Physical Activity in Individuals with Autism Spectrum Disorders (ASD): A Review

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Abstract

Current recommendations indicate that children and youth ages 5–17 should participate in 60 min and adults in 150 min of moderate-to-vigorous physical activity daily. Research suggests that physical activity levels of individuals with autism spectrum disorder (ASD) are lower than typically developing and developed peers. Despite evidence for PA decreasing negative behaviors and promoting positive behaviors, individuals with ASD may be less motivated and less likely to participate. Individuals with ASD may be more likely to be overweight or obese than their typically developing counterparts as a result of decreased activity levels. Conflicting findings regarding PA levels in individuals with ASD have been reported. Given mixed evidence, further inquiry is warranted. The present chapter provides a review of literature pertaining to PA in individuals with ASD. Four databases were searched. Predetermined search terms and inclusion/exclusion criteria were clearly outlined to identify relevant articles which were then critically appraised. This research provides a greater understanding of the status of PA participation of individuals with ASD.

Keywords: physical activity, autism spectrum disorder, exercise, recreation, leisure

1. Introduction

Numerous physical and mental health benefits have been attributed to regular participation in physical activity (PA) and limited sedentary behavior [1–3]. Nevertheless, global levels
of insufficient PA are reported, and physical inactivity levels are rising [4, 5]. The World Health Organization (WHO) [5] recommends that children and youth ages 5–17 should participate in 60 min and adults ages 18–64 should participate in 150 min of moderate-to-vigorous PA (MVPA) daily. For individuals with autism spectrum disorder (ASD), recent reports indicate that the levels of PA are significantly lower than typically developing and developed peers [6].

The WHO estimates one person in 160 has an autism spectrum disorder [7]. A group of neurodevelopmental disorders diagnosed in childhood and persisting throughout life, ASD is characterized by varying challenges with communication, social interaction, and repetitive behaviors and movements [8]. Although not recognized as a formal diagnostic feature, sensorimotor impairments have also been identified as a cardinal feature of ASD [9, 10]. Furthermore, comorbid conditions typically manifest in individuals with ASD, including attention-deficit hyperactivity disorder (ADHD), anxiety disorders, and chronic sleeping problems [11–13].

The aforementioned difficulties and comorbid conditions combined have been shown to significantly impact the quality of life for individuals with ASD [14]. Despite evidence for PA decreasing negative behaviors and promoting positive behaviors [15], individuals with ASD may be less motivated and less likely to participate in PA [16]. As a result of decreased activity levels, individuals with ASD are more likely to be overweight or obese than their typically developing counterparts [6], thus leading to further health-related challenges. Notwithstanding the previous literature, conflicting findings regarding physical activity in individuals with ASD have also been reported. In one recent example, Corvey et al. [17] identified no relationships between ASD and overweight or physical activity after controlling for comorbidities and medications. Tyler et al. [18] found that, despite being less active than their typically developing peers, children with ASD did meet physical activity guidelines set out by the US Department of Health and Human Services (i.e., 60 min of moderate-to-vigorous PA/day). Clearly, further inquiry is warranted.

The present chapter provides a review of literature pertaining to physical activity in individuals with ASD. Four research questions were assessed as follows: (1) What is the status of PA participation; (2) Does PA decrease negative behaviors and/or promote positive behaviors; (3) What facilitators and barriers exist; and (4) What PA intervention programs have demonstrated effectiveness?

2. Methods

In July of 2016, a computerized search of four electronic databases (PubMed, PSYCHINFO, Web of Science, and EBSCOhost) was conducted. Two sets of key words were used in the search strategy to identify articles that included participants with ASD (Autism Spectrum Disorder, ASD, Autism, Autistic disorder, Pervasive Developmental Disorder Not Otherwise
Specified, Asperger’s syndrome) and that included PA (physical activity, exercise, recreation, leisure, fitness, athletics, sport, and playing). Search terms were entered based on specific format requirements of each database.

Inclusion and exclusion criteria were as follows: Articles must have been available in English and published within the last decade (i.e., 2006–2016). Only studies with quantitative designs were included. In the case of mixed designs, qualitative data are not presented in results. Participants (no age restrictions) must have been diagnosed with an ASD according to current or previous iterations of diagnostic criteria. Due to the difference in classification, each article discussed in this review will utilize the terminology from each respective publication. Studies that included individuals with other disabilities and/or disorders were included only if individuals with ASD were separated as a subgroup for analyses and interpretation of results. Finally, a specific PA intervention, outcome, or predictor must have been present. Studies were excluded if PA was not separated from generally defined “play,” “leisure,” or “recreational activities.”

PA was defined in accordance with the WHO [5], Centers for Disease Control and Prevention (CDC) [19], and Compendium of Physical Activities [20]. The WHO [5] defines PA as “any bodily movement produced by skeletal muscles that requires energy expenditure” (p. 53). Similarly, the CDC [19] Glossary of Terms describes PA as “any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level” (p. 1). After consulting the Compendium of Physical Activities [20], the definition of PA was narrowed for the purpose of the current review. As such, the definition of PA was concurrent with the CDC [19] and the definition of health-enhancing PA described as “activity that, when added to baseline activity, produces health benefits. Brisk walking, jumping rope, dancing, playing tennis or soccer, lifting weights, climbing on playground equipment at recess, and doing yoga are all examples of health-enhancing physical activity” (p. 1). Studies were excluded if the PA did not fit this definition.

Figure 1 depicts a summary of the phases of the review process. The initial search produced 1823 articles. Titles were screened to remove irrelevant articles and duplicates. The first two authors subsequently appraised abstracts. Finally, full texts were assessed based on the specific inclusion and exclusion criteria outlined previously. A total of 69 articles were included in the final review. Articles were sorted into five categories: (1) levels of PA (n = 10); (2) predictors related to PA (n = 4); (3) PA related to other outcome variables (n = 4); (4) PA interventions leading to changes in other outcome variables (n = 30); and (5) interventions that lead to changes in PA (n = 5). Categories 1 (levels of PA) and 2 (predictors related to PA) were combined in consideration of articles that assessed both variables (n = 16 for a total n = 30). Each article was critically analyzed based on the following components: descriptive information, research methodology, participant characteristics, physical activity measures and/or intervention, outcome measures, and overall findings. Findings were then synthesized.
3. Results

3.1. Levels of PA and predictors related to PA

Thirty cross-sectional studies (see Table 1) that assessed levels of PA \((n = 10)\) [18, 21–28], predictors related to PA, \((n = 4)\) [6, 30–32], or both \((n = 16)\) [16, 17, 33–46] were obtained. Accelerometers were implemented as a primary measure in 59% of studies [16, 18, 21, 24–29, 33, 34, 37, 40, 42–44] and greater than half of studies were published in the USA \((n = 15)\) [6, 17, 18, 21, 23, 24, 27, 31–33, 35, 39–41, 54] or Taiwan \((n = 8)\) [16, 25, 26, 28, 29, 42–44]. Twenty-one articles included more male than female participants [6, 17, 18, 19–27, 30–35, 37–41, 45, 46], and seven studies included only male participants [16, 28, 29, 42–44]. Participants ranged in age from 3 to 21 years of age. Taken together, findings revealed lower levels of PA in individuals with ASD when compared directly to their typically developing peers [16, 18, 22, 23, 26, 28, 33, 36, 43, 44, 46], previous reports of typically developing children and/or CDC requirements [21, 27, 29, 38]; however, other studies reported no difference. More specifically, Boddy et al. [34] identified similar PA levels, albeit few children were active enough to meet recommended guidelines. Macdonald et al. [24] identified no difference when controlling for intelligence quotient, severity, and gender. Similarly, Corvey et al. [17] found no association between ASD and PA, although children with more severe symptoms were more sedentary. Pan et al. [43] revealed no difference in PA levels; however, children with ASD accumulated fewer steps per minute. Predictors related to PA included age, sex, family structure, SES, and the number and types of barriers and facilitators. For example, PA was greater in males than females [7] and decreased as a function of increasing age [21, 24, 27, 29, 33, 37, 38, 41].

3.2. PA related to other outcome variables

Four studies [47–49] were included (see Table 2), 75% of which were conducted in the USA [47, 48, 59]. Three studies included more male participants than females [47, 49, 50]. One study included participants between the ages of 4 and 6 years of age [49], whereas the remaining studies assessed 9- to 17-year-olds [47, 48, 50]. Studies were cross-sectional in nature,
| Author(s)         | Year/ Country | Purpose                                                                 | Participants                                                                                     | Method            | Primary measures                                                                 | Main findings                                                                                     |
|------------------|---------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Ayvazoglu et al. [21] | 2015 USA     | Assess MVPA                                                            | ASD: N = 6 (ages 4-13, 4 male; 1 A, 2 HFA, 1 PDD-NOS, 2 AS), 6 mothers (ages 30-51)              | Cross-sectional   | RT3 accelerometer—7d—MVPA                                                      | - Low levels of MVPA—2/6 children close to CDC recommendations  
- Decrease in PA with age                                                                 |
| Borremans et al. [22] | 2010 Finland | Assess physical fitness and PA levels                                  | AS: n = 30 (ages 15-21, 21 male), TD: n = 30 (ages 16-19, 21 male)                               | Cross-sectional   | Eurofit, PARQ                                                                   | - ASD: Lower physical fitness scores and levels of PA; Less intense PA; Prefer solitary activities |
| Breslin et al. [23] | 2015 USA     | Determine HR response and PA levels in response to free play PE experience | ASD: n = 3, all male, TD: n = 4 (2 male) (ages 4.33-6.83)                                        | Single-subject    | Actiheart HR monitor — PAHR—Tues/Thurs every other week for 6 weeks—morning free play | - ASD and TD: Similar HR response before, during, and after play session  
- ASD: % Time above PAHR-50 greater for TD  
- ASD: Less MVPA vs. TD                                                                 |
| Macdonald et al. [24] | 2011 USA     | Describe sedentary and MVPA patterns with age                         | ASD: N = 72 (ages 9-18, 55 male)                                                                | Cross-sectional   | Actical® accelerometer—7d prior to adapted PA intervention—4 days included: sedentary activity, MVA, VPA; WASI; SRS; BMI | - No difference in PA based on IQ, severity or gender  
- Differences in sedentary/PA time (total, in school, after school and evening): older children more sedentary and less active |
| Pan [25]         | 2008b Taiwan | Compare PA (ASD, WD) during inclusive recess settings                 | ASD: n = 24 (ages 7-12, 23 male;12 mild/HFA, 97 moderate A, 3 AS), WD: n = 24 (ages 7-12, 23 male) | Cross-sectional   | GT1M ActiGraph accelerometer—5d PA: % time MVPA (daily overall recess, AM/PM1,2,3, lunchtime) | - Activity levels during overall recess: WD greater than ASD  
- No pattern in MVPA according to specific recess time period (WD+ASD)                                                                 |
| Pan [26]         | 2008a Taiwan | Compare PA (PE + recess), assess contribution to health-related guidelines, assess MVPA | ASD: n = 24 (ages 7-12, 23 male, 20 A, 3 AS, WD: n = 24 (ages 7-12, all male)                  | Cross-sectional   | GT1M ActiGraph accelerometer—5d: %MVPA (PE and recess)                        | - ASD: Greater %MVPA during PE vs. recess relative to time spent in settings  
- ASD and WD: Activity levels similar during PE but ASD less active during recess vs. WD                                                                 |
| Pan and Frey [27] | 2006 USA     | Examine weekday/weekend PA and within day-time period to determine patterns | ASD: N = 30 (ages 10-19, 27 male; 14 A, 12 AS, 4 PDD-NOS)                                        | Cross-sectional   | MTI 7164 uniaxial accelerometer—4d: CPM, MVPA (total, 5/10/20-min bouts; CA AL) | - Participants less active vs. previous reports on TD peers  
- Decline in PA with age  
- Some meet recommended amount—varies with age  
- No patterns in overall PA/MVPA                                                                 |
| Author(s)          | Year/Country | Purpose                                                                 | Participants                                           | Method                      | Primary measures                                      | Main findings                                                                                     |
|--------------------|--------------|------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Pan et al. [28]    | 2015 Taiwan  | Assess PA (school day), compliance with guidelines for MVPA, and if compliance differs (ASD vs. TD) | ASD: n = 30, TD: n = 30 (ages 12–17, all male)         | Cross-sectional             | GT1M ActiGraph accelerometer — 5d: daily average PA: CPM, %MPA, %VPA, %MVPA, total during periods | - Daily PA (CPM, %MPA, %MVPA) higher among TD  
- All more active in PE vs. recess, lunchtime, and after-school  
- ASD: lower time in MVPA vs. TD (PE, recess and lunchtime)  
- ASD: lower compliance with MVPA guidelines during each period of day |
| Pan et al. [29]    | 2011 Taiwan  | Examine differences in patterns PA among weekdays/weekend days and among different time periods | ASD: N = 35 (ages 7–12, lower gr. 1–2: n = 13; middle gr. 3–4: n = 13; upper gr. 5–6: n = 9; all male, 13AS, 22 A) | Cross-sectional             | MTI Actigraph 7164 accelerometer — % total PA, CPM, %MPA, %VPA, %MVPA | - No differences in MVPA for each time period to daily total MVPA, but differences in periods  
- Lower grade more active overall  
- Upper grade more active on weekdays  
- Lower/middle grade more active on weekend |
| Tyler et al. [18]  | 2014 USA     | Determine physical fitness and PA levels                                | ASD: N = 17, (ages 9–17, 9 male), TD: N = 12 (ages 9–14, 6 male) | Cross-sectional             | ActiGraph GTX3+ accelerometer: 7d 20-meter multistage shuttle run, sit-and-reach test, handgrip, BMI | - ASD more sedentary, less physically active (less time in LPA, MPMA and MVPA) and fit (strength) compared to TD, but flexibility, aerobic fitness and BMI similar |
| Kuo et al. [30]    | 2013 Canada  | Investigate perceptions, and potential factors linked with friendships; Explore activities engaged in with friends, gender differences, and types of friends | ASD: N = 91 (ages 12–18, 74 male), parents: (M age = 47.2% fathers) | Cross-sectional             | 2 activity reports; questionnaire about relationship with best friend; parent-report family background/friend; SCQ | - ASD: 37% engage in PA with friends (33% of males, 57% of females) |
| McCoy et al. [6]   | 2016 USA     | Determine relationship between sedentary behaviors, daily PA and BMI    | ASD: N = 915 (ages 10–17, 81% male) TD: N = 41,879 (ages 10–17, 52% male) | Secondary analysis         | NSCH: Severity/classification, BMI, PA, screen time, computer usage, electronic media in bedroom, sport/club participation Covariates: age, sex, school setting, household income, highest level of education in household, comorbid ADHD | - ASD more likely to be overweight/obese vs. TD  
- ASD less likely to engage in regular PA, sports and clubs vs. TD |
| Author(s)          | Year/Country | Purpose                                                                 | Participants                                                                 | Method                                                                 | Primary measures                                                                 | Main findings                                                                                                                                                                                                 |
|--------------------|--------------|------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Obrusnikova and Miccinello [31] | 2012 USA     | Investigate parent perceptions of factors that influence afterschool PA participation | ASD: n = 104 (ages 5–21; 42% A, 41% AS, 18% PDD-NOS)
Parents: n = 103 (ages 29–57, 85 male) | Cross-sectional | Online questionnaire: demographics, ASD diagnosis, relationship to child, advantages/disadvantages, barriers/facilitators to PA | - 69% advantages and 31% disadvantages of afterschool PA participation reported
- Physical most frequently cited, followed by psychosocial and cognitive
- Disadvantages either psychosocial or physical                                                                 |
| Stanish et al. [32] | 2015 USA     | Assess PA enjoyment, perceived barriers, beliefs, and self-efficacy   | ASD: n = 35 (ages 13–21, 29 male); TD: n = 60 (ages 13–18, 36 males) | Cross-sectional (*Test-retest reliability assessed for subset: n = 15 with ASD, n = 20 TD) | 26-item closed ended questionnaire—7-items targeted PA enjoyment and preferences for where and with whom youth participate | - Enjoyment of walking/individual sports did not differ (ASD vs. TD). ASD do not like gym glass/team sports; prefer “something else” to sports or exercise in free time; reported sports/exercise a lot of fun, but less than TD
- Beliefs: ASD less likely to report sports/exercise as a way to make friends, make them feel good vs. TD; positive response about doing more sports/exercise but less than TD
- Barriers: ASD—getting hurt (would stop participation), too hard to learn (low n but greater than TD) |
| Bandini et al. [33] | 2013 USA     | Assess PA levels and relationship with BMI                             | ASD: N = 53 (ages 3–11, 44 male)
TD: N = 58 (ages 3–11, 45 male) | Cross-sectional | Actical® accelerometer—7d, min and %time in LPA, MPA, VPA, MVPA; activity count, total daily activity, Checklist: frequencies/types of PA | - No differences overall (ASD/TD)
- Control for sex/age: total activity counts/time spent MPA greater in TD
- Parental report of time spent in/viety of PAs correlated for both ASD and TD, but ASD: less time/activities, younger greater than older |
| Boddy et al. [34]  | 2015 UK      | Investigate levels of habitual PA/recess play behaviors, differences by sex, age group, and ID group | N = 70 (ages 5-15, M = 9.97, 57 male)—ASD/non-ASD group—n differed for each measure | Cross-sectional | BMI; ActiGraph accelerometer—3/7d—sedentary time, LPA, MPA, VPA, MVPA; SOCARP | - PA: No difference between groups—few active enough to benefit health
- No difference boys/girls
- ASD: less time standing, more time engaged in very active PA vs non-ASD |
| Author(s)       | Year  | Country | Purpose                                                                 | Participants                                      | Method            | Primary measures                                                                 | Main findings                                                                 |
|-----------------|-------|---------|-------------------------------------------------------------------------|--------------------------------------------------|------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Corvey et al.   | 2016  | USA     | Examine obesity/overweight, sedentary behaviors, and PA levels         | N = 65,680 (weighted = 49,586,134) — ASD (ages 12-17, n = 986,352, 816,263 male) | Cross-sectional | NSCH: Obesity, overweight, PA, sedentary behavior                               | ASD: Obesity higher                                                            |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - No differences: PA rates/sedentary behavior vs. TD but severe ASD more sedentary |
| Getchell et al. | 2012  | USA     | Compare EE during walking/running and compare EE/MVPA during Nintendo Wii with walking/running | HFA: N = 15 (M = 17.50, SD = 2.4, 12 male); TD: N = 15 (M = 17.23, SD = 4.1, 6 male) | Cross-sectional | Actical accelerometer — 2 or 3 - Similar EE as TD, but HFA greater in Wii Fit activities in 2 weeks in PE: EE and MVPA | - HFA: Nearly met daily recommended MVPA in DDR                               |
| Mangerud et al. | 2014  | Norway  | Assess frequency of PA and participation in individual/team sports, associations across psychiatric disorders, and if PA related to use of psychotropic medication, BMI, and chronic pain. | Clinical: n = 566 — ASD: n = 39 (82% AS), TD: n = 8173 (ages 13–18) | Cross-sectional | Questions: Frequency/time spent in PA outside school, chronic pain, BMI, SE5 | - Threefold increased risk of lower levels of PA overall for ASD               |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Low levels of PA, and of all groups, lowest participation in team sports     |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - ASD and mood disorders most inactive vs. other disorders                     |
| Memari et al.   | 2013  | Iran    | Address demographics/other factors affecting PA and examine time-activity patterns | ASD: N = 90 (ages 7–14, 55 male)                 | Cross-sectional | GT3X Actigraph™ accelerometer — 7d: time sheet/activity log — overall PA, time in PA (weekdays, weekends, in/after-school), survey: health status | - Lowest PA levels in 13-to 14-year-olds, girls (weekdays, after-school, overall), single-parent children, obesity group, with comorbidity |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Less active in vs. after-school                                             |
| Memari et al.   | 2015  | Iran    | Assess participation in physical and daily activities and examine individual/social factors contributing to the level of participation in leisure PAs. | HFASD: N = 83 (ages 6-15, 53 male)                | Cross-sectional | Checklist adapted from Godin-Shephard Leisure Time Questionnaire, parent-report barriers, | - Few children met minimum PA criteria—only 12% physically active             |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Low due to finances, lack of resources/opportunities                        |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Low social/high solitary play during typical day                           |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Male greater than female                                                     |
|                 |       |         |                                                                         |                                                  |                  |                                                                                 | - Negative effect of age                                                      |
| Author(s)          | Year/Country | Purpose                                                                                     | Participants                                                                 | Method                        | Primary measures                                                                                          | Main findings                                                                                      |
|--------------------|--------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Must et al. [39]   | 2015 USA     | Compare prevalence of parent-reported child/family, social, and community barriers and assess association of barriers to PA with parent-reported levels of PA and total screen time | ASD: n = 53 (ages 3–11, 44 male), TD: n = 58 (ages 3–11, 45 male.)             | Cross-sectional               | 17-item questionnaire (perceived child/family, social, community barriers to PA; Questionnaire—types + frequency of PA in 12 months (17 activities total); Question about hours of screen time in past week | - Greater number of child/family, social and community barriers to PA (ASD) for nearly every barrier question; greater than half (ASD) reported 6+ barriers to PA; most common: poor motor skills, behavior and learning problems, need supervision - Similar barriers (ASD/TD): time constraints, lack of transportation, neighborhood safety - ASD: Positive relationship between age and total number of barriers, and social barriers - Total number of barriers: Inversely correlated with number of PA hours and types of activities per year; directly related to total screen time |
| Obrusnikova and Cavalier [40] | 2011 USA     | Assess barriers/facilitators of after-school MVPA and determine if PA patterns exist in relation to barriers | ASD: N = 14 (ages 8–14, M = 10.64, SD = 1.65, 12 male; 1A, 10 AS, 3 PDD-NOS) | Cross-sectional               | SRS; Actical accelerometer—7d in 14-d period, Photovoice (barriers/facilitators of after-school MVPA | - All: More time LPA vs. MVPA - 3 met minimum MVPA on all days, 5 did not meet minimum MVPA on any days - Barriers: time in sedentary activities, lack of partner - Facilitators: good equipment, community programs |
| Ormond and Kuo [41] | 2011 USA     | Describe activities, who engaged with, factors associated with time spent in, and if had effect on symptoms | ASD: N = 103 (ages 12.7–21.8, 75.7% male)                                       | Cross-sectional – From longitudinal         | Mother-report 24-h time diaries—activity participation (weekday + weekend day)                             | - PA third most frequency discretionary activity (47% of participants, total mean = 0.56 h), behind watching TV and computer use - Discretionary time spent along or with mothers, little time with peers - Time use associated with: age, gender, presence of ID, family income, marital status, maternal education |
| Author(s)       | Year/Country | Purpose                                                                 | Participants                                                                 | Method                      | Primary measures                                                                 | Main findings                                                                 |
|-----------------|--------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Pan [42]        | 2009 Taiwan  | Examine associations of age, social engagement and PA in structured (PE) and unstructured (recess) play opportunities | ASD N = 25 (ages 7–12, all male, all A)                                      | Cross-sectional             | BMI, GTIM ActiGraph — 5d, PA — 1 PE class + 1 recess; SPM, CPM, MVPA, VPA; Engagement Check | - More active physically/socially during PE vs. recess  
- Age positively correlated with CPM, SPM in recess, 5-min MVPA in PE, peer-interactive and total social engagement during PE  
- Non-interactive engagement with adults during PE positively correlated with VPA and SPM |
| Pan et al. [43] | 2011 Taiwan  | Assess PA, environment/personal correlates that influence PA during PE    | ASD: n = 19 (M = 14.19, SD = 0.82, all male); TD (n = 76, M = 14.10, SD = 0.80, all male) | Cross-sectional             | GTIM ActiGraph — 2 PE lessons in 1 week: CPM, SPM, %MPA, %VPA, %MVPA; Social interaction/initiation frequency | - No differences in PA, but ASD lower SPM than TD  
- Social initiations in ASD positively correlated with CPM, SPM, %MVPA  
- Social interactions in ASD positively correlated with CPM, %MPA, %VPA, %MVPA  
- Fitness/free-play: higher MVPA vs. team/individual activities, more active with female teachers, non-certified teachers, outdoor, in combined spaces (all) |
| Pan et al. [16] | 2011 Taiwan  | Examine differences in PA, motivational processes in PE, associations between PA/patterns of motivational processes | ASD: n = 25 (M = 14.26, SD = 0.89, all male), WD: n = 75 (M = 14.08, SD = 0.80, all male) | Cross-sectional             | ActiGraph GTM1 accelerometer during 2 PE lessons — %MPA, %VPA, %MVPA, SPM; modified MPES | - ASD: less active (less walking, %MPA, %VPA, %MVPA), variable and externally regulated  
- ASD: less perceived competence/relatedness, lower intrinsic motivation, identified regulation and introjected regulation, motivation higher, SDI lower, effort, enjoyment in PE and intention to be active lower  
- Similar motivational processes for ASD and WD |
| Pan et al. [44] | 2016 Taiwan  | Compare physical fitness/PA levels, assess relationships between PA/physical fitness (weekday vs. weekend) | ASD: n = 35; 10 AS, 25 mild AD, without ASD: n = 13 (ages 12–17, all male) | Cross-sectional             | BMI; GT1M accelerometer — 7d: min/d, MVPA min/d, CPM, %MVPA; BPFT (pre-/post-PA assessment) | - ASD: less active and less MVPA — 37%  
ASD/60% without ASD met daily 60min+ MVPA standard  
- ASD: lower physical fitness measures, except body composition |
| Author(s)     | Year/Country | Purpose                                                                 | Participants                      | Method          | Primary measures                                                                 | Main findings                                                                                                                                 |
|--------------|--------------|-------------------------------------------------------------------------|-----------------------------------|-----------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Soden et al. [45] | 2012 USA     | Assess nutritional intake (diet logs and laboratory testing), determine if low BMD is detectable, and quantify/assess clinical/medical history data correlates, and parental perceptions of lifestyle with BMD | ASD (N = 26, ages 10-18, 21 male; 6 AS, 9 AD, 11 PDD-NOS) | Cross-sectional | - 5-point likert scale (dietary pickiness, PA, sunlight, electronic media use; Fan beam DXA—BMD of lumbar spine); parent-report food, beverage, supplement intake, minutes of sunlight PE and electronic media use over 72 h | - Mean PA less than 1/3 mean electronic media use  
- Parent rating: 13 extremely/somewhat picky, 13 little to no exercise or less than average amount of exercise, 8 average media greater than 3 h per day  
- Parents perceptions of PA, electronic media use, sunlight exposure correlated with 3-d activity diaries  
- High screen time to PA ratio |
| Taheri et al. [46] | 2016 Canada | Compare social participation, quantity and quality of friendships | ASD: n = 232, 79.7% male); TD: n = 210, 69% male); ID: n = 186, 56.8% male); ages 3–19 | Cross-sectional | GO4KIDS questionnaire: child/parent demographics, activities questionnaire, # friends | - ID and ID+ASD less than TD: fewer social activities, participate less often  
- ID+ASD less than ID in special occasions with friends and in taking lessons |

*Note: See Appendix A for list of abbreviations used in this table.*

**Table 1.** Articles that assessed levels of PA (light gray), predictors related to PA (dark gray), or both (no shading).
| Author(s)         | Year/Country | Purpose                                                | Participants                          | Method          | Primary measures                                                                 | Main findings                                                                                                                                                                                                 |
|------------------|--------------|--------------------------------------------------------|---------------------------------------|-----------------|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Dreyer et al.    | 2015 USA     | Examine prevalence of overweight/obesity and how health behaviors relate to weight status | N = 45,000 responses (ages 10–17; non-ASD: 50.3% male; ASD: n = 900, 84% male) | Cross-sectional | NSCH: ASD diagnosis, weight/height, sleep, VPA, family meals, time spent watching TV/videos/playing games, with electronic devices, screen in bedroom | - ASD: more likely to have 0 days/week with 20-min VPA; less likely to get 4-6 days of VPA/week  
- Groups did not differ on likelihood of engaging in VPA 1–3 days/week  
- ASD: less PA, no differences (sleep, most measures screen time, mealtimes), overweight/obese did not differ from normal weight peers with ASD on days of engaging in VPA |
| McManus et al.   | 2012 USA     | Examine relationship between parent-child function and adolescent PA/TV viewing, and whether parent-child function is important | N = 86,777, ages 10–17, 1.5(0.1)%A | Cross-sectional | NSCH: Frequency of PA/TV viewing in week; age, race, ethnicity, presence of SHCN, BMI, primary caregiver education, physical health, exercise, family structure, function and income | - Low parent-child function linked to less PA and more TV viewing  
- Higher parent-child function influential: At mean parent-child function score, adolescents with A 43% less likely to meet PA recommendations; Unit increase in score associated with 39% lower likelihood of engaging in recommended PA |
| Tatsumi et al.   | 2014 Japan   | Investigate association between daytime PA and sleep quantity/quality | ASD: N = 31 (ages 51–70 months, 25 male); TD: N = 16 (ages 61–68 months, 10 male) | Cross-sectional | Actiwatch 2 accelerometer, 7 days: sleep onset, sleep-end time, total sleep duration, snooze time, sleep %, PA (CPM); CBCL ages 4–18 | - 8 CBCL items (withdrawal, anxiety/depression, social problems, thought problems, attention problems, delinquent, and aggressive behaviors) higher in ASD  
- Sleep % higher, snooze time longer, % poor sleepers greater, TD vs. ASD  
- PA not different on weekdays (ASD vs. TD) but longer on weekend mornings (ASD)  
- Sleep % not modulated by PA but sleep onset earlier on active day  
- PA can advance sleep phase in ASD |
| Wachob and Lorenzi | 2015 USA     | Determine relationship that engagement in MVPA has on healthy sleep patterns | ASD: N = 10 (ages 9–16, 9 male) | Cross-sectional | CSHQ; Actigraph GT3X+ (ActiSleep) accelerometer, 7 days: sedentary time, MVPA (weekday, weekend, in school after-school), sleep efficiency, WASO; BMI | - Age contributed to PA  
- Less active in vs. afterschool  
- Older participants more sedentary and more disturbed sleep patterns  
- No relationship: sleep and CSHQ, BMI and test variables  
- Negative relationship: MVPA and WASO time  
- more PA children had overall higher sleep quality |

Note: See Appendix A for list of abbreviations used in this table.

Table 2. Articles that assessed the relationship between PA and other outcome variables.
assessing the relationship between PA and sleep (n = 2) [49, 50], parent-child functioning (n = 1) [48], TV viewing frequency (n = 1) [48], weight status (n = 1) [47], and child behavior (n = 1) [49]. Findings revealed that: (1) PA is related to sleep [49, 50]; (2) with an increase in parent-child functioning, there is an increase in PA [48]; and (3) overweight/obesity is not related to days of engaging in vigorous PA for children with ASD [47].

3.3. PA interventions leading to change in other outcome variables

Thirty studies [51–80] (see Table 3) were included, where over half (n = 16) were published in the USA. Only five articles included individuals over the age of 18 [51, 61, 62, 66, 74]. Eighty percent of the studies were comprised of over half, or all male participants [51, 53, 54, 56–62, 64, 65, 67, 69–75, 77–80]. Nineteen studies used repeated measures designs observing effects pre- and post-intervention [52–56, 58, 60, 61, 64–68, 71–74, 78, 79]. PA interventions most commonly included swimming/aquatic exercise (n = 5) [57, 71–72, 77, 80] and general exercise programs (n = 8, for example, aerobic and weight-bearing exercise, physical education, and recreational programs) [55, 58–59, 61–62, 65–66, 78]. Examples of outcomes included as follows: autistic behaviors and stereotypy [e.g., 53, 65], executive function [51, 73], motor skills [55, 73, 80], sleep [55], anxiety [61, 79] communication/social skills [e.g., 54, 67], exercise specific skills [e.g., 57, 63], and physical fitness [65, 71], where 53.3% of the articles assessed multiple outcomes [51, 55–58, 61, 64, 65, 68, 71–74, 76, 79, 80]. Of the fifty total outcome measures, improvement (n = 41; indicated by † in Table 3), or null effects (n = 9; indicated by † in Table 3) following the PA interventions were reported. Taken together, there is no evidence to suggest that PA interventions have negative effects, nor is there evidence to show one PA intervention is superior to others, likely attributed in part to the multiple outcome measures.

3.4. Interventions that lead to changes in PA

Five studies [81–85] were included (see Table 4), of which varying interventions influenced PA. Repeated measures (n = 3) [81, 82, 84] and multiple-baseline (n = 2) [83, 85] designs were used to investigate outcomes pre- and post-intervention. Of these studies, 80% were published in North America (Canada, n = 2; [84, 85] USA, n = 2; [82, 83]). Interventions were mainly PA based (n = 4) [81, 83–85] and included walking, jogging, snowshoeing, and cycling. One study investigated a motor skills intervention. All participant groups included over 50% males, and only two articles included participants over the age of 18 [83, 84]. Four studies [81, 83–85] found an increase in participation and overall levels of PA, whereas one study, focusing on a motor skills intervention, found no difference in PA levels [82]. Together, findings revealed PA and/or health interventions can influence sustained PA levels post-intervention; however, there is insufficient evidence to conclude whether interventions that are not PA-based influence PA levels.

4. Discussion

Taken together, findings revealed lower levels of PA in individuals with ASD [16, 18, 22–23, 26–28, 33, 36, 38, 43, 44, 46]; especially in male children [37, 38] and with increasing age [21,
| Authors               | Year/country | Purpose                                                                 | Participants                                      | Method                      | Intervention                                      | Outcome measure(s)/number | Main findings                                                                                       |
|----------------------|--------------|-------------------------------------------------------------------------|---------------------------------------------------|-----------------------------|--------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------|
| Anderson-Hanley et al. [51] | 2011 USA     | Assess effects of exergaming on repetitive behaviors and cognitive performance | ASD: N = 22 (ages 8–21, 18 male)                   | Within-subjects experimental design | DDR or Cybercycling for 20 min                    | Behavioral assessment: video-taped and coded using GARS-2 Executive function: Digit Span Forward and Backward, The Color Trails Test, and The Stroop task | Main findings - Behavioral†† and cognitive†† performances increased after exergaming compared to the control condition |
| Arzoglou et al. [52]  | 2013 Greece  | Investigate effect of a traditional dance program on neuromuscular coordination | ASD: N = 10 (M = 16.8)                           | Pre-post                     | Traditional Greek dance: 3x/week, 35-45min      | Neuromuscular coordination: KTK Physical characteristics also measured | Main findings - Dance improved the aspects of motor skills and fitness (lateral jumps right to left, lateral movement and repositioning, and total score of test) and neuromuscular coordination†† |
| Bahrami et al. [53]   | 2012 Iran    | Determine if Kata techniques reduce stereotypic behaviors               | ASD: N = 30 (ages 5–16, 26 male)                  | Pre-post                     | Kata: 14 weeks, 4x/week 30-90 min/session       | Stereotypy severity: GARS-2 | Main findings - Kata intervention reduced stereotypic behaviors†† |
| Bahrami et al. [54]   | 2016 Iran    | Determine if karate techniques reduce communication deficits             | ASD: N = 30 (ages 5–16, 26 male)                  | Pre-post                     | Kata: 14 weeks, 4x/week, 30–90 min/session      | Communication deficits: GARS-2 | Main findings - Karate training improved the communication deficits of children with ASD†† |
| Brand et al. [55]     | 2015 Switzerland | Explore if aerobic and motor skills training intervention lead to positive changes in sleep and motor skills | ASD: N = 10 (ages 7–13, 5 male; 6A, 3AS, 1 HFASD) | Pre-post                     | Aerobic exercise and motor skills training: 3x/week for 3 weeks, 30 min biking, 30-min coordination and balance training | Sleep: EEG device, Insomnia Severity Index, Pittsburgh Sleep Quality Index Motor skills: recorded each session, ball skills and balancing | Main findings - Intervention improved specific motor skills†† (catching, throwing, and balancing) - Improved objectively assessed sleep on nights following PA†† |
| Authors                           | Year/country | Purpose                                                                 | Participants                                                                                                     | Method                                                                 | Intervention                                                                 | Outcome measure(s)/number | Main findings                                                                                                                                                               |
|----------------------------------|--------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Casey et al. [56]                | 2015 Canada  | Evaluate effects of a 12-week therapeutic skating intervention         | ASD: N = 2 (ages 7 and 10, both male)                                                                          | Repeated measures: baseline, weeks 4 and 8                             | Skating: 1 h 3x/week, 12 weeks                                               | Dynamic balance: Pediatric Balance Scale and Flamingo Test Functional mobility: 6MWT, Floor to Stand, Timed Up and Go, Timed Up and Down Stairs Test Personal goals: Participant Goal Attainment Scaling | 3 outcomes - Improvements in balance††, motor behavior, and functional capacity†† following the 12 week skating program - Participant and parental goals were met†† |
| Fragala-Pinkham et al. [57]      | 2011 USA     | Examine effectiveness of a group aquatic exercise program on fitness and swimming skills | ASD: N = 12 (ages 6–12, 11 male; 6AS, 6 PDD-NOS, 1 HFASD)                                                      | Randomized control trial; pre- and post-testing                      | Swimming: 2x/week for 14 weeks, 40-min sessions                               | Swimming skills: Swimming Classification Scale, YMCA Water Skills Checklist Cardiorespiratory endurance: half mile walk/run Muscular endurance: curl-up and isometric push-ups Mobility skills: Multidimensional Pediatric Evaluation of Disability Inventory Mobility Scale | 4 outcomes - Significant improvement in swimming skills†† - No statistically significant results for muscular endurance†, cardiorespiratory endurance†, or mobility† |
| Fukasawa and Takeda [58]         | 2012 Japan   | Clarify validity of sAA as an index of sympathetic nervous system activity | ASD: N = 7 (ages 107 ± 8 months, all male)                                                                      | Pre-post Morning activities: 30 min daily                           | sAA: sAA monitor Heart rate: pulse oximeter                                  | sAA and HR significantly higher†† - Total exercise not correlated with change in sAA or HR† - sAA = indicator that can reflect changes in sympathetic nervous system over extended period of time | 2 outcomes                  |
| Authors                  | Year/country | Purpose                                                                 | Participants                          | Method                                                                 | Intervention                                                                 | Outcome measure(s)/number | Main findings                                                                 |
|-------------------------|--------------|-------------------------------------------------------------------------|---------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------|--------------------------------------------------------------------------------|
| Goodarzi and Hemayattalab [59] | 2012 Iran    | Assess effects of weight bearing exercise and Ca supplement BMD         | ASD: N = 60 (ages 8–10, all male)     | Randomized control trial; pre- and post-measurements                    | Weight bearing exercises: 6 months, 3x/week, 50 min/session Ca: 250 mg/d    | BMD: X-ray Absorptiometry 1 outcome | - Weight bearing exercise and Ca affected BMD  
- Exercise in combination with Ca most effective†† |
| Gruber and Poulson [60] | 2016 USA      | Assess effects of a parent-implemented graduated guidance and reinforcement to teach yoga poses | ASD: N = 3 (ages 3–4, 2 male)         | Multiple baseline design across subjects; pre- and post-testing         | Yoga: DVD with a parent, 3x/week, 92 days                                   | Independent responses: If child did same poses as video model  
Customer satisfaction survey 1 outcome | - Systematic increase of independent responses across all participants with the introduction of the intervention†† |
| Hillier et al. [61]    | 2010 USA      | Examine reductions in stress and anxiety in response to a low-intensity physical exercise and relaxation intervention | ASD: N = 18 (ages 13–27, 16 males; 3A, 5 PDD-NOS, 10 AS) | Repeated measures; Pre-post 3 sessions                               | PA program: 8 weeks, 75-min session 1x/week                               | Cortisol measured Anxiety: Self-report questionnaire 2 outcomes | - Significant reduction in levels of cortisol at the end of the exercise sessions††  
- Short-term within-session decrease in anxiety†† |
| Judge [62]             | 2015 USA      | Examine the effectiveness of a CBFS for students during PE class       | ASD: N = 1 (age 19, male)             | Single subject A-B-A-B design                                        | CBFS sessions: 15 sessions, 15 min each                                    | Independent transitioning: observational data 1 outcome | - Functional relationship between use of a CBFS and number of independent transitions†  |
| Kaplan-Reimer et al. [63] | 2011 USA      | Evaluate use of an intervention package for teaching indoor rock climbing | ASD: N = 2 (ages 11 and 6, both female) | Non-concurrent multiple baseline design across participants           | Rock climbing: 45-min sessions, 3x/week                                   | Observational: Did participants grab correct hold color on path 1 outcome | - Both participants successfully learned how to rock climb†† |
| Authors          | Year/country | Purpose                                                                 | Participants                          | Method          | Intervention                                                                 | Outcome measure(s)/number | Main findings                                                                                                                                 |
|------------------|--------------|--------------------------------------------------------------------------|---------------------------------------|-----------------|-------------------------------------------------------------------------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| MacDonald et al. | 2012 USA     | Investigate the effectiveness of an individualized adapted bicycle intervention | ASD: N = 40 (ages 9–18, 26 male) DS: N = 30 (ages 9–18, 14 males) | Pre-post        | Bicycling: 5-day intervention                                                  |                              | Majority able to ride a bicycle independently upon completion†† - Leg strength greater after intervention†† - Balance not affected between riders and non-riders† |
| Magnusson et al. | 2012 New Zealand | Investigate if an individually-tailored, high-intensity exercise program would have a positive effect on physical fitness and behaviors | ASD: N = 6 (ages 9–15, 4 males; 4A, 1 AS, 1 PDD-NOS) | Pre-post        | Exercise program: 2x/week, 8–12 weeks                                         |                              | Exercise program improves all physical fitness and behavioral outcomes†† - Increase in positive behaviors and reduces negative behaviors†§ |
| Morrison et al.  | 2011 USA     | Extend research on antecedent exercise by incorporating several methodological advances | A: N = 4 (ages 10-21, 2 male)         | Pre-post        | Preferred exercise: 10- min pre-intervention, 10-min intervention, post-intervention |                              | Antecedent exercise was effective in suppressing problem behavior during the intervention†† |
| Movahedi et al.  | 2013 Iran    | Determine if teaching Karate techniques leads to improvement in social dysfunction | ASD: N = 30 (ages 5–16, 26 male)      | Pre-post        | Kata training: 4 sessions/week, 14 weeks, 30–90 min/session                 |                              | Exercise group demonstrated a improvement in social interaction - Social dysfunction decreased†§ |
| Authors                     | Year/country | Purpose                                                                 | Participants                                                                 | Method                                                                 | Intervention                                                                                     | Outcome measure(s)/number | Main findings                                                                                           |
|-----------------------------|--------------|-------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------------------|
| Neely et al. [68]           | 2015 USA     | Evaluate effects of antecedent physical exercise on stereotypy and academic engagement | ASD: N = 2 (ages 7-8, 1 male)                                                | Pre-post                                                              | Trampoline jumping; jumped until specified level of satiation prior to instructional session 3x/week | Stereotypy: 10-s partial interval recording procedure Academic engagement: 10s-whole interval recording procedure | 2 outcomes                | - Greatest reduction in stereotypy was following exercise until satiation condition††  
  - Academic engagement was highest in the exercise until satiation condition††  

Nicholson Kehle et al. [69] | 2011 USA     | Examine the impact of antecedent PA on academic engagement              | ASD: N = 4 (age 9, all male)                                                 | Single-subject, multiple-baseline design                              | Jogging: 12-min, 3x/week                                                                            | Academic engagement: BOSS 1 outcome | - Positive correlation: time spent jogging and academic engagement†† |

Oriel et al. [70]            | 2011 USA     | Determine if aerobic exercise before classroom activities improved academic engagement and reduces stereotypic behaviors | ASD: N = 9 (ages 3-6, 7 male; 7A, 1 ID, 1 DD)                                | Within-subjects crossover design                                     | Jogging: 15 min for 3 weeks                                                                       | Academic engagement: direct observation of children’s responses, stereotypic behaviors, and on-task behaviors 1 outcome | - 7 of the 9 participants improved in correct responding following the treatment condition  
  - No statistically significant improvements in on-task behavior or stereotypic behaviors' |

Pan [71]                     | 2011 Taiwan  | Assess effects of aquatic intervention on aquatic skills and physical fitness | ASD: N = 15 Siblings: N = 15 (ages 7-12, 20 male)                            | Within-participant repeated-measures design                          | Aquatic skills program: 14 weeks, 2x/week, 60-min/session                                          | Physical fitness: PACER Aquatic skills: HAAR checklist 2 outcomes                                | - Increase in all aquatic skills†† and physical fitness† subtests except body composition |

Pan [72]                     | 2010 Taiwan  | Determine effectiveness of a WESP on the aquatic skills and social behaviors | ASD: N = 16 (ages 6-9, all male; 8 HFA, 8 AS)                               | Within-participant repeated-measures design                          | Swimming program: 10 weeks, 2 sessions/week, 90-min/session                                        | Aquatic skills: HAAR checklist Social behaviors: SSBS-2 2 outcomes                              | - Improved aquatic skills†† and decreased the antisocial behavior problems†† |
| Authors          | Year/country | Purpose                                                                 | Participants                      | Method            | Intervention                  | Outcome measure(s)/number | Main findings                                                                 |
|------------------|--------------|-------------------------------------------------------------------------|-----------------------------------|-------------------|-------------------------------|----------------------------|--------------------------------------------------------------------------------|
| Pan et al. [73]  | 2016 Taiwan  | Evaluate effects of PA intervention (table tennis exercise) on motor skill proficiency | ASD: N = 22 (ages 6–12, all male) | Pre-post          | Table tennis: 12 weeks, 2x/week, 70-min/session | Motor skill proficiency: The BOT-2, Executive function: WCST | 2 outcomes - Improvements in the experimental vs. control group in total motor composite†† and executive functioning†† - Effect sustained for 12 weeks |
| Pitetti et al. [74] | 2006 USA     | Determine the efficacy of a treadmill walking program in weekly academic curriculum | A: N = 10 (ages 14–19, 6 male)    | Pre-post          | Walking: 9 months, 2–5 sessions/week, up to 20-min/session | Caloric expenditure: VO2 and equations, BMI: body measurements | 2 outcomes - Increase in exercise capacity and monthly caloric expenditure†† decrease in BMI†† |
| Reynolds et al. [75] | 2016 USA     | Examine bicycle riding maintenance and differences from parent-report 1 year following bicycle camp | ASD: N = 51 (ages 9–18, 42 male)  | Observation after bicycle camp, follow-up with parents 1 year after completion of camp | Bicycle camp: 5 consecutive days, 75 min/day | Parent-report: child’s maintenance of riding skills one year after the camp | 1 outcome - 86% rode 100 feet independently by the end of the week - HSC group reported higher rates of rider retention†† |
| Ringenbach et al. [76] | 2015 USA    | Determine effects of ACT versus VC on motor and cognitive function in adolescents with ASD | ASD: N = 10 (ages 8–16, 5 male)   | Within-subjects, randomized crossover design | Cycling: Three sessions on non-consecutive days, 20 min/session | Dexterity: Purdue Pegboard test, Cognitive and functional assessments: Exercise Perception Scale, Off-task Behavior Assessment, Stroop task, Trail Making Test, reaction time test, The Tower of London test | 2 outcomes - Positive effects on motor†† and cognitive†† functioning in clinical populations with compromised nervous system function, low exercise motivation, and reduced cognition and motor function |

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http://dx.doi.org/10.5772/66680
| Authors                  | Year/country | Purpose                                                                 | Participants          | Method                    | Intervention                                                                 | Outcome measure(s)/number | Main findings                                                                 |
|-------------------------|--------------|-------------------------------------------------------------------------|-----------------------|---------------------------|-----------------------------------------------------------------------------|----------------------------|--------------------------------------------------------------------------------|
| Rogers et al. [77]      | 2010 USA     | Determine if 4s CTD procedure is effective in teaching foundational swimming skills | A: N = 3 (ages 3-4, all male) | Multiple-probe design     | Swimming: 2-3x/week, 45-60-min/session, using CTD                        | Target behaviors observed 1 outcome | - CTD procedure was effective in teaching foundational swimming skills†† |
| Sarol and Cimen [78]    | 2015 Turkey  | Determine effect of ARPA program on the life quality                    | ASD: N = 59 (ages 4-18, 42 male) | Pre-post                  | ARPA program: 8 weeks, 2 sessions/week, 2 h/session                       | Life quality: PedsQL 1 outcome | - Increase in physical and emotional functionality, no change in social functionality or school aspects†† |
| Strahan and Elder [79]  | 2015 USA     | Determine feasibility and effectiveness of active video game playing   | ASD: N = 1 (age 15, male) | Pre-post                  | Wii video game: 6 weeks, 4+ x/week, minimum of 30 min/day              | Body measurements: weight, BMI, triceps skin fold, waist-to-hip ratio Stress and anxiety: Stress Survey Schedule for Persons with Autism and Other Developmental Delays, and Behavior Assessment System for Children Second Edition 2 outcomes | - Reductions in weight after introduction of the active video gaming†† - Stress and anxiety: minimal changes from pre- to post-intervention† |
| Yanardag et al. [80]    | 2013 Turkey  | Examine effectiveness of video prompting on teaching aquatic play skills, and the effect on motor performance | A: N = 3 (ages 6-8, 2 male) | Multiple-probe design across behaviors | Aquatic exercise: 12 weeks, 3 sessions/week, 1 h/session                  | Aquatic play skills: observation Motor skills: MABC-2 2 outcomes | - Increase in correct target skills, and maintenance observed†† - Aquatic training improved motor performance skills†† |

Note: See Appendix A for list of abbreviations used in this table.

Table 3. Articles that assessed PA interventions leading to changes in other outcome variables.
| Author(s)            | Year/Country  | Purpose                                                                 | Participants                                                                                     | Method                                       | Intervention                                                                 | Outcome                                                                                   | Main findings                                                                                   |
|---------------------|---------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Hinckson et al. [81]| 2013 New Zealand | Determine effectiveness of program on PA, dietary habits and overall health | Total: N = 17 (ages 7+, M = 14Y 4M, 10 male—A subgroup: n = 7, 5 male)                             | Repeated Measures (pre-/post-intervention)   | 10 weeks, 2x/week, 18 sessions of 1 h PA (family + students), 10 1 h healthy eating and 8 1-h motivational skills (parents/caregivers) | PA (active/inactive time, PA vs. age group, time in MVPA, start a new sport, activities longer than 30 min/week), nutrition (frequency of breakfast, carbonated drinks, white bread, wholegrain, and confectionary, and cooking fresh food), 6MWT, BMI, waist circumference qualitative interview | - Trend for increased distance in 6MWT 6 24-week post-intervention                           |
| Ketcheson et al. [82]| 2016 USA     | Measure efficacy of motor skill intervention on motor skills and levels of PA, and changes in socialization behavior in experimental group | Experimental: n = 11 (ages 4–6, 9 male) Control: n = 9 (ages 4–6, 6 male)                          | Repeated Measures (pre-/post-follow-up)      | 8 weeks, 4h/day 5 days/week, weekly rotation between TGMD-2 subtests (4-week object control, 4-weeks locomotion) | All participants: TGMD-2, ActiGraph GT3X+ accelerometer (3 days, 3 h wear time) sedentary PA, LPA, MPA, VPA, MVPA | Experimental group: Increase in locomotor, object control, partial and gross quotient scores | - Trend for decreasing min in solitary time - No difference in PA; both groups met or exceeded PA guidelines but spend majority of day (8 h) sedentary |
| Lalonde et al. [83] | 2014 USA     | Examine procedure for young adults with ASD to walk long/often enough to meet/exceed minimum guidelines for aerobic activity | ASD: N = 5 (ages 21–26, 4 male)                                                               | Multiple-baseline across participants design | Walking with specified step number goals daily; 25–42 s depending on participant | Number of steps taken: Zip Wireless Activity Tracker by FitBit Follow-up questions asked to participants about wearing the FitBit and goals Teacher asked questions from the modified TARF-F | - Differences in the number of SPD at baseline. During treatment, all participants met the goal of 10,000 SPD | - Instructional strategy with self-monitoring, verbal cuing, and edible reinforcers increased sustained participation |
| Todd and Reid [84]  | 2006 Canada   | Investigate impact of an intervention (edible reinforcers, verbal cuing, and self-monitoring) on sustained PA | ASD: N = 3 (ages 15–20, all male)                                                             | Pre-post                                      | Showshoeing and walking/jogging; 6-month program, 2 sessions/week, 30 min/session | Number of circuits completed at end of each session | - Instructional strategy with self-monitoring, verbal cuing, and edible reinforcers increased sustained participation | |
| Todd et al. [85]    | 2010 Canada   | Investigate impact of intervention (goal setting, self-monitoring, and self-reinforcement) on sustained PA, and monitor self-efficacy | ASD: N = 3 (ages 15–17, 2 male)                                                               | Multiple-baseline changing criterion design   | Cycling; 3 days/week from March to June, 30 min/session, total 31 sessions completed | Distance and goal setting (intensity, - Distance travelled increased (n = 2) - Attention to attitudes required in self-determined behavior is beneficial when designing interventions to increase PA for ASD | - Instructional strategy with self-monitoring, verbal cuing, and edible reinforcers increased sustained participation | |

Note: See Appendix A for list of abbreviations used in this table.

Table 4. Articles including interventions that led to changes in PA.
Nevertheless, studies that report no difference were also common [e.g., 17, 34]. Barriers to PA include, but are not limited to, finances, lack of resources and opportunities, poor motor skills, behavioral and learning problems, the need for supervision, family time constraints, lack of a partner, and lack of available transportation. Must et al. [39] reported a positive relationship between age and the total number of barriers. Furthermore, the number of barriers was inversely related to the number of PA hours and total number and types of activities per year. Facilitators to PA included good equipment and community programs. There was evidence that PA interventions can improve certain outcome measures, such as communication, balance, and fitness levels [e.g., 54, 56, 71]; however, it is also important to note that others observed no effect [e.g., 62, 70]. Importantly, there was no evidence to suggest that PA interventions cause negative effects. Interventions that aimed to address levels of PA specifically found that PA interventions lead to increased PA levels, while one motor skill intervention [82] was not effective. Overall, no one intervention was suggested as optimal for decreasing negative and/or promoting positive behaviors.

Common limitations included small sample sizes with little ethnic and socioeconomic diversity that limited generalizability and underpowered analyses. Unequal sex distributions were repeatedly observed, as many participant groups were comprised of mainly males. It is important to consider that this may be a result of the intrinsic property of ASD being five times more prevalent in males than in females (CDC, 2014). Assessments of PA levels were limited, in some cases by parent-report assessments, where more objective assessments (i.e., accelerometer data) were limited by compliance, and the inability of the tool to assess all PAs (e.g., water activities). With respect to interventions, short durations were commonly reported. Furthermore, studies investigating a change in PA as the outcome variable were limited. Finally, most studies included children that were high functioning on the spectrum. Methodologically this review was limited to four search engines, and papers published within the last decade. Unpublished studies and studies published in languages other than English were not included. The quality of the studies was also not evaluated. These may have biased the results.

Future research of PA interventions should investigate the legitimacy and benefits of specific PA interventions, which may help determine the effects of distinct outcome measures. Furthermore, research on interventions leading to a change in PA should investigate non-PA interventions in the future to determine the plausibility of changing PA levels through other intervention methods (i.e., motor skill interventions). In addition, it would be beneficial to investigate the long-term changes in PA following these interventions to determine whether this effect is sustained over time. Overall, research investigating physical activity for individuals with ASD should be explored with larger sample sizes, over longer time periods and across the spectrum. This would provide more comprehensive information on the pros and cons of physical activity for this vulnerable population.
Appendix A

Abbreviations included in the tables

| Word/Phrase                                      | Abbreviation          |
|-------------------------------------------------|-----------------------|
| Adapted Recreational Physical Activity          | ARPA                  |
| Asperger’s Syndrome Assisted Cycling Therapy    | AS ACT                |
| Attention Deficit/Hyperactivity Disorder        | ADHD                  |
| Autism                                          | A                     |
| Autism Spectrum Disorder                        | ASD                   |
| Behavioral Observation of Students in Schools   | BOSS                  |
| Body Mass Index                                 | DMI                   |
| Bone Mineral Density                            | BMD                   |
| Brockport Physical Fitness Test                 | BPFT                  |
| Bruininks-Oseretsky Test of Motor Proficiency Second Edition | BOT-2 |
| Calcium                                         | Ca                    |
| Child Behavior Checklist                        | CBCL                  |
| Child/Adolescent Activity Log                   | CAAL                  |
| Children’s Activity Rating Scale                | CARS                  |
| Children’s Sleep Habits Questionnaire           | CSHQ                  |
| Computer-Based Fitness Schedule Constant Time Delay | CBFS CTD               |
| Counts Per Minute                               | CPM                   |
| Dance Dance Revolution                          | DDR                   |
| Day                                             | d                     |
| Developmental Delay                             | DD                    |
| Down Syndrome                                   | DS                    |
| Dual-Energy X-ray Absorptiometry                | DXA                   |
| Energy Expenditure                              | EE                    |
| Gilliam Autism Rating Scale-Second Edition      | GARS-2                |
| Great Outcomes for Kids Impacted by Severe Developmental Disabilities | GO4KIDDS |
| Heart Rate                                      | HR                    |
| High Functioning Autism                         | HFA                   |
| High Functioning Autism Spectrum Disorder Home-Support Consultation | HFASD HSC |
| Humpfries Assessment of Aquatic Readiness       | HAAR                  |
| Intellectual Disability                         | ID                    |
| KorperkoordinationstestfurKinder                | KTK                   |
| Light Physical Activity                         | LPA                   |
| Light to Moderate to Vigorous Physical Activity | LMVPA                 |
| Mean                                            | M                     |
| Metabolic Equivalent                            | MET                   |
| Minute                                          | min                   |
| Moderate Physical Activity                      | MPA                   |
| Moderate to Vigorous Physical Activity          | MVPA                  |
Motivation in Physical Education Scale MPES
Movement Assessment Battery for Children Second Edition MABC-2
National Survey of Children’s Health NSCH
Neurotypical NT
Observational System for Recording Physical Activity of Children-Preschool OSRAC-P
Progressive Aerobic Cardiovascular Endurance Run PACER
Pediatric Quality of Life Inventory PedsQL
Pervasive Developmental Disorder – Not Otherwise Specified PDD-NOS
Physical Activity PA
Physical Activity Heart Rate PAHR
Physical Activity Research Questionnaire PARQ
Physical Education PE
Playground Observation of Peer Engagement POPE
Salivary Alpha-Amylase sAA
School Social Behavior Scales SSBS-2
Six-minute Walk Test 6MWT
Social Communication Questionnaire SCQ
Social Economic Status SES
Social Responsiveness Scale SRS
Special Healthcare Need SHCN
Standard Deviation SD
Steps Per Day SPD
Steps Per Minute SPM
System for Observing Children’s Activity and Relationships During Play SOCARP
Television Td
Treatment Acceptability Rating Form Revised TAR-F
Typically Developing TD
United States of America USA
Vigorous Physical Activity VPA
Very Vigorous Physical Activity Voluntary Cycling VVPA VC
Wake after sleep onset WASO
Water Exercise Swimming Program WESP
Weshsler Abbreviated Scale of Intelligence WASI
Wisconsin Card Sorting Test WCST
Without Disability WD

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References

[1] Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. British Journal of Sports Medicine, 45(11), 886–895.

[2] Janssen I, & Leblanc AG. (2010) Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity, 7(40), 1–16.

[3] Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., Goldfield, G., & Connor Gorber, S. (2011). Systematic review of sedentary behavior and health indicators in school-aged children and youth. International Journal of Behavioral Nutrition and Physical Activity, 8, 98, 1–22.

[4] Moraes, A. C. F. D., Guerra, P. H., & Menezes, P. R. (2013). The worldwide prevalence of insufficient physical activity in adolescents; a systematic review. Nutrición hospitalaria, 28(3), 575–584.

[5] World Health Organization. (2010). Global recommendations on physical activity for health. Switzerland: WHO Press.

[6] McCoy, S. M., Jakicic, J. M., & Gibbs, B. B. (2016). Comparison of Obesity, Physical Activity, and Sedentary Behaviors Between Adolescents With Autism Spectrum Disorders and Without. Journal of Autism and Developmental Disorders, 1–10.

[7] World Health Organization. (2013). Autism spectrum disorders & other developmental disorders. From raising awareness to building capacity. Switzerland: WHO Press.

[8] American Psychiatric Association. (2013). Autism Spectrum Disorder. Retrieved from http://www.dsm5.org/Documents/Autism%20Spectrum%20Disorder%20Fact%20Sheet.pdf

[9] Fournier, K.A., Hass, C.J., Naik, S.K., Lodha, N., & Cauraugh, J.H. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. Journal of Autism and Developmental Disorders, 40, 1227–1240.

[10] Gowen, E., & Hamilton, A. (2013). Motor abilities in autism: a review using a computational context. Journal of Autism and Developmental Disorders, 43(2), 323–344.

[11] Goldin, R. L., Matson, J. L., Tureck, K., Cervantes, P. E., & Jang, J. (2013). A comparison of tantrum behavior profiles in children with ASD, ADHD and comorbid ASD and ADHD. Research in Developmental Disabilities, 34(9), 2669–2675.

[12] Richdale, A. L., & Schreck, K. A. (2009). Sleep problems in autism spectrum disorders: Prevalence, nature, & possible biopsychosocial aetiologies. Sleep Medicine Reviews, 13(6), 403–411.

[13] White, S. W., Oswald, D., Ollendick, T., & Scahill, L. (2009). Anxiety in children and adolescents with autism spectrum disorders. Clinical Psychology Review, 29(3), 216–229.
[14] Lee, L. C., Harrington, R. A., Louie, B. B., & Newschaffer, C. J. (2008). Children with autism: Quality of life and parental concerns. *Journal of Autism and Developmental Disorders, 38*(6), 1147–1160.

[15] Prupas, A., & Reid, G. (2001). Effects of exercise frequency on stereotypic behaviors of children with developmental disabilities. *Education and Training in Mental Retardation and Developmental Disabilities, 26*, 196–206.

[16] Pan, C.-Y., Tsai, C.-L., Chu, C.-H., & Hsieh, K.-W. (2011). Physical activity and self-determined motivation of adolescents with and without autism spectrum disorders in inclusive physical education. *Research in Autism Spectrum Disorders, 5*, 733–741.

[17] Corvey, K., Menear, K. S., Preskitt, J., Goldfarb, S., & Menachemi, N. (2016). Obesity, physical activity and sedentary behaviors in children with an autism spectrum disorder. *Maternal and Child Health Journal, 20*(2), 466–476.

[18] Tyler, K., Macdonald, M., & Menear, K. (2014). Physical activity and physical fitness of school-aged children and youth with autism spectrum disorders.

[19] Centers for Disease Control and Prevention (2015). Physical activity glossary of terms. Retrieved from http://www.cdc.gov/physicalactivity/basics/glossary/index.htm

[20] Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., … Leon, A. S. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine & Science in Sports & Exercise, 32*(Supplement), S498–S516.

[21] Ayvazoglu, N. R., Kozub, F. M., Butera, G., & Murray, M. J. (2015). Determinants and challenges in physical activity participation in families with children with high functioning autism spectrum disorders from a family systems perspective. *Research in Developmental Disabilities, 47*, 93–105.

[22] Borremans, E., Rintala, P., & McCubbin, J. A. (2010). Physical fitness and physical activity in adolescents with asperger syndrome: a comparative study. *Adapted Physical Activity Quarterly, 27*(4), 308–320.

[23] Breslin, C. M., Rudisill, M. E., & Wadsworth, D. D. (2015). Heart rate profiles of children with and without autism spectrum disorder in response to physical play: a preliminary investigation. *Physical Educator, 72*(1), 1–19.

[24] Macdonald, M., Esposito, P., & Ulrich, D. (2011). The physical activity patterns of children with autism. *BMC Research Notes, 4*(1), 422.

[25] Pan, C. (2008b). School time physical activity of students with and without autism spectrum disorders during PE and recess. *Adapted Physical Activity Quarterly, 25*(4), 308–321.

[26] Pan, C.-Y. (2008a). Objectively measured physical activity between children with autism spectrum disorders and children without disabilities during inclusive recess settings in Taiwan. *Journal of Autism and Developmental Disorders, 38*(7), 1292–1301.
[27] Pan, C.-Y., & Frey, G. C. (2006). Physical activity patterns in youth with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 36*(5), 597–606.

[28] Pan, C. Y., Hsu, P. J., Chung, I. C., Hung, C. S., Liu, Y. J., & Lo, S. Y. (2015). Physical activity during the segmented school day in adolescents with and without autism spectrum disorders. *Research in Autism Spectrum Disorders, 15–16*, 21–28.

[29] Pan, C.-Y., Tsai, C.-L., Hsieh, K.-W., Chu, C.-H., Li, Y.-L., & Huang, S.-T. (2011). Accelerometer-determined physical activity among elementary school-aged children with autism spectrum disorders in Taiwan. *Research in Autism Spectrum Disorders, 5*(3), 1042–1052.

[30] Kuo, M. H., Orsmond, G. I., Cohn, E. S., & Coster, W. J. (2011). Friendship characteristics and activity patterns of adolescents with an autism spectrum disorder. *Autism: The International Journal of Research and Practice, 17*(4), 481–500.

[31] Obrusnikova, I., & Miccinello, D. L. (2012). Parent perceptions of factors influencing after-school physical activity of children with autism spectrum disorders. *Adapted Physical Activity Quarterly, 29*(1), 63–80.

[32] Stanish, H., Curtin, C., Must, A., Phillips, S., Maslin, M., & Bandini, L. (2015). Enjoyment, barriers, and beliefs about physical activity in adolescents with and without autism spectrum disorder. *Adapted Physical Activity Quarterly : APAQ, 32*(4), 302–17.

[33] Bandini, L. G., Gleason, J., Curtin, C., Lividini, K., Anderson, S. E., Cermak, S. A., ... Must, A. (2012). Comparison of physical activity between children with autism spectrum disorders and typically developing children. *Autism, 17*(1), 44–54.

[34] Boddy, L. M., Downes, S. J., Knowles, Z. R., & Fairclough, S. J. (2015). Physical activity and play behaviours in children and young people with intellectual disabilities: A cross-sectional observational study. *School Psychology International, 36*(2, SI), 154–171.

[35] Getchell, N., Miccinello, D., Blom, M., Morris, L., & Szaroleta, M. (2012). Comparing Energy Expenditure in Adolescents With and Without Autism While Playing Nintendo® Wii™ Games. *Games for Health Journal, 1*(1), 58–61.

[36] Mangerud, W. L., Bjerkeset, O., Lydersen, S., & Indredavik, M. S. (2014). Physical activity in adolescents with psychiatric disorders and in the general population. *Child and Adolescent Psychiatry and Mental Health, 8*(1), 1–10.

[37] Memari, A. H., Ghaferi, B., Ziaee, V., Kordi, R., Hafizi, S., & Moshayedi, P. (2013). Physical activity in children and adolescents with autism assessed by triaxial accelerometry. *Pediatric Obesity, 8*(2), 150–158.

[38] Memari, A. H., Panahi, N., Ranjbar, E., Moshayedi, P., Shafiei, M., Kordi, R., & Ziaee, V. (2015). Children with autism spectrum disorder and patterns of participation in daily physical and play activities. *Neurology Research International, 531906*, 1–7.

[39] Must, A., Phillips, S., Curtin, C., & Bandini, L. G. (2015). Barriers to physical activity in children with autism spectrum disorders: relationship to physical activity and screen time. *Journal of Physical Activity & Health, 12*(4), 529–534.
[40] Obrusnikova, I., & Cavalier, A. R. (2011). Perceived barriers and facilitators of participation in after-school physical activity by children with autism spectrum disorders. Journal of Developmental and Physical Disabilities, 23(3), 195–211.

[41] Orsmond, G. I., & Kuo, H.-Y. (2011). The daily lives of adolescents with an autism spectrum disorder: Discretionary time use and activity partners. Autism, 15(5), 579–599.

[42] Pan, C.-Y. (2009). Age, social engagement, and physical activity in children with autism spectrum disorders. Research in Autism Spectrum Disorders, 3(1), 22–31.

[43] Pan, C. Y., Tsai, C. L., & Hsieh, K. W. (2011). Physical activity correlates for children with autism spectrum disorders in middle school physical education. Research Quarterly for Exercise and Sport, 82(3), 491–498.

[44] Pan, C. Y., Tsai, C. L., Chu, C. H., Sung, M. C., Ma, W. Y., & Huang, C. Y. (2016). Objectively measured physical activity and health-related physical fitness in secondary school-aged male students with autism spectrum disorders. Physical Therapy, 96(4), 511–520.

[45] Soden, S. E., Garrison, C. B., Egan, A. M., & Beckwith, A. M. (2012). Nutrition, physical activity, and bone mineral density in youth with autistic spectrum disorders. Journal of Developmental & Behavioral Pediatrics, 33(8), 618–624.

[46] Taheri, A., Perry, A., & Minnes, P. (2016). Examining the social participation of children and adolescents with intellectual disabilities and autism spectrum disorder in relation to peers. Journal of Intellectual Disability Research : JIDR, 60(5), 435–43.

[47] Dreyer Gillette, M. L. D., Borner, K. B., Nadler, C. B., Poppert, K. M., Stough, C. O., Romine, R. S., & Davis, A. M. (2015). Prevalence and health correlates of overweight and obesity in children with autism spectrum disorder. Journal of Developmental & Behavioral Pediatrics, 36(7), 489–496.

[48] McManus, B. M., Mandic, C. G., Carle, A. C., & Robert, S. A. (2012). The effect of parent-child function on physical activity and television viewing among adolescents with and without special healthcare needs. International Journal of Disability, Development and Education, 59(3), 305–319.

[49] Tatsumi, Y., Mohri, I., Shimizu, S., Tachibana, M., Ohno, Y., & Taniike, M. (2014). Daytime physical activity and sleep in pre-schoolers with developmental disorders. Journal of Paediatrics and Child Health, 51, 396–402.

[50] Wachob, D., & Lorenzi, D. G. (2015). Brief report: influence of physical activity on sleep quality in children with autism. Journal of Autism and Developmental Disorders, 45(8), 2641–2646.

[51] Anderson-Hanley, C., Tureck, K., & Schneiderman, R. L. (2011). Autism and exergaming: effects on repetitive behaviors and cognition. Psychology Research and Behavior Management, 4, 129–37.
[52] Arzoglou, D., Tsimaras, V., Kotsikas, G., Fotiadou, E., Sidiropoulou, M., Proios, M., & Bassa, E. (2013). The effect of a traditional dance training program on neuromuscular coordination of individuals with autism. *Journal of Physical Education and Sport, 13*(4), 563–569.

[53] Bahrami, F., Movahedi, A., Marandi, S. M., & Abedi, A. (2012). Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. *Research in Developmental Disabilities, 33*(4), 1183–1193.

[54] Bahrami, F., Movahedi, A., Marandi, S. M., & Sorensen, C. (2016). The effect of karate techniques training on communication deficit of children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 46*(3), 978–986.

[55] Brand, S., Jossen, S., Holsboer-Trachsler, E., Pühse, U., & Gerber, M. (2015). Impact of aerobic exercise on sleep and motor skills in children with autism spectrum disorders – a pilot study. *Neuropsychiatric Disease and Treatment, 11*, 1911.

[56] Casey, A. F., Quenneville-Himbeault, G., Normore, A., Davis, H., & Martell, S. G. (2015). A therapeutic skating intervention for children with autism spectrum disorder. *Pediatric Physical Therapy, 27*, 170–177.

[57] Fragala-Pinkham, M. a, Haley, S. M., & O’Neil, M. E. (2011). Group swimming and aquatic exercise programme for children with autism spectrum disorders: a pilot study. *Developmental Neurorehabilitation, 14*(4), 230–241.

[58] Fukasawa, M., & Takeda, K. (2012). Relationship between salivary -amylase activity and heart rate for evaluation of the sympathetic nervous system of children with autism. *Japanese Journal of Special Education, 49*(6), 671–684.

[59] Goodarzi, M., & Hemayattalab, R. (2012). Bone mineral density accrual in students with autism spectrum disorders: effects of calcium intake and physical training. *Research in Autism Spectrum Disorders, 6*(2), 690–695.

[60] Gruber, D. J., & Poulson, C. L. (2016). Graduated guidance delivered by parents to teach yoga to children with developmental delays. *Journal of Applied Behavior Analysis, 49*(1), 193–198.

[61] Hillier, A., Murphy, D., & Ferrara, C. (2011). A pilot study: Short-term reduction in salivary cortisol following low level physical exercise and relaxation among adolescents and young adults on the autism spectrum. *Stress and Health, 27*(5), 395–402.

[62] Judge, J. P. (2015). The effects of a computer-based fitness schedule on independent transitioning for a student with autism. *Palaestra, 29*(1), 17–21.

[63] Kaplan-Reimer, H., Sidener, T. M., Reeve, K. F., & Sidener, D. W. (2007). Using stimulus control procedures to teach indoor rock climbing to children with autism. *Behavioral Interventions, 22*(November 2006), 83–97.
[64] MacDonald, M., Esposito, P., Hauck, J., Jeong, I., Hornyak, J., Argento, A., & Ulrich, D. A. (2012). Bicycle training for youth with Down syndrome and Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities, 27*(August), 12–21.

[65] Magnusson, J. E., Cobham, C., & McLeod, R. (2012). Beneficial effects of clinical exercise rehabilitation for children and adolescents with autism spectrum disorder (ASD). *Journal of Exercise Physiology Online, 15*(2), 71–79.

[66] Morrison, H., Roscoe, E. M., & Atwell, A. (2011). An evaluation of antecedent exercise on behavior maintained by automatic reinforcement using a three-component multiple schedule. *Journal of Applied Behavior Analysis, 44*(3), 523–541.

[67] Movahedi, A., Bahrami, F., Marandi, S. M., & Abedi, A. (2013). Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. *Research in Autism Spectrum Disorders, 7*(9), 1054–1161.

[68] Neely, L., Rispoli, M., Gerow, S., & Ninci, J. (2014). Effects of antecedent exercise on academic engagement and stereotypy during instruction. *Behavior Modification, 39*(1), 98–116.

[69] Nicholson, H., Kehle, T., Bray, M. A., & Van Heest, J. (2011). The effects of antecedent physical activity on the academic engagement of children with autism spectrum disorder. *Psychology in the Schools, 48*(2), 198–213.

[70] Oriel, K. N., George, C. L., Peckus, R., & Semon, A. (2011). The effects of aerobic exercise on academic engagement in young children with autism spectrum disorder. *Pediatric Physical Therapy : The Official Publication of the Section on Pediatrics of the American Physical Therapy Association, 23*(2), 187–193.

[71] Pan, C.-Y. (2010). Effects of water exercise swimming program on aquatic skills and social behaviors in children with autism spectrum disorders. *Autism : The International Journal of Research and Practice, 14*(1), 9–28.

[72] Pan, C. Y. (2011). The efficacy of an aquatic program on physical fitness and aquatic skills in children with and without autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*(1), 657–665.

[73] Pan, C.-Y., Chu, C.-H., Tsai, C.-L., Sung, M.-C., Huang, C.-Y., & Ma, W.-Y. (2016 – online ahead of print). The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism*, doi:10.1177/1362361316633562

[74] Pitetti, K. H., Rendoff, A. D., Grover, T., & Beets, M. W. (2007). The efficacy of a 9-month treadmill walking program on the exercise capacity and weight reduction for adolescents with severe autism. *Journal of Autism and Developmental Disorders, 37*(6), 997–1006.

[75] Reynolds, J. L., Pitchford, E. A., Hauck, J. L., Ketcheson, L. R., & Ulrich, D. A. (2016). Outcomes of home-support consultation on the maintenance of bicycle-riding skills for youth with autism spectrum disorder. *Journal of Educational and Psychological Consultation, 26*(2), 166–185.
[76] Ringenbach, S. D. R., Lichtsinn, K. C., & Holzapfel, S. D. (2015). Assisted cycling therapy (ACT) improves inhibition in adolescents with autism spectrum disorder. *Journal of Intellectual and Developmental Disability*, 0(September), 1–12.

[77] Rogers, L., Hemmeter, M. L., & Wolery, M. (2010). Using a constant time delay procedure to teach foundational swimming skills to children with autism. *Topics in Early Childhood Special Education*, 30(2), 102–111.

[78] Sarol, H., & Çimen, Z. (2015). The effects of adapted recreational physical activity on the life quality of individuals with autism. *Anthropologist*, 21(3), 522–527.

[79] Strahan, B. E., & Elder, J. H. (2015). Video game playing effects on obesity in an adolescent with autism spectrum disorder: a case study. *Autism Research and Treatment, 2015*, 1–7.

[80] Yanardag, M., Akmanoglu, N., & Yilmaz, I. (2013). The effectiveness of video prompting on teaching aquatic play skills for children with autism. *Disability and Rehabilitation*, 35(April 2012), 1–10.

[81] Hinckson, E. A., Dickinson, A., Water, T., Sands, M., & Penman, L. (2013). Physical activity, dietary habits and overall health in overweight and obese children and youth with intellectual disability or autism. *Research in Developmental Disabilities*, 34(4), 1170–1178.

[82] Ketcheson, L., Hauck, J., & Ulrich, D. (2016 – online ahead of print). The effects of an early motor skill intervention on motor skills, levels of physical activity, and socialization in young children with autism spectrum disorder: A pilot study. *Autism*, doi: 10.1177/1362361316650611.

[83] Lalonde, K. B., MacNeill, B. R., Eversole, L. W., Ragotzy, S. P., & Poling, A. (2014). Increasing physical activity in young adults with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 8(12), 1679–1684.

[84] Todd, T., & Reid, G. (2006). Increasing physical activity in individuals with autism. *Focus on Autism and Other Developmental Disabilities*, 21(3), 167–176.

[85] Todd, T., Reid, G., & Butler-kisber, L. (2010). Cycling for students with ASD self regulation promotes sustained physical activity, *Adapted Physical Activity Quarterly*, 27(3), 226–241.
