Chapter 15

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

Sara M. Scharoun, Kristen T. Wright,
Jennifer E. Robertson-Wilson, Paula C. Fletcher and
Pamela J. Bryden

Additional information is available at the end of the chapter

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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.

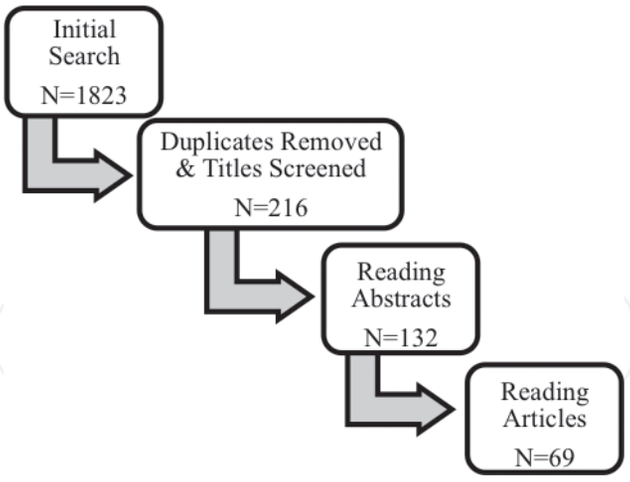

Figure 1. Summary of the different phases of the review.

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, 21–27, 30–35, 37–41, 45, 46], and seven studies included only male participants [16, 28, 29, 30 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 design	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/MVPA 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, 9 7moderate 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; CAAL	- 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

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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, MPA 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/variety 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

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Author(s)	Year/ Country	Purpose	Participants	Method	Primary measures	Main findings
Corvey et al. [17]	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. [35]	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 activities in 2 weeks in PE: EE and MVPA	- Similar EE as TD, but HFA greater in Wii Fit - HFA: Nearly met daily recommended MVPA in DDR
Mangerud et al. [36]	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, SES	- 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. [37]	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. [38]	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
Orsmond 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

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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	GO4KIDDS 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).

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Author(s)	Year/Country	Purpose	Participants	Method	Primary measures	Main findings
Dreyer Gillette et al. [47]	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. [48]	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. [49]	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 [50]	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 **2 outcomes**	- 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 **1 outcome**	- 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 **1 outcome**	- 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/r week, 30–90 min/session	Communication deficits: GARS-2 **1 outcome**	- 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 **2 outcomes**	- 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 Muscle endurance: curl-up and isometric push-ups Mobility skills: Multidimentional 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 **2 outcomes**	- Post-learning values of 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

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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 (ages13–27, 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. [64]	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	Leg strength: handheld manual muscle tester Standing balance: timed trial for each leg Independent bicycle riding skills: observed **3 outcomes**	- 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. [65]	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, 1AS, 1 PDD-NOS)	Pre-post	Exercise program: 2x/week, 8–12 weeks	Physical testing: cardiorespiratory fitness, lower and upper body strength, abdominal strength and endurance, lower back and hamstring flexibility, and balance Behaviors: questionnaires **2 outcomes**	- Exercise program improves all physical fitness and behavioral outcomes[††] - Increase in positive behaviors and reduces negative behaviors[††]
Morrison et al. [66]	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, 10-min post-intervention	Direct observation of problem behaviors **1 outcome**	- Antecedent exercise was effective in suppressing problem behavior during the intervention[††]
Movahedi et al. [67]	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	Social interaction: GARS-2 **1 outcome**	- Exercise group demonstrated a improvement in social interaction - Social dysfunction decreased[††]

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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 (ages14–19, 6 male)	Pre-post	Walking: 9 months, 2–5 sessions/week, up to 20-min/session	Caloric expenditure: VO_2 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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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/care givers)	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: POPE	- 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
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, self-efficacy)	- Distance travelled increased (n = 2) - Attention to attitudes required in self-determined behavior is beneficial when designing interventions to increase PA for ASD

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

Table 4. Articles including interventions that led to changes in PA.

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24, 27, 29, 33, 37, 38, 44]. 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.

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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

Author details

Sara M. Scharoun[1], Kristen T. Wright[2], Jennifer E. Robertson-Wilson[2], Paula C. Fletcher[2] and Pamela J. Bryden[2,*]

*Address all correspondence to: pbryden@wlu.ca

1 Schulich School of Education, Nipissing University, North Bay, ON, Canada

2 Department of Kinesiology & Physical Education, Wilfrid Laurier University, Waterloo, Ontario, Canada

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