity interventions on young individuals with ASD. There were a total of 23 studies with 23 independent samples that included 896 participants meeting inclusion criteria. Figure 1 provides an overall presentation of the search strategy and article screening process, while Tables 1 and 2 displays the coded methodological, participant, and study features as well as each study's overall treatment effect. When interpreting the treatment effects, Cohen's (1988) criteria were used for interpretation of standardized mean differences and summarized effect sizes as small (0.20), medium (0.50), and large (0.80). Positive effect sizes are interpreted as treatment groups (physical activity/education intervention groups) showing stronger results than control groups or groups not included in the interventions or programs. Negative treatment effects indicated that the control group or non-intervention group produced larger outcome results than the intervention group.

Random Effects Model

The average treatment effect for all physical activity/physical education intervention studies was moderate (g=0.761; SE=0.233; 95% C.I.=0.305, 1.218; p=0.001) and represented about seven-tenths a standard deviation advantage for treatment groups over control groups. Figures 3 displays the relevant statistical analyses utilized when evaluating the overall effect sizes. Moderator analyses of characteristics coded for studies

were conducted in order to further explain the between-study variation based on a heterogeneous distribution (QT=206.675, p=0.000; I2=89.355). In addition, one independent sample (Favazza et al., 2013) was found to be an outlier (z=15.678), thus an outlier analysis was conducted through evaluation of residual values and a "one-study removed" procedure was performed. The single effect size was retained in the analysis as results indicated a change (0.195), holding a moderate effect size (g = 0.566) and remaining within the 95% confidence interval.

Outcome Analyses

Several outcome analyses that were conducted produced both positive and negative effects, which ranged from *k*=-0.181 to *k*=2.756. Due to a diversity of outcome measures outlined in individual studies and the relatively small number of studies meeting inclusion criteria, authors chose to combine outcomes into several different constructs based on characteristics of study outcomes; these constructs included (i) body composition, (ii) muscular strength/endurance, (iii) cardiovascular endurance, (iv) locomotor skills, (v) manipulative skills, (vi) skill-related fitness, and (vii) social functioning. Maladaptive outcomes such as anxiety, boredom, competitive strategies, ego orientation, and perceptions of a performance climate were largest for control groups or groups exposed to performance climate conditions. Outcomes that were positive for groups included muscular strength/endurance, locomotor skills, manipulative skills, skill-related fitness, and social functioning. The largest positive effects were found for manipulative skills (*k*=3, *g*=2.756), locomotor skills (*k*=6, *g*=1.604), skill-related fitness

(*k*=11, *g*=1.294), muscular strength/endurance (*k*=8, *g*=0.818), and social functioning (*k*=5, *g*=0.785). The most negative effect sizes within the outcome analysis were found for the outcomes of cardiovascular endurance (*k*=5, *g*=0.103) and body composition (*k*=5, *g*=-0.181).

Moderator Analyses

Heterogeneity statistics for the random effects model confirmed that there was a heterogeneous (QT=206.675, $p < 0.05$) distribution and that a moderate level (I^2=89.355) of between-study variation existed to justify conducting sub-group analyses for coding characteristics. Tables 4 through 7 display all relevant statistical results from moderator analyses on intervention characteristics, participant characteristics, and study characteristics.

Intervention characteristics

No significant differences between moderators were found within intervention characteristics, however several trends were discovered within individual moderators including implementing a true experimental design (g=0.898, Z=3.087, p≤0.05), implementing an intervention for less than 10 weeks (g=1.612, Z=3.379, p≤0.05), implementing an intervention in a specialized class (g=1.425, Z=3.699, p≤0.05), practitioners trained in Adapted Physical Education (APE) (g=1.946, Z=2.835, p≤0.05), and focusing on the development of psychomotor outcomes (g=0.986, Z=2.763, p≤0.05).

Participant characteristics

No significant differences between moderators were found within participant characteristics, however several trends of intervention effects were discovered within participants diagnosed with a 'severe' degree of ASD ($g=1.678$, $Z=2.029$, $p\leq0.05$), implementing an intervention within a Physical Education setting ($g=1.217$, $Z=3.542$, $p\leq0.05$), including either both males and females or focusing on males only within an intervention ($g=0.677$, $Z=2.528$, $p\leq0.05$), and implementing an intervention for students with ASD at elementary, high school, or combined age groups ($g=0.863$, $Z=2.336$, $p\leq0.05$).

Study characteristics

No significant differences between moderators were found within characteristics of studies, however several trends of intervention effects were discovered amongst studies not utilizing parental support in study protocol ($g=0.726$, $Z=2.845$, $p\leq0.05$), studies reported from environments other than urban environments ($g=0.733$, $Z=2.967$, $p\leq0.05$), and utilizing objective measurement tools to assess study outcomes ($g=0.802$, $Z=3.338$, $p\leq0.05$).

Publication Bias

Publication bias was assessed across all constructs of outcomes referenced in Table 2 and reported with the 'Fail Safe N' measurement. Across five outcomes, several studies were deemed necessary to produce non-significant results (Muscular strength/endurance $N=66$; Locomotor skills $N=171$; Manipulative skills $N=166$; Skill-

related fitness *N*=364; Social functioning *N*=45). However, the two outcomes of body composition and cardiovascular endurance produced a Fail Safe *N* of 0, suggesting that publication bias may have been violated and no studies were required to yield non-significant (p=0.01) results within these outcomes.

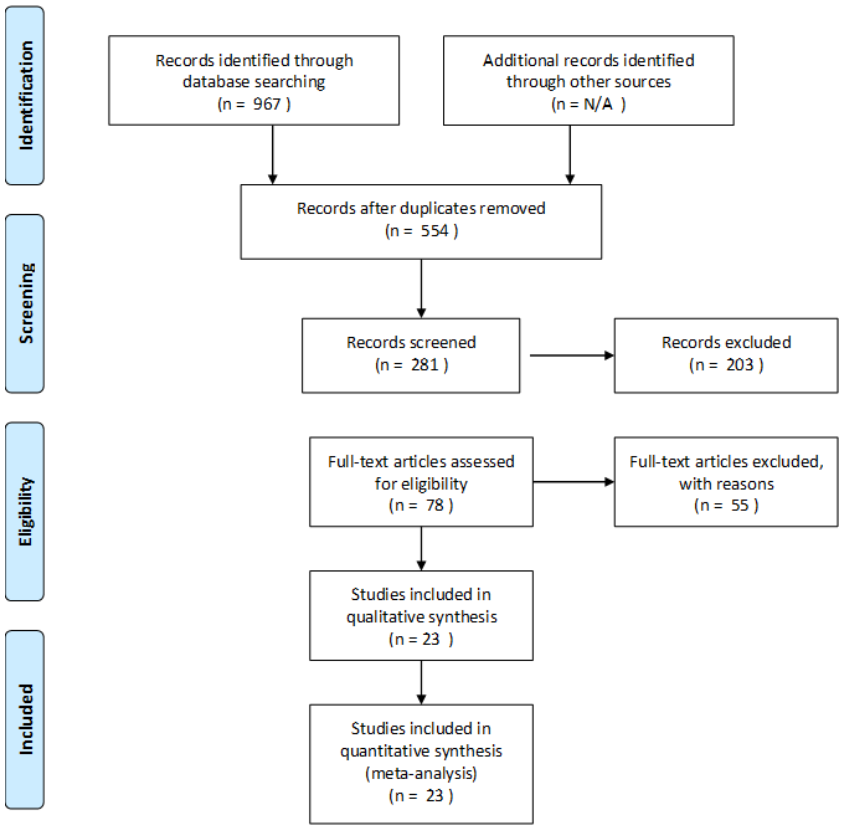

Figure 1. Search Strategy and Article Screening Process

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Table 1. Study Characteristics Meeting Inclusion Criteria

Intervention Characteristics										
Study	**Design**	**Duration (weeks)**	**Setting**	**Training**	**Outcomes**	**Level**	**N**	**Age (Years)**	**Gender**	**Environment**
Anderson-Hanley_2011	QE	<10	Study	NS	C	NR	22	12-14.99	Both	PA
Borgi_2016	E	>16	Inclusive	Other	Combined	NR	28	5-14.99	Male	PA
Chi-Hua_2012	E	10-16	Specialized	PE	Combined	Mild	42	5-11.99	Both	PE
Dickinson_2014	E	>16	Study	PE	P	Moderate	100	5-14.99	Both	PE
Favazza_2013	E	<10	Specialized	Other	P	NR	233	5-11.99	Both	PE
Fragala-Pinkham_2008	QE	10-16	Study	Medical	P	Mild	16	5-11.99	Both	PA
Fragala-Pinkham_2011	QE	10-16	Study	Medical	P	Mild	12	5-14.99	Both	PA
Gabriels_2015	E	10-16	Specialized	Medical	Combined	NR	116	5-≥15	Both	PA
Giagazoglou_2013	E	10-16	Specialized	PE	P	Moderate	18	5-11.99	Both	PE
Hilton_2014	QE	10-16	Study	Medical	Combined	NR	14	NR	NR	PA
Hinckson_2013	QE	10-16	Specialized	Other	P	NR	17	12-≥15	Both	PE
Lanning_2014	E	10-16	Study	Other	Combined	NR	13	5-14.99	Both	PA
Lourenco_2015	E	>16	Study	Other	P	Mild	17	5-11.99	Both	PA
MacDonald_2012	E	NR	Study	Other	P	NR	42	5-≥15	Both	PA
Oriel_2011	E	<10	Specialized	PE	C	Severe	9	5-11.99	Both	PE
Pan_2010	QE	>16	Study	PE	Combined	Mild	16	5-11.99	NR	PA
Pan_2011	QE	>16	Study	PE	P	NR	15	5-11.99	Both	PA
Pan_2016	E	10-16	Study	PE	Combined	NR	22	5-11.99	NR	PA
Pitetti_2007	E	>16	Study	Other	P	NR	10	≥15	Both	PA
Schleien_1990	E	NR	Inclusive	APE	A	NR	34	5-11.99	Both	PE
Weber_1989	QE	<10	Specialized	APE	P	Severe	28	5-14.99	Male	PE
Weber_1992	QE	NR	Specialized	APE	P	NR	12	5-≥15	Male	PE
Wuang_2010	E	>16	Study	Medical	Combined	NR	60	5-11.99	Both	PA

Note. Design: QE=Quasi-Experimental; E=Experimental. Duration (Weeks): NR=Not Reported. Training: NS= Not Specified; PE= Physical Education; APE= Adapted Physical Education. Outcomes: C= Cognitive; P=Psychomotor; A=Affective. Level: NR=Not Reported. Gender: NR=Not Reported. Environment: PA=Physical Activity; PE=Physical Education.

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Table 2. Study Characteristics Meeting Inclusion Criteria Continued

Intervention Characteristics						
Study	**Country**	**School**	**Support**	**Location**	**Measure**	**Effect (g)**
Anderson-Hanley_2011	United States	Middle	Parents	Not Reported	Objective	-0.07
Borgi_2016	Italy	Combined	Not Reported	Not Reported	Objective	0.874
Chi-Hua_2012	Taiwan	Elementary	No Parents	Urban	Objective	1.455
Dickinson_2014	United Kingdom	Combined	No Parents	Not Reported	Objective	0.305
Favazza_2013	United States	Elementary	Parents	Not Reported	Objective	3.106
Fragala-Pinkham_2008	United States	Elementary	No Parents	Not Reported	Objective	0.066
Fragala-Pinkham_2011	United States	Combined	Parents	Not Reported	Objective	0.211
Gabriels_2015	United States	Combined	No Parents	Not Reported	Objective	0.468
Giagazoglou_2013	Greece	Elementary	No Parents	Not Reported	Objective	-0.292
Hilton_2014	United States	Combined	No Parents	Not Reported	Objective	-0.209
Hinckson_2013	New Zealand	Combined	Parents	Not Reported	Combination	-0.056
Lanning_2014	United States	Combined	No Parents	Not Reported	Objective	0.654
Lourenco_2015	Austria	Elementary	No Parents	Not Reported	Objective	0.211
MacDonald_2012	United States	Combined	No Parents	Not Reported	Objective	0.692
Oriel_2011	United States	Elementary	No Parents	Not Reported	Objective	0.669
Pan_2010	Taiwan	Elementary	No Parents	Not Reported	Objective	0.233
Pan_2011	Taiwan	Elementary	No Parents	Not Reported	Objective	0.057
Pan_2016	Taiwan	Elementary	No Parents	Not Reported	Objective	0.33
Pitetti_2007	United States	High	No Parents	Not Reported	Objective	3.439
Schleien_1990	United States	Elementary	No Parents	Not Reported	Objective	0.885
Weber_1989	United States	Combined	No Parents	Not Reported	Objective	2.735
Weber_1992	United States	Combined	No Parents	Not Reported	Objective	2.533
Wuang_2010	Taiwan	Elementary	No Parents	Urban	Objective	0.675

Note. Design: QE=Quasi-Experimental; E=Experimental. Duration (Weeks): NR=Not Reported. Training: NS= Not Specified; PE= Physical Education; APE= Adapted Physical Education. Outcomes: C= Cognitive; P=Psychomotor; A=Affective. Level: NR=Not Reported. Gender: NR=Not Reported. Environment: PA=Physical Activity; PE=Physical Education.

Table 3. Outcome Analysis

Outcome Analysis										
VARIABLE	***k***	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2	**Fail Safe *N***
Body Composition	5	-0.181	0.145	0.021	(-0.465, 0.103)	-1.248	1.532	0	0	0
Muscular Strength/Endur.	8	0.818	0.224	0.05	(0.379, 1.257)	3.654*	17.397*	0.225	59.764	66
Cardiovascular Endurance	5	0.103	0.297	0.088	(-0.48, 0.686)	0.346	13.424*	0.294	70.203	0
Locomotor Skills	6	1.604	0.555	0.308	(0.516, 2.693)	2.889*	50.04*	1.593	90.008	171
Manipulative Skills	3	2.756	0.846	0.715	(1.099, 4.413)	3.259*	23.085*	1.921	91.336	162
Skill Related Fitness	11	1.294	0.506	0.256	(0.301, 2.286)	2.555*	176.738*	2.573	94.342	364
Social Functioning	5	0.785	1.55	0.024	(0.481, 1.089)	5.063*	5.36	0.03	25.378	45

Note. k = Number of effect sizes. g = Effect size (Hedges g). SE = Standard error. s2 = Variance. 95% C.I. = Confidence intervals (lower limit, upper limit). Z = Test of the null hypothesis. τ2 = Between-study variance in random effects model. I2 = Total variance explained by moderators. *Indicates a significant Q Total value, $p \leq 0.05$.

Table 4. Moderator Analysis

Moderator Analysis									
	k	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2
Random Effects Model[A]	23	0.761	0.233	0.054	(0.305, 1.218)	3.269*	206.675*	1.039	89.355
Design							0.59		
Experimental	14	0.898	0.291	0.085	(0.328, 1.469)	3.087*	153.962*	1.113	91.556
Quasi	9	0.537	0.37	0.137	(-0.188, 1.262)	1.452	33.942*	0.632	76.43
Duration							6.029		
<10 Weeks	4	1.612	0.477	0.228	(0.677, 2.548)	3.379*	89.208*	3.211	96.637
>16 Weeks	7	0.63	0.382	0.146	(-0.119, 1.378)	1.649	10.745	0.139	44.161
10 to 16	9	0.293	0.325	0.105	(-0.344, 0.929)	0.901	11.791	0.068	32.154
Not Reported	3	1.224	0.576	0.331	(0.096, 2.353)	2.127*	4.739	0.248	58
Setting							5.282		
Inclusive	2	1.141	0.628	0.394	(-0.089, 2.372)	1.818	1.314	0.039	23.895
Specialized	6	1.425	0.385	0.148	(0.670, 2.179)	3.699*	98.080*	2.953	94.902
Study	15	0.423	0.242	0.059	(-0.052, 0.898)	1.746	16.354	0.023	14.396

Note. k = number of effect sizes. g = Effect size (Hedges g). SE = Standard Error. S2 = variance. 95% C.I.= Confidence Intervals (lower limit, upper limit). Z = test of the null hypothesis. τ2 = Between study variance in Random Effects Model. I2 = Total variance explained by moderators. *p < .05.

Table 5. Moderator Analysis Continued

Moderator Analysis									
	k	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2
Random Effects Model[A]	23	0.761	0.233	0.054	(0.305, 1.218)	3.269*	206.675*	1.039	89.355
Training							4.385		
APE	3	1.946	0.686	0.471	(0.601, 3.292)	2.835*	13.762*	1.3	85.467
Medical	5	0.698	0.545	0.297	(-0.460, 1.676)	1.116	10.755*	0.438	62.809
Not Specified	1	-0.07	1.111	1.235	(-2.248, 2.108)	-0.063	0	0	0
Other	7	0.879	0.43	0.185	(0.036, 1.722)	2.044*	126.43*	1.991	95.254
PE	7	0.398	0.436	0.19	(-0.456, 1.253)	0.914	8.876	0.074	32.401
Outcomes							0.944		
A	1	0.885	1.147	1.315	(-1.363, 3.133)	0.772	0	0	0
C	2	0.283	0.843	0.711	(-1.369, 1.936)	0.336	1.791	0.121	44.162
Combined	8	0.563	0.428	0.183	(-0.275, 1.401)	1.316	7.926	0.02	11.682
P	12	0.986	0.357	0.127	(0.287, 1.685)	2.763*	174.230*	2.122	93.687

Note. k = number of effect sizes. g = Effect size (Hedges g). SE = Standard Error. S2 = variance. 95% C.I.= Confidence Intervals (lower limit, upper limit). Z = test of the null hypothesis. τ2 = Between study variance in Random Effects Model. I2 = Total variance explained by moderators. *p < .05.

Table 6. Moderator Analysis Continued

Moderator Analysis									
	k	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2
Random Effects Model[A]	23	0.761	0.233	0.054	(0.305, 1.218)	3.269*	206.675*	1.039	89.355
Level							2.609		
Mild	5	0.435	0.517	0.267	(-0.578, 1.448)	0.842	6.757	0.141	40.8
Moderate	2	0.027	0.789	0.622	(-1.518, 1.573)	0.035	1.378	0.049	27.433
Not Reported	14	0.867	0.309	0.095	(0.261, 1.472)	2.805*	165.050*	1.334	92.124
Severe	2	1.678	0.827	0.684	(0.057, 3.298)	2.029*	8.6*	1.885	88.372
Environment							3.008		
PA	14	0.446	0.282	0.08	(-0.108, 0.999)	1.579	16.279	0.04	20.143
PE	9	1.217	0.344	0.118	(0.544, 1.891)	3.542*	148.427*	1.74	94.61
Gender							4.348		
Both	17	0.677	0.268	0.072	(0.152, 1.202)	2.528*	181.583	1.101	91.189
Male	3	1.975	0.671	0.45	(0.660, 3.289)	2.944*	9.325*	1.075	78.551
Not Reported	3	0.123	0.646	0.417	(-1.143, 1.389)	0.191	0.713	0	0

Note. k = number of effect sizes. g = Effect size (Hedges g). SE = Standard Error. S2 = variance. 95% C.I.= Confidence Intervals (lower limit, upper limit). Z = test of the null hypothesis. τ2 = Between study variance in Random Effects Model. I2 = Total variance explained by moderators. *p < .05.

Table 7. Moderator Analysis Continued

Moderator Analysis									
	k	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2
Random Effects Model[Δ]	23	0.761	0.233	0.054	(0.305, 1.218)	3.269*	206.675*	1.039	89.355
School							4.765		
Combined	9	0.863	0.369	0.136	(0.139, 1.587)	2.336*	29.39*	0.328	72.78
Elementary	11	0.709	0.33	0.109	(0.062, 1.355)	2.149*	136.177	1.602	92.657
High	1	3.439	1.472	2.167	(0.554, 6.324)	2.336*	0	0	0
Middle	1	-0.07	1.055	1.114	(-2.138, 1.999)	-0.066	0	0	0
Not Reported	1	-0.209	1.132	1.281	(-2.428, 2.009)	-0.185	0	0	0
Support							0.068		
No Parents	18	0.726	0.255	0.065	(0.226, 1.227)	2.845*	49.155*	0.26	65.415
Not Reported	1	0.874	1.05	1.103	(-1.185, 2.933)	0.832	0	0	0
Parents	4	0.863	0.519	0.269	(-0.154, 1.880)	1.663	116.172*	3.785	97.418

Note. k = number of effect sizes. g = Effect size (Hedges g). SE = Standard Error. S2 = variance. 95% C.I.= Confidence Intervals (lower limit, upper limit). Z = test of the null hypothesis. τ2 = Between study variance in Random Effects Model. I2 = Total variance explained by moderators. *p < .05.

Table 8. Moderator Analysis Continued

Moderator Analysis									
	k	***g***	***SE***	s^2	**95% *C.I.***	***Z***	***Q***	τ^2	I^2
Random Effects Model$^{\Lambda}$	23	0.761	0.233	0.054	(0.305, 1.218)	3.269*	206.675*	1.039	89.355
Location							0.158		
Not Reported	21	0.733	0.247	0.061	(0.249, 1.218)	2.967*	204.705*	1.102	90.23
Urban	2	1.067	0.802	0.643	(-0.504, 2.638)	1.331	1.445	0.094	30.776
Measure							0.591		
Combination	1	-0.056	1.09	1.188	(-2.192, 2.080)	-0.052	0	0	0
Objective	22	0.802	0.24	0.058	(0.331, 1.272)	3.338*	200.218*	1.056	89.511

Note. k = number of effect sizes. g = Effect size (Hedges g). SE = Standard Error. S2 = variance. 95% C.I.= Confidence Intervals (lower limit, upper limit). Z = test of the null hypothesis. τ2 = Between study variance in Random Effects Model. I2 = Total variance explained by moderators. *p < .05.

DISCUSSION

The purpose of the present study was to assess the effectiveness of physical activity interventions on young individuals with ASD across several areas (i.e. psychomotor, cognitive, and affective). Results indicated an overall moderate-positive effect for participants exposed to physical activity interventions, mainly for interventions targeting the development of locomotor skills, skill-related fitness, social functioning, and muscular strength/endurance. A moderator analysis was conducted following the evaluation of outcomes, indicating that several possible factors may have influenced the effectiveness of each intervention upon young individuals with ASD.

Locomotor Skills

The Locomotor Skills category encompassed studies measuring psychomotor outcomes that assessed the development of basic locomotor skills. Multiple studies assessed the locomotor skills of young individuals with ASD utilizing a variety of intervention types, such as the Young Athletes program (Favazza et al., 2013), trampoline training (Lourenço, Esteves, Corredeira, & Seabra, 2015), and horseback riding programs (Wuang, Wang, Huang, & Su, 2010). The implementation of physical activity interventions on young individuals with ASD has shown to have an overall large effect on the development of locomotor skills ($g \geq 0.80$). Research indicates that the development of locomotor skill in young individuals with ASD can be attributed to the

motor content that is addressed, the structure of the intervention, instructional approaches, and training of researchers (Favazza et al., 2013).

Skill-Related Fitness

Skill-related fitness, such as aquatic/swimming skills, was greatly affected for experimental groups by the implementation of physical activity interventions ($g \geq 0.80$). These skills may have been influenced by the use of curriculum-based assessments, which act as the basis for the instructional approaches utilized by the researchers in these studies (Pan, 2010; Pan, 2011). This would lend more credence to the factor of appropriate training of practitioners to influence the effect of an intervention's outcome by utilizing a curriculum-based approach with developmentally appropriate learning tasks to develop aquatic skills in young individuals with ASD.

Social Functioning

The Social Functioning category encompassed studies that examined affective outcomes. Multiple studies measuring outcomes in this category utilized horseback riding as physical activity (Borgi et al., 2016; Gabriels et al., 2016; Lanning, Baier, Ivey-Hatz, Krenek, & Tubbs, 2014; Wuang et al., 2010) while others utilized various types of group play (Schleien, Rynders, Mustonen, & Fox, 1990), running/jogging programs (Oriel, George, Peckus, & Semon, 2011), peer and sibling guidance (Chu & Pan, 2012), and exergaming interventions (Anderson-Hanley, Tureck, & Schneiderman, 2011). The outcome analysis indicated that social functioning (e.g. repetitive behaviors, adaptive

functioning, social communication) in young individuals with ASD was moderately influenced by the implementation of physical activity interventions (g=0.785). Physical activity has been shown to lead to a decrease in the frequency of repetitive behaviors for young individuals with ASD (Lang et al., 2010; Petrus et al., 2008). Improvements in other outcomes, such as adaptive functioning and social communication, may be explained through the training of practitioners to facilitate communication with young individuals with ASD. For future researchers, it is recommended that studies be developed targeting similar outcomes in order to determine more effective intervention types for improving social functioning components.

Muscular Strength and Endurance

The categories of muscular strength and muscular endurance were psychomotor components in which experimental groups outperformed control groups to a large effect (g=0.818). Studies measuring these outcomes utilized a number of intervention modalities, such as Nintendo Wii exergaming (Dickinson & Place, 2014), aquatic exercise programs (Fragala-Pinkham, Haley, & O'Neil, 2008; Fragala-Pinkham, Haley, & O'Neil, 2011; Pan, 2011), and horse riding programs (Wuang et al., 2010). One study in particular (Fragala-Pinkham et al., 2011) discusses the duration of the intervention as a characteristic feature leading to improvements in these areas of physical fitness within their ASD sample. Additional research suggests that training amongst researchers to

facilitate and correct physical movement in young individuals with ASD can explain improvements within these areas (Wuang et al., 2010).

Experimental Design

The moderator analysis detected a significant influence on the performance of treatment groups from studies that utilized an experimental design as opposed to a quasi-experimental design. A true experimental design allows researchers to make a clear and sensible interpretation of whichever variables they are attempting to detect within their research, whereas quasi-experimental designs are subject to internal validity as participants may not be comparable at baseline (Quinn & Keough, 2002). For future researchers to make clearer interpretations about the effects of physical activity interventions on young individuals with ASD, it is recommended that true experimental designs be employed in order to ensure participants are at comparable levels prior to the implementation of an intervention.

Specialized Classes & Training

The moderator analysis indicated that specialized classes (i.e. classes consisting of students with ASD) had a significant influence on the performance of the experimental groups. Specialized classes are designed to help physical educators modify the environment to suit the specific needs of individual students, and this ability to modify has been shown to be a vital component to the success of students with ASD within a physical education context (Hamilton, 2006). These findings may also explain the fact

that the moderator analysis indicated a significant influence on the overall effect through adapted physical education (APE) training; instructors trained to deliver a physical education curriculum to students with special needs, students with ASD in this case, are able to modify the environment of their classes to help increase student success in the APE environment. Teachers trained within the discipline of APE alter the environment of the physical education class for students with ASD in several ways, such as: (i) limiting the amount of external stimuli that may cause students to feel a sense of over stimulation, (ii) establishing clearly defined boundaries within the play space of class, (iii) implementing strict time limits and routines for tasks, (iv) and facilitating communication for students through the use of visual cues (e.g. picture cards, posters) and supplemental languages (e.g. gestures, hand signals), all of which are examples that have been shown to help increase success for students with ASD in the physical education environment (Case & Yun, 2015; Hamilton, 2006). Additional research has shown that APE training for physical educators is a significant predictor for more inclusionary practices of students with ASD in an inclusive physical education class (Beamer & Yun, 2014).

Gender

The moderator analysis detected significant differences in studies that included both genders (i.e. male and female) and males only. None of the studies included in this present meta-analysis focused on a sample of females only. While these analyses support the literature that there is a greater occurrence of the ASD condition in males (Simonoff et al., 2008), it may benefit future researchers to expand their samples to include females.

Parental Support

The moderator analysis indicated that studies not utilizing parental support within the study protocols had the greatest influence on the performance of experimental groups. This is an interesting discovery, as the most current literature suggests that involving parents as support personnel in physical activity for young individuals with ASD is a vital component to their child's success; including parents allows them to be advocates for their children, increases collaborative efforts, and can decrease teaching challenges for practitioners (Obrusnikova & Dillon, 2011; An, 2011). It is possible that the significant findings within this moderator were due to the fact that only four of the 23 total studies reported any parental involvement; perhaps many authors may have overlooked reporting the fact that they specifically chose to not include parents in the study protocols.

Duration

The moderator analysis indicated that a duration of up to 16 weeks had a significant influence on the performance of experimental groups. As Raudenbush and Liu (2001) discuss, the duration of a study ultimately affects a study's reliability and can have influence on a study's attrition rate. According to literature on the duration of social skills interventions for youth with ASD, a time duration of less than 10 weeks would be insufficient; developing social skills specifically have been recommended to be prescribed for more than 10 to 12 weeks (Gresham, Sugai, & Horner, 2001). Perhaps the explanation for this phenomena can be explained by the demand of the activity; while

social skill development may be implemented at a higher frequency, the intensity of implementing a physical activity intervention may be more demanding on the individual's physical self, therefore yielding greater results in a shorter amount of time. It would be most beneficial for future researchers to examine the influence of intervention duration on the physical activity outcomes of young individuals with ASD in order to further pinpoint what specifically about the time span influences a study's effectiveness.

CONCLUSIONS

The physical activity interventions examined in this study have been shown to have a measureable effect on the development across several physical and social outcomes in young individuals with ASD. Several characteristics of these interventions have also been revealed to have a measureable effect on the intervention's effectiveness. However, several recommendations should be made for future researchers. In terms of study quality, it is important for researchers to report study quality as specifically as possible without overlooking several factors. Despite previous research that suggests ASD is most prevalent in males, future researchers should consider focusing solely on the effects of physical activity interventions on females with ASD. In addition to further examining similar outcomes and moderators presented in this study, future research should seek to expand the list of characteristics that could potentially have an effect on the influence of a physical activity intervention for this population; for example, how integrative technology could influence the effectiveness of a physical activity intervention. Finally, additional research should be conducted to replicate or expand on these findings to continue contributing to the field of research seeking to improve the physical activity experience for young individuals diagnosed with Autism Spectrum Disorder.

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