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Review

Physical exercise and individuals with autism spectrum disorders: A systematic review

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ABSTRACT

Studies involving physical exercise and individuals with autism spectrum disorders (ASD) were reviewed. Systematic search procedures identified 18 studies meeting predetermined inclusion criteria. These studies were evaluated in terms of: (a) participant characteristics, (b) type of exercise, (c) procedures used to increase exercise, (d) outcomes, and (e) research methodology. Across the corpus of studies, exercise was implemented with 64 participants with ASD aged 3–41 years. A variety of exercise activities were employed (e.g., jogging, weight training, bike riding). Following the exercise interventions decreases in stereotypy, aggression, off-task behavior and elopement were reported. Fatigue was not likely the cause of decreases in maladaptive behavior because on-task behavior, academic responding, and appropriate motor behavior (e.g., playing catch) increased following physical exercise. Results suggest that programs for individuals with ASD may benefit from including components designed to incorporate regular and specific types of physical activity. Areas in need of further research are discussed.

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The term autism spectrum disorder (ASD) refers to a range of neurodevelopmental disorders that include the diagnoses of autism, Asperger syndrome, and pervasive developmental disorder not otherwise specified (PDD-NOS) (Sturmey & Fitzer, 2007). The diagnostic characteristics of ASD include difficulty with social interaction, delayed or limited development of communication skills, and restrictive patterns of behavior or interests (American Psychiatric Association, 2000). In addition to these characteristics, individuals with ASD may also experience delays or deficits in the development of motor behaviors (Ghaziuddin & Butler, 1998; Green et al., 2008; Manjoiviona & Prior, 1995; Ozonoff et al., 2008).

Specifically, when compared to individuals without ASD, individuals with ASD are more likely to have difficulties with balance, postural stability, gait, joint flexibility, and movement speed (e.g., Jansiewics et al., 2006; Minshew, Sung, Jones, & Furman, 2004; Page & Boucher, 1998). Manjoiviona and Prior (1995) found impaired movement in 50% of children with Asperger's syndrome and 67% of children with autism using the Henderson Test of Motor Impairment (Stott, Moyes, & Henderson, 1972). Ghaziuddin and Butler (1998) found similar results with individuals diagnosed with autism, Asperger's syndrome, and PDD-NOS using the Bruininks–Osertsky Test of Motor Proficiency (Bruininks, 1978). In a more recent analysis, Green et al. (2008) sampled 101 children with ASD across a wide range of intellectual functioning. In that sample, 79% of the children with ASD had definite movement impairments and another 10% were rated as borderline impaired, according to the Movement Assessment Battery for Children (Henderson & Sugden, 1992).

These deficits in motor abilities may be exacerbated by reduced opportunity to engage in physical activity. For example, Pan (2008) compared levels of physical activity during school by elementary students with ASD ($n = 23$) and those without disabilities ($n = 23$). In that study, accelerometer measurements indicated that children with ASD were significantly less active than the comparison group ($p < .01$). Similarly, Draheim, Williams, and McCubbin (2002) reported survey results suggesting that 47–51% of older individuals with intellectual disabilities, including ASD, residing in community settings may be living dangerously sedentary lifestyles. Previous research also suggests that health problems related to a sedentary lifestyle including cardiovascular disease, insulin resistance syndrome, and obesity are more common amongst individuals with intellectual and developmental disabilities such as ASD, than amongst individuals without developmental disabilities (e.g., Chanias, Reid, & Hoover, 1998; Draheim et al., 2002a,b; Janicki & MacEachron, 1984; Rimmer, Braddock, & Fujiura, 1993, 1994; Rimmer, Braddock, & Marks, 1995). However, when exercise is increased, improvements in physical health (e.g., Chanias et al., 1998), intellectual functioning, perception, behavior, affect, and personality have been reported (e.g., Folkins & Sime, 1981; Gabler-Halle, Halle, & Chung, 1993).

Given that individuals with ASD may suffer impairments in motor skills, are likely to engage in little exercise, and the potential physical, psychological, and behavioral benefits of increased exercise, it is not surprising that studies have been conducted to investigate exercise behavior in individuals with developmental disabilities. At least four literature reviews related to developmental disability and exercise exist (Block & Obrusnikova, 2007; Chanias et al., 1998; Folkins & Sime, 1981; Gabler-Halle et al., 1993). Block and Obrusnikova (2007) reviewed studies from 1995 to 2005 in which students with disabilities were included in school based physical education classes. That study found that students with disabilities can be successfully included in physical education classes with appropriate support. Chanias et al. (1998) conducted a meta-analysis to determine the effects of exercise on the physical fitness of individuals with intellectual disability and found large effect sizes for improvements in muscular and cardiovascular endurance, moderate effects for strength, and small effects for flexibility. Folkins and Sime (1981) reviewed studies involving physical fitness and mental health for both disabled and non-disabled populations, and reported general psychological improvement for children with intellectual disabilities. Gabler-Halle et al.'s (1993) review focused on the effects of aerobic exercise on psychological variables and found various degrees of relationships between increased aerobic exercise and positive changes in intellectual functioning, behavior, and self-concept. However, there continues to be a need for reviews that focus on the behavioral, psychological, and physical effects of exercise specifically in individuals with ASD. Additionally, from a clinical perspective, there is also a need for reviews focused on methods utilized for increasing physical exercise in individuals with ASD.

To facilitate evidence-based practice in this important area, we herein provide a systematic review of interventions designed to increase the exercise behavior of individuals with ASD. The objective of this review is to describe the characteristics and exercise interventions of the included studies (e.g., participants, how exercise behaviors were taught, and benefits of increased exercise). A review of this type is primarily intended to guide and inform practitioners as they develop school and residential programs for individuals with ASD. A secondary aim is to build upon the existing database so as to stimulate future research efforts aimed at using exercise to improve the physical and psychological health of individuals with ASD.

1. Method

This review involved a systematic analysis of studies that focused on interventions designed to increase the exercise behavior of individuals with ASD. Each identified study that met predetermined inclusion criteria was analyzed and summarized in terms of: (a) participant characteristics, (b) exercise behavior taught, (c) teaching procedures, (d) outcomes, and (e) research methodology. To assess research methodology, each study's design and related methodological details (e.g., research design and reliability of data) were appraised.

1.1. Search procedures

A five step systematic search procedure was used to identify studies for possible inclusion in this review. First, searches were conducted in three electronic databases: Education Resources Information Center (ERIC), MEDLINE, and PsycINFO. Publication year was not restricted, but the search was limited to studies written in English and appearing in peer-reviewed journals. On all three databases, the keywords "exercise", "fitness", "aerobic" and "physical activity" were paired with "autism", "Asperger", and "PDD-NOS" (e.g., exercise plus autism) and searched. This process identified 86 studies for possible inclusion. Second, the abstracts of these studies were reviewed to identify studies meeting the inclusion criteria (see Section 1.2). Third, reference lists of studies meeting these criteria were then reviewed to identify additional articles for possible inclusion. Fourth, the surname of the first author of each of the included studies was then searched to identify additional work by those authors to be considered for inclusion. Finally, in order to identify recent studies that were not yet listed in the aforementioned databases, hand searches covering January–November 2009 were then completed for the journals that had published more than two of the included studies. This systematic multi-step search procedure occurred during November 2009.

1.2. Inclusion and exclusion criteria

To be included in this review, studies had to meet two inclusion criteria. First, the study had to contain at least one participant with an ASD diagnosis (i.e., autism, Asperger's, or PDD-NOS). Second, exercise had to be either the dependent variable (i.e., an intervention intended to increase exercise behavior was implemented) or an independent variable (e.g., effect of exercise on stereotypy). Exercise was defined as repetitive gross-motor movement requiring physical exertion. Although it was possible, no studies considered for inclusion were excluded based on the decision that the motor behavior targeted was not "exercise". Studies in which exercise was used as a punishment (often called "contingent exercise") were excluded (e.g., Luce, Delquadri, & Hall, 1980) because the effect of punishment and/or the ability of exercise to serve as a punisher were not the focus of this review.

1.3. Data extraction

Each identified study was first assessed for inclusion/exclusion. Then, each included study was summarized in terms of the following features: (a) participant characteristics, (b) exercise behavior taught, (c) teaching procedures, (d) outcomes, and (e) research methodology. Various procedural aspects were also noted, including setting, experimental design, and interobserver agreement. The effects of exercise or the changes in frequency of exercise behavior were summarized by reporting the statistical findings of group designs or by calculating the Percent Non-Overlapping Data (PND; Scruggs, Mastropieri, & Casto, 1987) in single-subject designs. In some cases it was possible to calculate the mean PND for a group of participants within a single-subject study. This was done by first calculating the PND for each participant individually and then averaging those percentages. In single-subject designs in which PND could not be calculated (e.g., due to an extreme baseline point or the absence of individual session data) outcomes were summarized in the terms used by the author of that study.

1.4. Reliability of search procedures and inter-rater agreement

In order to ensure the accuracy of the systematic search, the first and third authors both independently ran the multi-step search procedures and made an initial determination as to whether each study identified met inclusion criteria. Agreement as to whether a study should be included or excluded was 83% (i.e., agreement was obtained on 15 of the 18 studies). Two reasons accounted for the three disagreements. First, one author did not identify two studies in the search that were located by the other author. Once identified, both authors agreed that the overlooked studies met inclusion criteria. Second, one study (Gordon, Handleman, & Harris, 1986) was included by one author and excluded by the other. This disagreement occurred because the study did contain a condition in which exercise was a punisher (an exclusion criteria), but also contained a condition in which exercise was used as an antecedent intervention. Ultimately, this study was included because the relative effects of antecedent and contingent exercise were considered in line with the focus of this review (i.e., to inform practitioners as they incorporate exercise into programs for individuals with ASD).

After the list of included studies was agreed upon, the first author extracted information to develop an initial summary of the 18 included studies. The accuracy of these summaries was independently checked by one of the remaining co-authors using a checklist that included the initial summary of the study and five questions regarding various study details. Specifically, (a) is this an accurate description of the participants? (b) Is this an accurate description of exercise behavior being targeted? (c) Is this an accurate summary of the procedures used to increase exercise? (d) Is this an accurate description of the outcomes? and (e) Is this an accurate summary of the research methodology? Co-authors were asked to read the study and the summary and then complete the checklist. In cases where the summary was not considered accurate, the co-authors were asked to edit the summary to improve its accuracy. The resulting summaries were then agreed upon and used to create Table 1.

This approach was intended to ensure accuracy in the summary of studies and to provide a measure of inter-rater agreement on data extraction and analysis. There were 90 items on which there could be agreement or disagreement (i.e., 18 studies with 5 questions per study). Agreement was obtained on 82 items (91%). In the eight instances where aspects of the summaries were initially considered inaccurate, changes were made to more accurately summarize the studies.

2. Results

2.1. Participants

Collectively, the 18 studies provided intervention to a total of 64 participants with ASD. Thirty-four (53%) of the participants were male and six (9%) were female, consistent with the male to female ratio within the ASD population (American Psychiatric Association, 2000). The sex of the remaining 24 participants' (38%) was not identified. The mean age was 12.5 years old (range, 3–41). Autism was the most common diagnosis ($n = 57$) followed by PDD-NOS ($n = 7$).

2.2. Settings

In most studies exercise occurred in one setting and the effects of exercise on dependent variables (e.g., stereotypy, task engagement, disruptive behavior) were assessed in a separate setting. The most common arrangement was to exercise on a school track, in the school gym, or on a school sports field and then to go directly from the exercise setting to the participant's classroom setting (Celiberti, Bobo, Kelly, Harris, & Handleman, 1997; Gordon et al., 1986; Levinson & Reid, 1993; Prupas & Reid, 2001; Rosenthal-Malek & Mitchell, 1997; Todd & Reid, 2006; Watters & Watters, 1980). A comparable approach was used for older individuals in residential settings, in which exercise occurred in a park, or similar setting, near the residential facility and then dependent variables were assessed within the residential facility or community work place (Allison, Basile, & MacDonald, 1991; Elliot, Dobbin, Rose, & Soper, 1994; Pitetti, Rendoff, Grover, & Beets, 2007; Powers, Thibadeau, & Rose, 1992). Five studies were conducted in university or clinic settings (Fragala-Pinkham, Haley, & O'Neil, 2008; Kern, Koegel, & Dunlap, 1984; Kern, Koegel, Dyer, Blew, & Fenton, 1982; Lochbaum & Crews, 2003; Reid, Factor, Freeman, & Sherman, 1988). Rosenthal-Malek and Mitchell (1997) measured the effects of exercise on work performance and self-stimulatory behavior in a classroom setting and in a community work placement.

2.3. Exercise behaviors used

The majority of studies ($n = 11$) instructed participants to run or jog around a track or on a large open field (e.g., park, lawn of school, sports field). In three studies participants engaged in water-based exercises (e.g., swimming and water aerobics). Exercises used in only one study each included, stationary bike riding, lifting weights, treadmill walking, roller-skating, muscle toning with stretching, and walking in snow shoes. See Table 1 for a list of exercises taught in each study.

2.4. Teaching procedures

The procedures used to teach exercise were reported in 15 of the 18 studies (83%). The most common exercise taught was jogging and the most common instructional or support procedure used to increase jogging was modeling and physical guidance. Specifically, eight studies taught participants to jog by having a teacher or therapist run alongside the participant (Allison et al., 1991; Celiberti et al., 1997; Gordon et al., 1986; Kern et al., 1982, 1984; Levinson & Reid, 1993; Prupas & Reid, 2001; Watters & Watters, 1980). The proximity of the teacher or therapist to the participant while jogging allowed for verbal praise to be delivered contingent on jogging and for the therapist or teacher to adjust the pace of the jog as needed. In four studies a graduated guidance prompting system was used to keep participants running at the target pace for the intended amount of time (Allison et al., 1991; Celiberti et al., 1997; Levinson & Reid, 1993; Watters and Watters, 1980). This prompting system involved using physical guidance (i.e., holding the hand or arm while running) and verbal prompts (i.e., stating, ''keep running'') as needed. Prupas and Reid reported that one participant in their study refused to run alongside the teacher. However, when his classmates without disabilities ran the same route the participant would run with them. Prupas and Reid also embedded jogging within the context of games and activities (e.g., ''Follow-the-Leader'', ''Tag'', and similar age appropriate playground games). The purpose of this was to make the exercise more enjoyable thereby increasing the participants motivation to engage in the exercise.

The teaching procedures for the other exercise behaviors (e.g., bike riding, weight training, roller-skating) involved providing verbal reinforcement ($n = 7$), edible reinforcement ($n = 1$), use of systematic prompting hierarchies with prompt fading ($n = 12$), and modeling with verbal instructions ($n = 6$) (see Table 1). Although teaching procedures were mentioned in the majority of the studies (83%), few studies provided substantial detail. The two studies providing the most detailed descriptions of the instructional procedures were Best and Jones (1974) and Todd and Reid (2006).

Best and Jones (1974) taught 4 children ages 2–4 with autism to engage in water-based exercises (e.g., swimming and water aerobics). These exercise behaviors were taught using a most to least prompting hierarchy that involved systematically fading prompts from most intrusive (physical guidance) to least intrusive (modeling). All instruction was delivered individually and exercises were play orientated and embedded within preferred activities.

Todd and Reid (2006) involved exercise (i.e., snow shoeing or walking) as the dependent variable for the evaluation of a self-management/monitoring intervention package designed to increase exercise behavior. In this study three participants with autism were taught to snow shoe or walk around a 57 m $\times$ 50 m athletic field. These exercises were taught using a self-monitoring board, verbal prompting, and edible reinforcement (i.e., small pieces of preferred food). The participants were taught to walk/snow shoe around the athletic field with verbal instructions and modeling from the therapist. Participants were then taught to place stickers on the self-monitoring board after completing each exercise session. After a certain number of stickers had been earned, a small edible reinforcer was delivered. Over time the reinforcement schedule was thinned and verbal prompts were faded. Participants continued exercising without these procedures being implemented.

2.5. Outcomes of reviewed studies

All of the reviewed studies reported improvements in either behavior (e.g., reduced stereotypy, aggression, or self-injury), academics (e.g., increased amount of time on-task or increased accuracy in academic responding), physical fitness (e.g., increased endurance or strength), or increased exercise behavior (e.g., spent more time engaged in exercise). The most common behavioral improvement associated with increases in exercise was reduced stereotypy or self-stimulatory behavior, which was reported in eleven studies (Allison et al., 1991; Celiberti et al., 1997; Elliot et al., 1994; Kern et al., 1982, 1984; Levinson & Reid, 1993; Powers et al., 1992; Prupas & Reid, 2001; Reid et al., 1988; Rosenthal-Malek & Mitchell, 1997; Yilmaz, Yanardag, Birkan, & Bumin, 2004; Waters and Waters, 1980). One study reported reduced aggression (Allison et al., 1991), one study reported reduced self-injury (Elliot et al., 1994), and two studies reported reduced classroom disruptive behaviors (Celiberti et al., 1997; Gordon et al., 1986). Four studies reported improvement in physical fitness associated with increases in exercise (e.g., improved endurance, strength, flexibility, and aerobic fitness) (Best & Jones, 1974; Fragala-Pinkham et al., 2008; Lochbaum & Crews, 2003; Pitetti et al., 2007; Yilmaz et al., 2004). Four studies reported improvements in academics. This included increased amount of time spent involved with academics (on-task behavior) (Kern et al., 1982; Powers et al., 1992; Reid et al., 1988), increased responses to academic demands and questions (Kern et al., 1982), and increased correctness or accuracy to academic demands (Kern et al., 1982; Rosenthal-Malek & Mitchell, 1997). One study reported improvements in vocabulary following exercise (Best & Jones, 1974) and one study involved exercise as the dependent variable and reported improvements in exercise behavior (Todd & Reid, 2006). Best and Jones (1974) and Watters and Watters (1980) found improvements in some variables but not on standardized tests of social development and academic behaviors, respectively.

2.6. Research methodology

Six studies used a form of a group design or statistical procedures and 13 studies used a single-subject design. Of the 18 studies, five were classified as not utilizing an experimental design (e.g., did not demonstrate experimental control in a single-subject design or did not use randomize assignment within a group design). See Table 1 for a description of the research design used in each study. Twelve studies measured interobserver agreement and reported agreements above 80% or correlations above r .90 (see Table 1). In three studies heart rate monitors were used to ensure participants were engaged in sufficiently strenuous levels of exercise. The use of heart rate monitors for this purpose can be considered a type of treatment fidelity measure (Allison et al., 1991; Elliot et al., 1994; Levinson & Reid, 1993). Two studies attempted to use heart rate monitors for this purpose but the participants refused to use these devices (Pitetti et al., 2007; Prupas & Reid, 2001). In these studies and in Kern et al. (1982, 1984) behavioral indicators such as rapid breathing and red flushed face were used to gage levels of exertion during exercise.

3. Discussion

Our systematic search yielded 18 studies involving the exercise behavior of individuals with ASD. Summaries of these studies revealed that the existing literature base is perhaps best described as limited with respect to the overall scope of the existing corpus of studies, and the relatively few number of participants (N = 64). In terms of methodological quality, perhaps the most important limitation is that many of the studies would benefit from the use of a strong experimental design. Despite these important limitations, the ubiquitous positive findings across a wide range of dependent variables does suggest that increasing the exercise, or at least the physical activity, of individuals with ASD is likely beneficial. Not only in terms of physical health, but perhaps also in terms of decreased maladaptive behavior (e.g., stereotypy) and increased adaptive behavior (e.g., classroom on-task behavior).

Gabler-Halle et al. (1993) suggested that perhaps physical fitness programming for those with developmental disabilities would have a wider appeal and application if it were embedded in the broader context of positive psychological and behavioral change. The findings of this review do suggest that exercise may produce positive changes in behavior beyond direct effects on physical fitness. However, the mechanism of action for these improvements is not clear. Folkins and

Table 1
Summarizes the (a) Participant characteristics, (b) exercise used, (c) teaching procedures, (d) outcomes, and (e) research methodology for each of the 18 included studies.

Citation	Participant characteristics	Exercise behavior and teaching procedure	Outcomes	Research methodology
Allison et al. (1991)	1 male, 24 years old, with autism.	*Behavior*: jog for 20 min on an outdoor track. *Teaching procedures*: Two therapists jogged along with the participant guiding him as needed.	Number of aggressive episodes decreased from *M*[a] of 2 in baseline to *M* of .36 following exercise. Exercise + medication (Lorazepam) resulted in *M* of .93, medication alone resulted in a *M* of 1.26.	An ABACD design compared no exercise (A), to exercise alone (B), exercise + medication (C), and medication alone (D). Only 1 phase of each condition was implemented and, the effect of medication cannot be determined because medication was never withdrawn once implemented. IOA[b] was NR[c].
Best and Jones (1974)	4 children, 2–4 years old ($M = 3$), autism.	*Behavior*: swim and water aerobics for 30 min. *Teaching procedures*: Instruction was embedded in games and play. Prompts were faded from most to least starting with physical guidance. Praise was used as reinforcer.	Qualitative descriptions of improvements in gross-motor behavior while in the water were reported. Measures on the Purdue Motor Development Survey indicated a *M* of 61 (“extreme [motor] retardation”) improved to a *M* of 107. Improvements were reported on the Peabody Picture Vocabulary Test, Merrill Palmer Mental Test, and the Fels Behavior Rating Scale. No improvement was detected n the Frostig Developmental Test, or the Gunzberg Test of Social Development.	Pre/post-test design was used. Replication with an experimental design and the inclusion of quantifiable outcome measures for standardized tests is needed. IOA was NR.
Celiberti et al. (1997)	1 male, 5 years old, with autism.	*Behavior*: jog for 6 min on the lawn in front of school. *Teaching procedures*: A therapist ran with the participant physically guiding him by holding hands as needed.	Stereotypy decreased from *M* of 60% in baseline to *M* of 40% following exercise (PND[d] = 100%), Out-of-seat behavior decreased from *M* of 18 occurrences in baseline to *M* of 9.5 occurrences following exercise (PND = 50%). Decreases in these behaviors were less pronounced towards the end of sessions than at the beginning, but remained below baseline levels for up to 40 min.	An ABCBC design compared no outdoor activity or exercise (baseline, A), to jogging (B), and walking (C). Certainty regarding the effects of jogging is strengthened by including a walking condition that controlled for possible effects due to change in schedule and trips outside. IOA was above 80%.
Elliot et al. (1994)	3 males and 3 females, 22–41 years old ($M = 30$), with autism.	*Behavior*: jog for 20 min on a treadmill and slowly riding a stationary bike. *Teaching procedures*: NR	Maladaptive behavior (e.g., aggression, self-injury, property destruction) and stereotypy (e.g., body rocking) was significantly less following vigorous exercise (jogging) than no exercise ($x2(1) = 11.568$, $p < .001$). General motor training (stationary bike) did not significantly differ from either vigorous or no exercise ($x2(1) = 1.672$, $p < .30$).	A one-factor repeated measures design compared vigorous exercise (jogging) to general motor activity (slowly riding a stationary bike) and a non-exercise control condition. Certainty regarding the benefits of vigorous exercise was increased by use of heart rate measures and the control condition which controlled for the possible confounds of change in schedule and attention. IOA correlation between observers was $r = .97$.

Fragala-Pinkham et al. (2008)	6 males, 9–11 years old ($M = 10$), 3 with autism and 3 with PDD-NOS.	*Behavior*: water aerobics. *Teaching procedures*: NR	Significant reduction in the amount of time to complete a half mile run/walk ($F = 231.7$; df; $p < .001$) a moderate effect size (ES = .67). Other measures of strength and flexibility did not result in a significant increase.	A repeated measures ANOVA design with 2 baseline data points and 1 post-test. Data for the 6 participants with ASD is not differentiated from the 10 other children with different disabilities included in the design.
Gordon et al. (1986)	1 male, 7 years old, with autism.	*Behavior*: jog for 1/4 mile. *Teaching procedures*: The classroom teacher ran with the participant before class.	The effects of antecedent exercise were compared to contingent exercise. In the antecedent exercise condition, out-of-seat behavior decreased from a *M* of 77 episodes in baseline to *M* of 4 (PND = 60%). In the contingent exercise condition out-of-seat behavior was decreased from a *M* of 77 episodes in baseline to a *M* of 9 (PND = 94%).	An ABACB design compared baseline (A), contingent exercise (B) and antecedent exercise (C). Jogging was initially used as a punisher which may have changed the effects of the antecedent exercise condition by potentially conditioning running to be aversive. IOA was above 90%.
Kern et al. (1984)	3 children, ages 7, 7, and 11 years old, with autism.	*Behavior*: jog for 15 min and playing catch with a ball for 15 min. *Teaching procedures*: In the jogging condition, an adult ran with the participant. The adult verbally reinforced the child for running. In the ball-playing condition, an adult threw a 20 cm soft ball to the child with a distance of 2–3 m. Correct ball-playing responses were verbally reinforced by the adult.	Vigorous exercise (jogging) was found to reduce stereotypy more (*M* of 58% of intervals contained stereotypy) than mild exercise (ball play) (*M* of 78% of intervals contained stereotypy).	A simultaneous-treatments design was used to compare vigorous exercise (jogging) to mild exercise (playing catch) Certainty regarding the benefits of vigorous exercise was increased by counter balancing the order of the conditions to control for sequence effects. IOA was above 90%.
Kern et al. (1982)	7 children, 4–14 years old ($M = 8$), with autism.	*Behavior*: jog for 20 min. *Teaching procedures*: Adult ran with the participant.	Behavior following jogging was measured in 3 settings. In an academic setting on-task behavior increased (*M* PND = 72%), self-stimulation decreased (*M* PND = 100%), number of responses to academic demands increased (*M* PND = 92%), and number of correct responses increased (*M* PND = 96%). In ball play setting, self-stimulation decreased (*M* PND = 70%). In clinic room self-stimulation decreased (*M* PND = 81%).	A repeated-reversal design with 45 reversals between pre- and post-jogging conditions and multiple baseline across participants. IOA was above 90%.
Levinson and Reid (1993)	2 males and 1 female, 11 years old, with autism.	*Behavior*: jog for 15 min in a large open field near school. *Teaching procedures*: A therapist walked or jogged with the participant using a graduate guidance prompting procedure and verbal praise.	Following vigorous exercise, stereotypy decreased from baseline levels by a *M* of 17.5% across participants. Mild exercise did not affect stereotypy. The effects of vigorous exercise on stereotypy diminished over time. Stereotypy returned to baseline levels 90 min post-exercise.	An ABCA design compared no exercise (A), to a mild exercise program (B), and a vigorous program (C). Sessions within phases were averaged together to make one data point per phase which prevented calculation of PND. IOA was above 80%.

Table 1 (*Continued*)

Citation	Participant characteristics	Exercise behavior and teaching procedure	Outcomes	Research methodology
Lochbaum and Crews (2003)	5 individuals, 16–21 years old, with autism.	*Behavior*: 3 participants were taught to ride a stationary bike and 2 were taught to lift weights on a Nautilus© exercise machine. *Teaching procedures*: A therapist provided modeled target behaviors, verbal prompts, and reinforcement.	All participants improved between 33% and 50% aerobic fitness as measured by the Power Work Capacity fitness test (PWC; Astrand & Rodahl, 1986, pp. 358–359). Participant 1 improved 19% on bench press, 47% on low row, and 29% on leg press. Participant 2 improved 28% on bench press, 21% on low row, and 12% on leg press.	Pre/post-test design. IOA was above 80%. Replication with an experimental design would be useful.
Pitetti et al. (2007)	3 males and 2 females, 14–18 years old ($M = 16$), with autism (5 additional participants in control group who did not receive an exercise intervention).	*Behavior*: walk on treadmill. *Teaching procedures*: NR	Improvement in exercise capacity (i.e., speed and elevation settings on treadmill) and caloric expenditure were reported. Statistically significant decrease in body mass index ($t(4) = 3.23$, $p = .016$) with a modest effect size (ES = .38).	Participants were randomly assigned to exercise or no exercise control group and differences between groups were calculated in an independent sample t-test. A larger sample size would be helpful for making conclusions.
Powers et al. (1992)	1 male, 8 years old, with autism.	*Behavior*: roller skate for 10 min outside residential facility. *Teaching procedures*: A therapist provided verbal prompting.	Self-stimulatory behavior decreased from a *M* of 64% during baseline (range, 0–100%) to *M* of 19% following roller skating (range, 6–33%). On-task behavior increased from *M* of 46% in baseline (range, 14–94%) to *M* of 75% (range, 54–94%) following roller skating.	An ABAB design was used. PND could not be calculated due to maximum baseline quantities. IOA was above 90%.
Prupas and Reid (2001)	4 children, 5–9 years old, with autism or PDD-NOS	*Behavior*: jog for 10 min outside school *Teaching procedures*: A therapist ran with participants. Music Games, such as "tag" and "Follow-the-Leader", were played to motivate the participants to keep jogging. For 1 participant who would not run with the teacher, peers without disabilities jogged with the participant.	When exercise sessions were held 1 time daily *M* reduction in stereotypy across participants was 51.6%. When exercise sessions were held 3 times daily the *M* reduction in stereotypy was 58.9%. Decreases in stereotypy also seemed to be related to adherence to a routine in the classroom. With more structured classroom routines being associated with the greater reductions in stereotypy.	An ABACA design compared no exercise (A), 1 daily session of exercise (B), and 3 daily sessions of exercise (C). In order to control for possible sequence effects, 2 participants received the single session first and 2 participants the 3 sessions first. IOA was above 80%.
Reid et al. (1988)	3 males, 12, 17, and 17 years old, 1 with autism and 2 with PDD-NOS.	*Behavior*: muscle toning and stretching techniques including, arm circles, toe touches, leg bicycling, and sit-ups. *Teaching procedures*: Verbal prompting and reinforcement.	Across participants, on-task behavior improved ($M = 28\%$), off-task behavior decreased ($M = 43\%$), self-stimulation decreased ($M = 23\%$), inappropriate vocalizations decreased ($M = 20\%$), and pro-social behavior and speech did not change.	An ABA design across conditions was used. PND could not be calculated because individual session data within each condition was averaged and reported as 1 data point with graph. IOA was above 90%.
Rosenthal-Malek and Mitchell (1997)	5 males, 14–15 years old, with autism.	*Behavior*: jog for 20 min around the school gym.	Correct responses to academic demands were greater following exercise than the comparison non-exercise conditions ($M = 33.6$, $SD = 16.15$; $M = 29.6$, $SD = 15.57$, respectively) which was a significant difference ($t(4) = 2.83$, $p < .05$). Number of work tasks completed during the workshop condition was greater following exercise than non-exercise comparison condition ($M = 24.2$, $SD = 6.42$; $M = 21.8$, $SD = 6.98$, respectively) which was a significant difference ($t(4) = 4.71$, $p < .01$). Self-stimulatory behavior was lower following exercise condition for all participants (*M* PND for the decrease = 80%).	The effects of exercise were measured in the classroom and during a community work placement. In a multielement design, 2 conditions (following exercise and following academics) were compared for each participant in both settings. IOA was above 90%.

		Teaching procedures: Verbal prompting and reinforcement.		
Todd and Reid (2006)	3 males, 15, 16, and 20 years old, with autism.	*Behavior*: snowshoe and jog for 30 min in a field or park. *Teaching procedures*: Participants used a self-monitoring procedure that involved placing a happy face sticker on a chart after completing exercises. Edible reinforcement (small pieces of candy) was given after a specific number of stickers. Verbal prompting and praise were given during exercise sessions by a therapist.	This study evaluated the use of the teaching procedures to increase exercise behavior (i.e., exercise behavior was the dependent variable). Exercise behavior was measured in distance traveled during 30 min sessions. At baseline the *M* distance traveled across participants was 114 m following implementing and then fading reinforcers and prompting, the *M* distance traveled was 456 m.	Across the phases of a changing criterion design components of the teaching procedure were removed (e.g., stop providing edible reinfor cement and prompting). Replication with an experimental design is needed. Improvements in distance traveled could have been due to intervention or a change from snowshoe to walking. IOA was above 90%.
Yilmaz et al. (2004)	1 child, 9 years old, with autism.	*Behavior*: swim and engage in a variety of movements within the water. *Teaching procedures*: A prompting system that included modeling, physical, verbal, and visual prompts was used.	Improvements in flexibility, strength, and balance were reported. Three topographies of stereotypy decreased immediately following swim sessions, "swinging" decreased from a *M* of 7 min out of a 60 min observation to 5 min, "spinning" from 2 min to 0 min, and echolalia from 4 min to 2 min.	Pre/post-test design and no reported IOA. Additional research using an experimental design is needed.
Waters and Watters, 1980	5 males, 9–11 years old, with autism.	*Behavior*: jog for 8–10 min outside school. *Teaching procedures*: The classroom teacher ran with the participants physically prompting as needed but gradually faded physical prompts until participants ran independently.	Across participants, self-stimulation was lower following exercise (*M* = 32%) than following a no exercise control session. The amount of responding to academic task demands was not affected by exercise.	Stereotypy and academic responding were measured following a TV watching session, academic demand session, and exercise session. Amount of stereotypy and academic responding were compared for each of these sessions. Use of an experimental design is needed. IOA was above 90%.

[a] *M* = mean.
[b] IOA = interobserver agreement.
[c] NR = not reported.
[d] PND = percent non-overlapping data.

Sime (1981) reviewed theories relating exercise to psychological variables and reported similar findings and limitations in individuals with mental retardation and individuals without disabilities (i.e., improvements in psychological variables but no clear mechanism of action).

One possible explanation for the improvements that involve decreases in maladaptive behavior is that fatigue resulting from exercise leads to a decrease in all behavior, including dependent variables such as stereotypy and self-stimulation. Although this explanation is plausible, studies in which concurrent increases in appropriate behavior are reported would seem to control, at least to some extent, for the effects of fatigue. For example, Rosenthal-Malek and Mitchell (1997) taught five children with ASD to jog around a gymnasium for 20 min. Following jogging, self-stimulatory behavior in the classroom and a community work place was substantially decreased, which could be explained by fatigue. However, responses to academic demands and number of work tasks completed increased following exercise, suggesting participants were not too fatigued to work with increased proficiency and accuracy. Similar results involving increased adaptive behaviors were also found in Kern et al. (1982), Powers et al. (1992), and Reid et al. (1988). These few studies with a limited number of participants do not completely discount the potential effects of fatigue as one possible factor contributing to improvements. However, they do suggest other factors may also be involved.

One such factor that may contribute to reductions in stereotypy (the most common reported improvement in the reviewed studies) is the possibility that the physical stimulation obtained via exercise may be similar to that obtained via stereotypy for some children. Stereotypic behaviors (e.g., body rocking, arm flapping, and spinning in circles) are often hypothesized to occur because the behavior itself produces pleasant internal consequences for the individual (i.e., automatic reinforcement) (Rapp, Vollmer, Peter, Dozier, & Cotnoir, 2004). Because exercise may involve similar body mechanics to that of stereotypy and therefore may produce similar internal states, it is possible that the participants' need for this automatic reinforcement is obtained sufficiently during exercise sessions, thereby, creating a brief window in which behavior is allocated to obtaining other reinforcers (e.g., reinforcers available for the completion of academic or work related tasks). The idea that prior access to a reinforcer maintaining an undesirable behavior may reduce that behaviors occurrence for brief periods is consistent with the motivation operation concept (see McGill, 1999; Michael, 2000) and has been investigated in several intervention studies (e.g., Lang et al., 2009; McComas, Thompson, & Johnson, 2003; O'Reilly et al., 2007, 2008). If such a relationship between exercise and stereotypy does exist, then improvements in exercise-based stereotypy interventions might be possible by matching the type of exercise chosen to the topography of the stereotypy. For example, if a participant's stereotypy involves arm flapping then an exercise or physical activity that also involves arm motion might more closely match the putative reinforcing properties than exercise that does not involve the arms.

In terms of the main aim of this paper, to guide and inform practitioners as they develop school and residential programs for individuals with ASD, the following points have emerged from this review. First, it appears that vigorous exercise has a more pronounced effect than milder less strenuous exercise. Vigorous exercise was compared to mild exercise in four studies involving a total of 13 participants and, in all cases, vigorous exercise produced more substantial improvements than less strenuous exercise (Celiberti et al., 1997; Elliot et al., 1994; Kern et al., 1984; Levinson & Reid, 1993). Second, the positive effects of exercise may be temporary. The duration of positive effects following exercise was assessed in three studies involving a total of eight participants. The amount of time required to return to baseline levels ranged between 40 min (Celiberti et al., 1997) and 90 min (Levinson & Reid, 1993). This suggests that in some cases multiple exercise sessions per day may be preferable (Prupas & Reid, 2001).

In some of the reviewed studies, information regarding the procedures used to teach exercises to individuals with ASD was limited, however many incorporated activities, such as jogging, that may not require extensive teaching procedures. Indeed, across studies several common procedures and strategies emerged. First, embedding exercise into age appropriate activities and games may increase motivation to engage in exercise. If exercise becomes a preferable or reinforcing activity, then procedures used to increase exercise may be simplified requiring less prompting and programmed reinforcement (e.g., Best & Jones, 1974; Prupas & Reid, 2001). Second, prompting hierarchies were specifically mentioned in most studies, with physical prompts that are gradually faded being the most common approach. Finally, reinforcement in the form of tangibles or social praise may be needed in some instances to encourage participation in exercise, particularly when the exercise is not initially embedded within a preferred activity.

In terms of the second aim of this review, to identify gaps in the existing database so as to stimulate future research, several areas would seem to warrant additional research. Perhaps the most important area for future research involves the evaluation of different procedures used to teach or maintain exercise. Only one of the reviewed studies evaluated such a procedure directly (Todd & Reid, 2006) other studies described only briefly how exercise was taught. Second, ASD involves a wide range of intellectual functioning and symptoms, yet the participants involved in the included studies were predominantly diagnosed with autism (a more severe ASD) and none with Asperger's syndrome. Future research investigating the effects of exercise across the whole spectrum of disorders would be beneficial. Finally, research aimed at determining the mechanism by which exercise positively influences behaviors is needed. Understanding this mechanism would likely lead to improvements in the use of exercise to treat various behaviors (e.g., stereotypy) and could further assist practitioners in the development of more efficient and effective programs for individuals with ASD.

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[1] Asterisks marks (*) denote studies included in the review.

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