

Social Skill Outcomes Following Physical Activity–Based Interventions for Individuals on the Autism Spectrum: A Scoping Review Spanning Young Childhood Through Young Adulthood

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Researchers posit that physical activity (PA) settings may provide an increased opportunity for social interaction. However, little consensus exists regarding the construct of social skills ~~and~~ what type or amount of PA is ~~needed to improve the quality of social functioning of~~ individuals on the autism spectrum. Thus, this scoping review synthesized the components (e.g., design, participants, independent and dependent variables, etc.) and findings of PA-based interventions that included social skill components to identify how interventions have incorporated these skills within different settings. Based on a review of 25 articles, this review revealed a great deal of variability in the types of PA, social skills, and instruments studied as well as the intensity of published findings. No longitudinal studies were identified as a part of the search. These results provide a foundation for the designing of effective PA-based interventions that may have an increased impact on the social skills of individuals on the autism spectrum. Future research should employ longitudinal designs to capture the relationship between social skills and PA as well as to increase the likelihood of capturing change.

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Keywords: autism spectrum disorder, human development, social functioning

As a core identified area of need in individuals on the autism spectrum, past research has resulted in several evidence-based practices that focus on developing social communication skills through intervention (Wong et al., 2015). Yet, these evidence-based practices, despite having the potential for modified use in a physical activity (PA) space (Colombo-Dougovito, 2015), have not been designed or validated for these PA settings. Furthermore, multiple definitions of social skills are used interchangeably to describe an individual's overall social functioning (Cordier et al., 2015), and because no current unifying definition of social skills exists, the construct tends to be misunderstood (Merrell & Gimpel, 2014).

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As a construct, social skills are a complex set of behaviors that vary based on setting; currently, no gold standard for measurement exists for this particular construct (Dowd, Rinehart, & McGinley, 2010). Broadly, social skills could include an individual's ability to initiate interactions, make meaningful verbal or nonverbal reactions to others, maintain eye contact, share enjoyment and interests, and understand nonverbal cues (American Psychiatric Association, 2013). The social communication differences found in individuals on the autism spectrum are considered to be derived from inherent neurological impairments in tandem with reduced opportunity to acquire skills (e.g., social withdrawal and social exclusion; American Psychiatric Association, 2013) and differences in social expectations (Perepa, 2014). Regardless of origin, the social difficulties of an individual can increase their vulnerability in other areas, such as social play skills with peers (Lee & Haegele, 2016) or quality of life (Barnhill, 2007).

PA as Intervention

Among the myriad behavioral intervention strategies, PA has been considered as a beneficial intervention component for individuals on the autism spectrum because of its role in promoting mental and physical health as well as naturalistic opportunities for social interactions (Lee & Vargo, 2017). Thus, researchers often address sedentary lifestyles (e.g., Pan & Frey, 2006; Tyler et al., 2014) and delayed movement skills (Liu, Hamilton, Davis, & ElGarhy, 2014; Lloyd, MacDonald, & Lord, 2013) as a rationale for the use of PA in behavioral interventions for individuals on the autism spectrum. Evidence (Bremer, Crozier, & Lloyd, 2016; Dillon, Adams, Goudy, Bittner, & McNamara, 2017; Healy, Nacario, Braithwaite, & Hopper, 2018; Lang et al., 2010; Rapp & Vollmer, 2005) supports the use of PA-based interventions to encourage social skill development, though the "active ingredient" (O'Haire, 2013, p. 1618) remains elusive.

Despite demonstrated improvements in the measured social skills of participants, captured improvements are often not universal across or, even, within studies and are often not assessed in natural environments. Typically, in many intervention studies, behaviors are observed in controlled settings and focus on nonreciprocal (e.g., echoic verbal behavior or an imitation of movement) behaviors rather than interactive actions. Moreover, social skills in these studies are narrowly defined to one aspect, such as "stereotypic behaviors" and "on-task behaviors." In many instances, the social skills that are being measured with each study vary greatly and capture only one aspect of social skills and not the broader construct (Cordier et al., 2015). Thus, it is unclear that demonstrated changes in social communicative behaviors would have a meaningful, generalizable impact on the social skills that are utilized in day-to-day social interaction.

Interconnected Domains

Coupled with differences in social skills, research has shown that individuals on the autism spectrum are more likely to exhibit significant fundamental motor skill delays (Berkeley, Zittel, Pitney, & Nichols, 2001) as well as poor gait, posture, and rhythm (Provost, Lopez, & Heimerl, 2007). In particular, individuals may be more likely to have delayed motor skill development (Liu et al., 2014; Lloyd et al., 2013;

Staples & Reid, 2010), potentially leading to increased rates of physical inactivity (MacDonald, Esposito, & Ulrich, 2011; Pan & Frey, 2006; Stanish et al., 2017), especially when participating in PA programs such as physical education and community-based programs (Todd & Reid, 2006). Furthermore, most types of PA require not only motor abilities and skills but also some elements of social function (Eime, Young, Harvey, Charity, & Payne, 2013; Leonard & Hill, 2014). In a 2016 systematic review of the behavioral outcomes of exercise interventions, Bremer, Balogh, and Lloyd (2015) observed the most benefit from activities such as martial arts, horseback riding, and jogging; benefits were shown to be more limited in yoga, dance, and swimming interventions. However, due to a large variability in intervention frequency, intensity, type, and dosage, as well as methodological design, the relative benefits remain unclear.

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Despite varying definitions, environment has been shown to be influential in the development of social skills (Cordier et al., 2015). Age-appropriate motor skills and activity, therefore, may provide an environment conducive to more social opportunities for individuals to practice (Barnett & Weber, 2008; Hawks, Constantino, Weichselbaum, & Marrus, 2019; Lee & Vargo, 2017). MacDonald, Lord, and Ulrich (2013) postulated that by improving an individual's motor skills, there may also be an effect on the individual's social skills (p. 278), although an increase in one construct does not necessarily result in a direct, equal immediate change in the other (e.g., Colombo-Dougovito, 2017), despite a seemingly bidirectional relationship (e.g., Reinders, Branco, Wright, Fletcher, & Bryden, 2019). Yet, for young children to young adults, the participation in PA—including games and sports—could be viewed as a more natural environment where social interactions occur with a lower barrier for engaging with others. In this setting, individuals may have a greater opportunity to develop physical, cognitive, and communication skills as well as to make friendships (Hoogsteen & Woodgate, 2010).

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Therefore, due to limited consensus, a scoping review was used to “map” current literature in pursuit of how social skills have been defined and measured, either primarily or secondarily, within PA-based interventions for individuals on the autism spectrum. The following research questions were used to guide this review: (a) What types of PA are used in PA-based interventions that have social skills outcomes? (b) What focal social skills are included and how are they measured? (c) How, if at all, are the unique social communication needs of the participants determined? (d) What are the protocols and components of the interventions, such as the duration, frequency, delivering agent, and location of the interventions? and (e) What overall impact do PA-based interventions have on social skills?

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Methods

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According to Peters et al. (2015), scoping reviews aim for “mapping the key concepts” from a body of literature to answer a broader research question than systematic reviews. Due to a limited understanding of how social skills are defined or incorporated within PA-based interventions, it was believed that the purpose of this review

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was well aligned with that of a scoping review. Therefore, the Preferred Reporting

Items for Systematic Reviews and Meta-Analyses (PRISMA) extension for scoping reviews (Tricco et al., 2018) protocol was used to guide this scoping review.

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Literature Search

The authors ($n = 2$) identified key terms relevant to the search, and the following databases were selected: ERIC, PsycINFO, SPORTDiscuss, and PubMed. The search strategy included three lines of search words, truncated whenever possible, as follows:

("autism" OR asd OR "autism spectrum disorder" OR "pervasive disorder" OR "pervasive developmental disorder*" OR asperger*) AND ("physical activity" OR "physical education" OR "adapted physical education" OR "motor skill" OR "gross motor" OR "fundamental motor" OR dance OR yoga OR horseback OR sport* OR aquatic* OR swimming) AND ("social skill*" OR "social interaction" OR "social behavior" OR conversation OR compliment* OR cooperation OR communication OR "social response" OR play OR "eye contact" OR reciprocity OR "peer initiation" OR pragmatic* OR "play skill*" OR "challenging behavior" OR affect OR routine* OR verbalization*).

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As the authors screened each search output, review articles that were found were filtered to conduct a hand search of the references for these articles to locate any potential additional articles not retrieved by the initial database search. The search protocol was reviewed by a university librarian and verified for adherence to PRISMA extension for scoping reviews protocol.

Operational Definitions

Physical activity is often used interchangeably with exercise (Taylor, 1983) and, indeed, the two share many defining characteristics (Caspersen, Powell, & Christenson, 1985, p. 127). For this review, PA—presented by Ross et al. (2016)—was defined as “experiences in physically demanding movement, sport,

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game, or recreational play that results in energy expenditure and perceptions of communal involvement” (p. 8).

Similar to PA and exercise, social skills have been broadly defined in the literature with varying terms that are used interchangeably (Cordier et al., 2015). Without an accepted guiding definition, for this review, the concept of *social skills* was operationally defined by the authors as interactive behavior demonstrated or observed between two or more individuals.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for this study were used as “limiters” for the database searches and served as a filtering mechanism to capture all relevant studies for the present scoping review.

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The inclusion criteria were that studies had to be (a) published empirical studies, (b) written in the English language, (c) published within peer-review

journals, (d) available in full-text format, and (e) published between January 1990 and August 2019. This time range was set for the review as studies focusing on motor skills, PA, and exercise were not prevalent until recently (see Case & Yun, 2019; Colombo-Dougovito, Block, Zhang, & Strehli, 2020; Healy et al., 2018; Sowa & Meulenbroek, 2012). As a part of the inclusion criteria, articles needed to have a clearly defined intervention that included PA; this may have encompassed leisure-time PA, weight training, martial arts, yoga, horseback riding, swimming, or any other type of sport or fitness or motor skill programs. In addition, each article needed to measure an element of social skills as a primary or secondary measure. The authors also accepted social skill interventions conducted in a PA environment, such as a play skill intervention or social skill training using sports.

Q17 The exclusion criteria applied to studies that focused on one aspect, such as including a PA measure but no social skills measures. Also, studies that used a PA intervention to affect noninteractive social behavior only, such as reducing the frequency or duration of stereotypic behaviors as a sole purpose, were excluded.

Q18 Exclusion criteria also extended to unpublished theses or dissertations, studies published as conference proceedings, and review or conceptual articles. Furthermore, this review did not consider studies using animal models or solely qualitative analyses.

Article Extraction

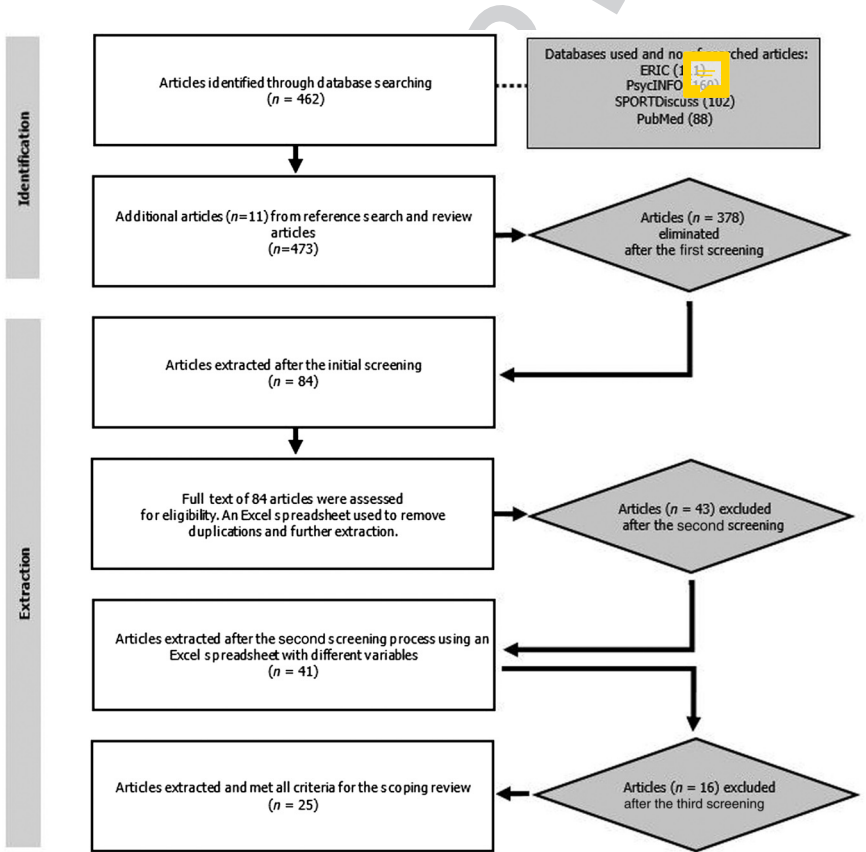
The initial database search produced 462 articles. Additional hand searching of reference lists identified an additional 11 articles. Each of the authors screened the searched articles ($n = 473$) while applying the inclusion and exclusion criteria. As a result, articles that did not meet the inclusion criteria were eliminated; common reasons for exclusion included publication in languages other than English, the type of paper (i.e., conference proceedings, theses or dissertations, and nonempirical articles such as reviews, editorials, or conceptual papers), lack of intervention components (i.e., contextual factors, structural elements, or intervention practices), or lack of a movement or PA component in the intervention. If an article's title and/or abstract did not provide sufficient information to make the eligibility decision, the full text was screened.

After the initial screening, 84 articles were identified. A full-text screening of these articles was completed using the inclusion and exclusion criteria. Initial agreement between the authors was above 80% and discussions continued until 100% agreement was reached. After discussions, the authors excluded an additional 43 articles. Common reasons for exclusion in this second extraction process included participants without a diagnosis and PA or social skills being the sole focus of the study. An example of an excluded article was Duronjić and Válková (2010); although the article had a dedicated PA-based intervention, Duronjić and Válková did not include a social skills measure.

The authors, then, went through a final review of the remaining 41 articles, focusing on the method of intervention and dependent variables. Common reasons for exclusion in this final extraction process included definitions of social skills or PA that deviated from the operational definitions developed for this scoping review. Through this process, 25 articles were identified that met the inclusion criteria with 100% agreement by all authors. Examples of excluded articles were

Rosenblatt et al. (2011), Stahmer (1995), and Yilmaz, Birkan, Konukman, and Erkan (2005). Rosenblatt et al. (2011) focused on “mood” instead of social interaction or functional social skills. They considered mood as a status of feeling or emotion and that does not directly represent an individual’s social competence or ability. Stahmer (1995) used “play” as an intervention environment in the study; however, play used in the context of this study did not involve any identifiable PA. Yilmaz et al. (2005) included age-appropriate water play skills. Although the water orientation skills used in the study were considered by the authors as appropriate water play skills, they were not considered to fit the definition of social skills used for this review.

Q19 With the final 25 articles, the authors used an Excel spreadsheet to chart relevant data using a coding scheme similar to Hansen et al. (2014); this included study design, participants (age and number), outcome measures, and major findings. Additionally, the authors identified indicators related to the rigor of **Q20** the methods and findings of each study, such as procedural fidelity, delivery agent,



Q21 Figure 1 — Article search process.

intervention setting, and participant characteristics (i.e., diagnosis), based on recommendations from Reichow and Volkmar (2010) and Pereplechikova and Kazdin (2005). Both authors independently reviewed each of the identified articles; using Google Drive, the authors compared the coded results and discussed any discrepancies. Interrater agreement (100%) was reached on the identification of the indicators.

Results

Intervention-Related Variables

Table 1 shows the essential characteristics extracted from each study, including study design, demographic information (age and number), independent and dependent variables, social skills targeted, and findings. Of the 25 articles, six (24%) used single-subject research designs, 12 (48%) used quasi-experimental designs (with and without a comparison group), four (16%) used experimental designs, two (8%) used a descriptive design, and one (4%) used a wait-list control group design. The ages of participants were screened with respect to the mean age and the age range of the participants. There was a large age range among the included studies that spanned from young childhood (e.g., 3 years old) to young adulthood (e.g., 24 years old), though the mean age from calculatable data was around 8.09 years old ($SD = 2.99$). Typically, studies focused on school age populations between 5 and 16 years old, or “adolescent” years. No studies were identified during the search that focused on participants older than 24 years.

Types of PA. There was considerable variance among the 25 included articles regarding the type of PA within the intervention. Of the 25 articles, five (20%) used an animal-assisted intervention (i.e., therapeutic horseback riding); four (16%) included either yoga or karate; ~~four~~ (12%) used fundamental motor skill practice (i.e., kicking, rolling, etc.); ~~three~~ (12%) used aquatics; ~~two~~ (8%) used group or individual sports components such as gymnastics, golf, soccer, or handball; and ~~one~~ (4%) incorporated fitness exercises.

Targeted Social Skills. Similar to the types of PA, there was no uniform focus or set of social skills across the included studies. Of the 25 articles reviewed, researchers attempted to gather insight into appropriate play, engagement, social interaction, speech/communication, attention, joint engagement, turn taking, compliments, adaptive behaviors, parallel play, and social functioning. The most common social skill variable among the studies was verbal and nonverbal communication; approximately 60% ($n = 15$) of the reviewed studies fully or partially identified the intended social skill as such. Beyond assessing social behavior using the chosen social skills assessment, little to no information was provided to determine how researchers accounted for the differing social behaviors of participants or how researchers identified the unique social needs of each participant. All studies, though, reported that baseline social behavior was measured either through administered questionnaires or behavioral observations, yet it was not apparent how—or if—this information was used to guide instruction during the intervention. Some accommodations for limited social communication

Table 1 Essential Characteristics Extracted From Each Study

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Alexander, Dummer, Snelzer, and Denton (2011)	United States	SS (ABCA)	N = 4 (all males; one with ASD); 14–24 years (M = 17.4 and SD = 2.57)	14-week social skills and sports program (Alexander, 2008, 90 min/week, 2 days/week). Sports: soccer (13–27 sessions, 74 min/session)	Parent Skill Rating Form using Alexander adaptation (2008) of Baker's Skill Rating Form (2003). Observation Skill Rating Form to judge social interactions while playing soccer	Turn taking, relevant information, and eye contact	After the intervention, participant with ASD (Jeff) showed significant improvement (increase more than 5%) on the three target skills: turn taking, relevant information, and eye contact. However, the results also showed a significant increase in the percentage of "did not attempt" for turn taking and eye contact.
Bahrami, Movahedi, Marandi, and Sorensen (2016)	Iran	Ex with Cont	N = 30 (four females); 5–16 years (M = 9.13 and SD = 3.27)	14-week Karate (4 days/week, 30–90 min/session, 56 sessions) #Heian-Sho-dan-Kata	The communication subscale of GARS-2	Communication	Karate significantly improved communication based on communication subscale of the GAR-2. In maintenance period, communication deficit in the Ex group remained significantly decreased compared with postintervention.
Bass, Duchowny, and Liabre (2009)	United States	QEx with Cont	N = 34 (five females); 4–10 years (Ex: M = 6.95 and SD = 1.67; Con: M = 7.73 and SD = 1.65)	12-week therapeutic horseback riding (1 hr/week). Riding skills, mounted games, and horsemanship activities	SRS and SP	Social functioning (sensory and autism severity, social awareness, social cognition, social communication, social motivation, and autistic mannerisms)	The intervention significantly increased sensory profile overall score compared with Cont. Interaction effects for four out of the five subscales were significant for the Ex; no significant interaction for the fine motor/perceptual subscale.
Buttaglia, Agró, Cataldo, Palma, and Alesi (2019)	Italy	Descriptive study using baseline and posttest data	N = 3 (one female); 11–15.11 years	12-week Caputo et al., implemented multisystemic aquatic therapy (2 days/week, 45–50 min/session) using three stages: emotional adaptation phase, swimming adaptation phase, and social integration phase.	An observation schedule adapted by Venuti (2001) for eight social behaviors; TGMD	Eight social skills (four for the interaction including joint attention, joint play, searching others' presence, and comply ones turn and four for contact including sensitivity to other's presence, loneliness, eye contact, and observation of other's behaviors)	Participants showed different levels of improvement in social behaviors (i.e., the sensitivity of other's presence, eye contact, and the comply one's turn), motor skills (locomotor and object control skills), and fine motor skills. Higher proportion of increases in social behavior in the sensitivity of other's presence, eye contact, and turn taking; increases were from ranking of "rarely" to "sometimes" or "sometimes" to "often."

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Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Bremer et al. (2015)	Canada	Wait-list control experimental design (Group 1: 12-week intervention [12 hr]; Group 2: waited then received 6-week intervention [12 hr])	$N = 9$ (one female); 4 years (Ex: $M = 4.3$ and $SD = 0.25$; Con: $M = 4.3$ and $SD = 0.22$)	12-week fundamental motor skills intervention (1 hr/week)	Anthropometric measurements (height and weight), motor proficiency assessed by the Peabody Developmental Motor Scales-2, adaptive behavior assessed by the VABS-2, and social skills assessed by the SSIS	Adaptive behavior and social skills	Significant differences in motor scores from preintervention to postintervention between Ex and Con groups on the PDMS-2. No significant differences between two groups on the VABS-2 and SSIS. When Groups 1 and 2 were used, all PDMS-2 variables showed significant differences between the pre, post, and 6-week follow-up assessments, while no social behavior variables showed such changes. At individual level, six participants showed increased appropriate play and verbal response and decreased inappropriate play and out of frame findings based on behavioral coding.
Bremer et al. (2016)	Canada	Descriptive	$N = 5$ (one female); 3–7 years. Four with ASD	Two 6-week blocks (total 12 weeks) of the fundamental motor skills intervention (3 days/week, 45 min/day), 27 hr of direct instruction for 12 weeks using teaching strategies suggested by Breslin & Liu (2014): Visual prompts, the name of skills to be completed, examples of the skill, verbal instructions, and physical prompts	Motor-skill proficiency assessed by the TGMD-2 and social skills assessed by the SSIS teacher	Social skills (communication, cooperation, assertion, responsibility, empathy, engagement, and self-control), problem behaviors (internalizing, externalizing, bullying, and hyperactivity) and autism spectrum profile behavior	Participants with ASD showed some improvement in raw scores for most of the items in the TGMD-2 and the SSIS from Assessment 1 (baseline) to Assessment 2 (Block 1) to Assessment 3 (Block 2).

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Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Gabriels et al. (2012)	United States	QEx with Cont	N = 42 (six females); M = 8.7 years	10-week therapeutic horseback riding (1 day/week, 45 min to 1 hr/session)—Routine: (a) put riding helmet on, (b) sit and wait on the bench, (c) mount horse, (d) THR activities, (e) dismount horse, (f) groom horse, and (g) put away equipment	The ABC-C; VABS-2—interview edition, survey form ; BOTMP-2, short form and SIPT	Self-regulation and adaptive skills	Significant improvements (i.e., decreased prevalence) on the ABC-C irritability, lethargy, stereotypic behavior, hyperactivity, and inappropriate speech; significant improvements on raw social scores, raw communication scores, raw daily scores, and adaptive total scores; scores are based on ranking of 0 (<i>never a problem</i>) to 3 (<i>severe problem</i>). Significant improvements were seen on the BOT-2 and verbal and postural subscales of the SIPT.
García-Gómez, Risco, Rubio, Guerri, and García-Peña (2014)	Spain	QEx with Cont	N = 16 (three females); 7–16 years	3-month therapeutic horseback riding (2 days/week, 24 sessions, 45 min to 1 hr/session)	A horse-riding program BASC-T or teachers	Social, affective, and emotional variables	Ex group showed significant differences in the aggressiveness subscale as reported by the “teacher.” Subscales are reported as aggregate of yes/no response and scales. Reduction of about 1 point based on the scale was deemed significant, though large overlap is present.
Guest, Ba-logh, Sogra, and Lloyd (2017)	Canada	QEx with Cont	N = 13 (all females); 8–11 years (M = 9.76 and SD = 1)	Five full-day multisport camp (based on Special Olympics Fundamentals program)	TGMD-2, pedometer, physical self-perception (CY-PSPP), SSIS, and the VABS-2	Adaptive behaviors, problem behaviors, and general social skills	Motor skills, physical self-perception, and the social skills domain significantly improved. Positive correlation between TGMD-2 motor quotient and CSAPPA adequacy, enjoyment, and total scores at the follow-up test. Improvements were seen in the overall social domain, as measured by the SSIS; no raw data were reported for social scores.
Holm et al. (2014)	United States	SS (multiple baseline, multiple case, and reversal)	N = 3 (all males); 6–8 years	Therapeutic horseback riding with dose control (1, 3, and 5 days/week) during B-phase	Parent-identified target behaviors, ABC-C, SRS, and SP-CQ	Social awareness, communication, and speech	Therapy helped significantly improve target behaviors at home and community; observed behavior changes consisted of frequency counts that were standardized (no raw frequencies were provided). Little change between phases on ABC-C, SRS, and SP-CQ

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Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Jam et al. (2018)	Iran	QEx with Cont	N = 30 (13 females) 8–12 years (Ex: M = 10.2; Cont: M = 10.12)	16-week gymnastic exercise program (total 48 sessions, 3 days/week, 45 min/session)	Motor skill development assessed by the short form of BOTMP-2, short form; neuropsychological skills assessed by Conners Neuropsychological Questionnaire (2007)	Neuropsychological skills: Attention, executive functions, sensory and motor functions, language functions, and memory and learning functions in two forms for parents and teachers	The Ex group showed higher scores for all motor development subsets except strength, running speed and agility, and reaction time. The Ex group showed higher scores for all neuropsychological skills subsets except language functions; subscale scores reported as aggregate means. No information is provided on units of measurement for the neuropsychological skills.
Ketcheson, Hauck, and Ulrich (2016)	United States	QEx with Cont	N = 20 (five females); 4–6 years	8-week motor skill instruction (4 hr/day, 5 days/week) through CPRT framework	TGMD-2, ActiGraph (GT3X+; ActiGraph LLC, Pensacola, FL) (PA), and playground observation of peer engagement	Joint engagement, solitary, proximity, parallel aware, parallel play, and onlooking	Significant difference between Ex and Cont groups. No effects were found for social measures other than decreasing time in solidarity (measured in minutes).
Koenig, Buckley-Reen, and Garg (2012)	United States	QEx with Cont	N = 46 (nine females); 5–12 years (Ex: M = 9.7; Cont: M = 8.7)	16 weeks (5 days/week) GRTL yoga program	Aberrant behavior checklist—community and VABS-2	Communication, ADL, adaptive behavior, and social skills	Yoga program demonstrated significant difference between Ex and Cont in teacher-reported ABC, but not parent-reported. A large effect size ($d = 1.19$) was reported between teacher-reported changes between the Ex and Cont groups.
MacDonald, Clark, Garrigan, and Vangala (2005)	United States	SS (multiple baseline- and AB)	N = 2 (all males); 4 and 7 years	Specific play scripts for each set of materials (town, ship, and house); each script had 16 verbalizations and 14 coordinated actions	Scripted verbalizations = social statements that matched the video, scripted play actions = motor responses that match video, and unscripted play actions = not modeled but appropriate	Verbalizations appropriate to the contexts	Video modeling increased scripted play across three commercially available play-sets. Verbalizations were frequency-recorded . Verbalizations increased from a low level (0–2) per session to a mastery level (15–17) after the addition of a video model. No reversal was included; effect size and percent overlap were not reported.
Macpherson, Charlop, and Miltenberger (2015)	United States	SS	N = 5 (one female); 9.5–11.2 years	Video modeling using a video clip of a ball rolling and then being kicked with a compliment and then making a gesture	Participants' verbal compliments and compliment gestures when being instructed to play kickball	Compliments and gestures	All participants increased from baseline (0–5) to intervention (30–50) on their use of verbal compliments and compliment gestures during intervention, but these behaviors were not well generalized across activities.

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Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Magnusson, Cobham, and Melton (2012)	New Zealand	QEx	N = 6 (two females); 9–15 years	8-week fitness exercise (total 16 sessions, 2 days/week, two “testing” sessions). Sessions include warm-up, high-intensity interval training, aerobic exercises, plyometric training, resistance training, a warm-down, and stretches.	Modified Bruce protocol (cardiorespiratory fitness), 1RM bench press, 1RM leg press, maximal curl-up test, sit and reach test, and modified Romberg test (balance)- measured pre-and post . Parents filled out surveys on behaviors	Social, attention, and behavior	All participants increased fitness measures. All positive and negative behavior measures improved. Improvements in social skills were not statistically significant, though parents reported an increase of 2 points (4.5–6.5); however, no information is provided as to how this construct was measured or how to infer what a 2-point gain means.
Martin and Farnum (2002)	United States	QEx within-subject, repeated-measures across three conditions	N = 10 (two females); 3–13 years	15-week AAT (total 45 sessions, 3 days/week, 15 min/session)	Frequency of interactions; durations were coded in terms of seconds per minute	Behaviors and verbalizations	Tentative support for the efficacy of AAT for children with PDD. Behaviors of the children varied as a function of experimental condition, and interaction with dogs appeared to have some positive benefits. For example, participants were more likely to talk about the dog and for longer duration than within the other conditions.
Miltenberger and Charlop (2014)	United States	SS (multiple baseline)	N = 3 (one female); 6, 9, and 9 years	Athletic skill and rules training session: Handball and Four square (duration and frequency were not clear)	Appropriate group play and speech; measured by percent of opportunity (interval coding; 10-s durations)	Independent play and speech	All three children increased group play, demonstrated gains in speech, and mastered the targeted athletic skills. Therapists reported significant changes in observed behavior pre and post; specifically, social skills increased between 1 and 2 points on a 7-point scale.
Movahedi, Bahrami, Marandi, and Abedi (2013)	Iran	Ex with Cont	N = 30 (four females); 5–16 years (M = 9.13 and SD = 3.27)	14-week Heian Shodan Kata (Karate) (total 56 sessions, 1 hr/session, 4 days/week) based on the TARGET model (Ames, 1992)	The social interaction subscale of GARS-2	Social interaction/dysfunction	A significant decrease in “social dysfunction” severity scores in the Ex at postintervention compared with the baseline and maintenance period (30 days after) using the aggregate score from the GARS-2.

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Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Najafabadi et al. (2018)	Iran	Ex with Cont	$N = 28$ (Ex = 12; Con = 14), 5–12 years (Ex: $M = 7.08$ and $SD = 2.06$; Con: $M = 8.07$ and $SD = 2.23$)	12-week SPARK program (3 days/week, 40 min/ session)	The social interaction subscale of GARS-2, the sociability subscale ATEC, and balance and coordination subsets of BOTMP	Social interaction and sociability	Only the Ex group showed a significant improvement in the static and dynamic balance as well as bilateral coordination compared with the Con group. Only the Ex group's social interaction subscale of GARS-2 and sociability subscale of ATEC showed a significant improvement after the intervention, though a large overlap was present.
Pan (2010)	Taiwan	QEx within-participant repeated measures (baseline, WESP or regular treatment, and after 10 weeks)	$N = 16$ (all males); 6–9 years (Ex: $M = 7.27$ and $SD = 1.25$; Con: $M = 7.2$ and $SD = 0.89$)	10-week water exercise swimming program (floor activities, one-to-two instruction, group activities, and cooldown) based on the HAAR and TEACCH	Aquatic skills—The HAAR checklist; social behaviors—the SSBS-2 completed by classroom teachers	School social behaviors (social competence and antisocial behavior)	WESP improved aquatic skills and antisocial behaviors (but not in social competence) as measured by the SSBS-2. Raw scores were not reported, though ranges were reported demonstrating a large difference among participants. Social competence and antisocial behavior scores ranged from 32 to 160.
Rosenblatt et al. (2011)	United States	QEx within-subject pre-treatment to posttreatment	$N = 24$ (two females); 3–16 years ($M = 8.9$ and $SD = 3.6$)	8-week yoga (total eight sessions, 45 min/week). Sessions included breathing skills, yoga postures, music and dance, and yoga relaxation.	BCSC-2 and ABC	Problematic behaviors	Yoga had significant impact on the BSI of the BASC-2 and atypicality subscale; although demonstrated significance, change was highly variable between subjects. A change in T score of 3.17 and 5.40 was reported on the BSI and atypicality, respectively. While significant, postscores of the BSI fall within the 90% CI of normative data (94th percentile).
Schleien, Rynders, Mustonen, and Fox (1990)	United States	SS (alternating treatment)	$N = 17$ (one female); 5–12 years	6-week play sessions (30 min/session, 2 days/week); four play categorizations (isolated, dyadic, group, and team)	Appropriate play behavior—"engaging in goal directed rec. activity including appropriate use of materials and/or equipment in age-appropriate measures"	Appropriate play and peer engagement	Appropriate behaviors were observationally recorded and reported as percentages of time. Isolation produced lowest percentage of appropriate play. Carefully structured integrated activities involving higher levels of social play elicited a sig. higher frequency of appropriate play behavior in school-age learners with autism.

(continued)

Table 1 (continued)

Study	Location	Design	Participant	IV	DV	Social skills	Results (#NI)
Shanok, Sotelo, and Hong (2019)	United States	QEx within-subject pre-treatment to posttreatment	N = 46 (nine females); 6–24 years (M = 11.46 and SD = 6.21)	6-week golf-training program (12 session, 45 min/ session using The Ernie Els #GameON Autism) focusing on communication skills, regulatory skills, motor skills, and social skills using visual cues	Communication skills, regulatory skills, motor skills, and social skills were observed and measured by raters using scores on a (1–5) Likert scale, with 1 being the lowest motor skills and 5 the highest motor skills	Receptive communication skills, expressive communication skills, social skills, and regulatory skills	There were significant increases in all behavioral skills from preassessment to postassessment. All subdomains were measured using a 5-point Likert scale (1–5). Responses to questions were reported as averages of the summed total. Receptive comm. increased from 6.0 to 7.37 out of a possible 10. Expressive comm. increased from 10.22 to 11.26 out of a possible 15. Social skills increased from 13.11 to 15.02 out of a possible 20. Regulatory skills increased from 9.65 to 11.33 out of a possible 15.
Zhao and Chen (2018)	China	Ex with Cont (this study used a random assignment but it said QEx in their study)	N = 41 (12 females); 5–8 years (Ex: M = 6.14 and SD = 0.96; Cont: M = 6.1 and SD = 0.98)	12-week structured PA program (60 min/ session, total 24 sessions), using the TEACCH model	ABLLS-R and SSIS-RS	Social interaction and communication skills	The social skills (in the communication, cooperation, and self-control subdomains) of the Ex group measured by SSIS were significantly improved compared with the Cont group (mean change from T1 to T3 of 7.621 vs. 1.2, respectively). The intervention improved the Ex group's overall social interaction scores in ABLLS-R compared with the Cont group (mean change from T1 to T3 of 9.429 vs. 1.8, respectively).

Q239

Note. ASD = autism spectrum disorder; Location = the location of data collection; SS = single-subject design; QEx = quasi-experimental; Ex = experimental; Cont = control; AAT = animal-assisted therapy; HAAR = Humphries assessment of aquatic readiness; WESP = water exercise safety program; PA = physical activity; ADL = activities of daily living; GARS-2 = Gilliam Autism Rating Scale—second edition; SRS = Social Responsiveness Scale; SP = sensory profile; TGMD-2 = test of gross motor development—second edition; VABS-2 = Vineland Adaptive Behavior Scales; SSIS = Social Skills Improvement System; ABC = Aberrant Behavior Checklist-community; BOTMP-2 = Bruininks-Oseretsky Test of Motor Proficiency; SIPT = Sensory Integration and Praxis Test; BASC-T = Behavior Assessment System for Children; CPRT = classroom pivotal response treatment; GRITL = Get Ready to Learn; ATEC = autism treatment evaluation checklist; TEACCH = Treatment and Education of Autistic and Communication Handicapped Children; SBS-2 = School Social Behavior Scales; BCSC-2 = Behavioral Assessment System for Children, second edition; BSI = behavioral symptom index; ABLLS-R = Assessment of Basic Language and Learning; SSIS-RS = Social Skills Improvement System Rating Scales.

were mentioned, such as a picture schedule (Gabriels et al., 2012), an enlarged Picture Exchange Communication System (Bremer et al., 2015), extra prompts (Macpherson et al., 2015), or incorporation of elements of the Treatment and Education of Autistic and Communication Handicapped Children method (Zhao & Chen, 2018); yet, no rationale was given as to why the particular strategy was chosen or if that accommodation was necessary.

Dosage/Frequency. The administered interventions varied from 3 to 5 times/week for 15–45 min and from 6 to 16 weeks. The type of sport had little noticeable effect on the dosage or frequency of the intervention. Of the included studies, those that used equine therapy ranged between 10 and 12 weeks of delivery, providing 45 min to 1 hr of instruction per week. ~~Those that used yoga ranged from 8 to 16 weeks and from one 45-min period of instruction per week to 5 days/week.~~ Interventions that focused on sports skills or motor skills appeared to be longer in duration overall. Schlieen et al. (1990) provided the shortest amount of instruction, which was over 6 weeks with each session lasting 30 min and occurring twice per week. In contrast, Ketcheson et al. (2016), while only providing an additional 2 weeks of instruction, provided instruction 5 days/week for 4 hr/day. ~~Ketcheson et al. suggested that future research be provided the intervention for a greater length of time.~~

Rigor-Related Variables

The authors further examined study variables, as shown in Table 2, including the diagnostic tools used in the studies, the delivery agent, procedural fidelity, completion rates, and the formation and setting of the interventions. All these variables are considered relative to the rigor of the studies and show the commonalities of PA-based intervention studies that may inform future research.

Diagnosis and Severity. The reviewed studies utilized various diagnostic tools to identify the target population or as part of their measurement tools to examine the effectiveness of the intervention. Two studies (8%) (Gabriels et al., 2012; Ketcheson et al., 2016) used the Autism Diagnostic Observation Schedule, second edition (Lord, Luyster, Gotham, & Guthrie, 2012; Lord, Rutter, et al., 2012) to confirm autism spectrum disorder diagnoses within their sample population. Several studies used parent-report screening tools, such as the Gilliam Autism Rating Scale—second edition (three studies), the Childhood Autism Rating Scale (two studies), Social Responsiveness Scale (two studies), Social Skills Improvement System Rating Scales (three studies), and the Vineland Adaptive Behavior Scales—second edition (four studies), as a confirmatory measure of autism spectrum disorder or as a measure of social skills. One study (i.e., Jam et al., 2018) used intelligence quotient and the high-functioning Autism Spectrum Screening Questionnaire to identify participants ~~with high-functioning autism~~. Seven studies (29.1%) referred to the Diagnostic and Statistical Manual–5 definition, or a previous version of the Diagnostic and Statistical Manual, when describing their participants. Ten studies (40%) did not include any confirmatory information or defaulted to a physician's or psychologist's diagnosis.

Table 2 Additional Variables in Studies

Study	Sampling method	Diagnosis	Diagnostic tool	Facilitator	Fidelity check, attendance	Instructional formation	Setting
Alexander et al. (2011)	Conv.	AU (selected for review)	None	Intervention staff	No fidelity check, but attendance was tracked	G	Community
Bahrani et al. (2016)	Conv.	AU	DSM-IV and GARS-2	Certified trainers	No fidelity check, but attendance was tracked	Mixed	Not mentioned
Bass et al. (2009)	Conv.	ASD	DSM-IV and SRS	Trained THR instructors	Neither was mentioned	I	A horse-riding center
Battaglia et al. (2019)	Conv.	ASD	None	Therapists	No fidelity check, but attendance was tracked	I	Community
Bremer et al. (2015)	Conv.	ASD	VABS-2 and SSIS	Researcher with trained graduate students	No fidelity check, but attendance was tracked	G	Local therapeutic center
Bremer et al. (2016)	Conv.	AU (selected for review)	None (ASD diagnosis provided by a family physician, pediatrician, psychiatrist, psychologist, or psychological associate)	Research assistants, the special education teacher, classroom educational assistants, and Grade 8 peer buddies from the school	Neither was mentioned	I	School

(continued)

Table 2 (continued)

Study	Sampling method	Diagnosis	Diagnostic tool	Facilitator	Fidelity check, attendance	Instructional formation	Setting
Gabriels et al. (2012)	Conv.	AP and AU	SCQ, ADOS, nonverbal intelligence using the Leiter-R Brief IQ, and VABS-2	Trained THR instructors and trained volunteers	No fidelity check, but attendance was tracked	I	A horse-riding center
García-Gómez et al. (2014)	Conv.	Mild AU	CARS	Trained THR instructors	Neither was mentioned	G	A horse-riding center
Guest et al. (2017)	Conv.	PDD-NOS, DCD, and ASD	DSM-5 and VABS-2	Researchers and trained staff	Neither was mentioned	G	Summer camp
Holm et al. (2014)	Conv.	ASD	CARS and SRS	Researcher (trained graduate students)	No fidelity check, but attendance was tracked	I	A horse-riding center
Jam et al. (2018)	Conv.	High-functioning autism	IQ ≥ 70 and high-functioning ASSQ	Not mentioned	Neither was mentioned	Not mentioned	Not mentioned
Ketcheson et al. (2016)	Conv.	ASD	ADOS	Trained instructors	Neither was mentioned	Mixed	Summer camp
Koenig et al. (2012)	Conv.	ASD	VABS-2	Trained classroom teachers (2.5 hr of training)	Fidelity check was done. No attendance reported	G	School

(continued)

Table 2 (continued)

Study	Sampling method	Diagnosis	Diagnostic tool	Facilitator	Fidelity check, attendance	Instructional formation	Setting
MacDonald et al. (2005)	Conv.	PDD and AU	None	Researchers	No fidelity check, but attendance was tracked	I	School
Macpherson et al. (2015)	Conv.	AU	None	Therapists	Both were done	G	School
Magnusson et al. (2012)	Purposive	AU, AP, ASD, and PDD-NOS	None	Researcher	No fidelity check, but attendance was tracked	I	Not mentioned
Martin and Farnum (2002)	Conv.	PDD, PDD-NOS, AP, and AU	None	Therapists	No fidelity check, but attendance was tracked	I	School
Miltenberger and Charlop (2014)	Conv.	AU	DSM	Therapists	Neither was mentioned	G	Outdoor areas of behavioral treatment center
Movahedi et al. (2013)	Conv.	ASD	GARS-2	Certified trainers	No fidelity check, but attendance was tracked	Mixed	Not mentioned
Najafabadi et al. (2018)	Conv.	ASD	DSM-IV-TR and GARS-2	Trained coaches with physical education teacher background	Neither was mentioned	G	An indoor complex

(continued)

Table 2 (continued)

Study	Sampling method	Diagnosis	Diagnostic tool	Facilitator	Fidelity check, attendance	Instructional formation	Setting
Pan (2010)	Conv.	ASD and AP	DSM	Research assistants	Neither was mentioned	I	Not mentioned
Rosenblatt et al. (2011)	Conv.	ASD	None	First author, who was licensed clinician with added cert. in yoga and dance therapy	No fidelity check, but attendance was tracked	G	Hospital
Schleien et al. (1990)	Purposive	AU	None	APE teacher and trained peer tutor	Neither was mentioned	Mixed	School
Shanok et al. (2019)	Conv.	ASD	None	Trained golf instructors	Neither was mentioned	Mixed	Various golf courses (multiple locations)
Zhao and Chen (2018)	Conv.	ASD	DSM-V and SSIS	Teachers	Neither was mentioned	Group	School

Q42 *Note.* Conv. = convenience; IQ = intelligence quotient; ASD = autism spectrum disorder; AU = autism; PDD = pervasive developmental disorder; PDD-NOS = pervasive developmental disorder-not otherwise specified; ASSQ = Autism Spectrum Screening Questionnaire; AP = Asperger; DCD = developmental coordination disorder; DSM = Diagnostic and Statistical Manual; GARS = Gilliam Autism Rating Scale; CARS = Childhood Autism Rating Scale; ADOS = Autism Diagnostic Observation Schedule; SCQ = Social Communication Questionnaire; SSIS = Social Skills Improvement System Rating Scales; SRS = Social Responsiveness Scale; VABS = Vineland Adaptive Behavior Scales; G = Group; I = Individual.

Delivery Agent. Of the 25 studies, three studies (12%) used interventions delivered by trained teachers and peers. Bremer and Lloyd (2016), in addition to teachers (special education and classroom) and peer buddies, used trained research staff to deliver the intervention. In all other studies, specialists, such as the researchers or therapists, delivered the intervention components. In general, the ~~facilitator of the PA-based interventions to teach social skills~~ was directly linked to the types of PA, rather than the type of social skills or types of the settings where the learned skills to be generalized. **Q44** No studies identified “why” or gave a reason for the selected delivery agent.

Procedural Fidelity and Intervention Completion Rate. Few studies provided both fidelity and completion rates. One study (Macpherson et al., 2015) reported both a fidelity measure and attendance rates. Macpherson et al. (2015) assessed 40% of sessions for procedural integrity (p. 3840); in addition, attendance was tracked for each session. Koenig et al. (2012) measured fidelity using a checklist covering the environment, organization, teacher implementation, student support, and program conclusion (p. 541); attendance was not recorded. Eleven studies (44%) reported attendance rates but not fidelity. The remaining 12 studies (48%) did not report either fidelity check information or attendance rates. When studies that reported attendance rates were screened, it was revealed that participants in those studies showed 84% or higher attendance rates on average. Two studies (Gabriels et al., 2012; Holm et al., 2014) applied an attendance-related inclusion criterion for their participants, such as “someone who attended at least 80% of the sessions” instead of reporting attendance rates. Single-subject studies reported a number of sessions because they used a visual representation of data. Thus, these studies were considered as studies that tracked the attendance rather than reported attendance rates. These studies used a varying number of sessions across participants depending on the design (e.g., a multiple baseline design with probes).

Group- or Individual-Based Format. Ten (40%) studies used group-based sessions (e.g., one instructor to three or more participants), whereas nine (36%) used individual-based sessions (e.g., one instructor to one or two participants). Five (20%) studies provided instruction in various formations, including individual, small group, and large group sessions. One study (Jam et al., 2018) did not provide enough information to determine the format that was chosen. Little to no rationale was provided for why the particular format was chosen.

Settings (School, After School, Home, etc.). Eight (32%) studies reported that the intervention took place within the community, such as at a community-based horse-riding center, an indoor complex, or a golf course (it was not specified whether the course was public or private). Seven (28%) took place at the participants’ school, two (8%) were done at a summer camp, and three (12%) were completed at a treatment center or hospital. Four (16%) studies did not provide any information on the setting. None of the studies reported that the intervention took place in the participant’s home.

Major Article Findings

All of the included studies reported “improvements” in social skill outcomes; however, the areas in which the outcomes improved were not universal.

Furthermore, the improvements reported were often not statistically significant. While statistical significance should not be the only measure of meaning or importance in a research finding, in looking at studies in aggregate, no clear determinations as to the findings can be made without it. Effect size is another output measure that can be valuable in determining the magnitude of change; however, this information was not consistently reported within the identified articles. Guest et al. (2017) and Bremer et al. (2015) used effect size to demonstrate changes in the motor domain but not the social domain; both expressed moderate effects ranging from 0.5 to 0.675. Koenig et al. (2012) used effect size to show differences between the experimental and control groups on their social measures, the largest being demonstrated in decreased “challenging behaviors” ($d = 1.19$). Similarly, García-Gómez et al. (2014) used effect size with their social measures, showing small differences ($d = 0.22$) in aggressiveness as a result of their intervention. Ketcheson et al. (2016) used effect size to show differences in the experimental and control groups prior to intervention, but did not report effect size as a part of the analysis of the intervention. Jam et al. (2018) reported high effect size differences (≥ 0.9) uniformly between the control and experimental groups, but how these values were calculated was indeterminable.

Studies that used broad measures of “social skills” and focused on clearly defined motor or PA-based outcomes (i.e., Bremer et al., 2015; Bremer & Lloyd, 2016; Guest et al., 2017; Ketcheson et al., 2016) were more likely to see “improvement.” In Guest et al. (2017), in addition to improvements in motor outcomes, participants showed significant improvements in adaptive skills and overall social domain scores measured by the Social Skills Improvement System and the Vineland Adapted Behavior Scales, second edition. Ketcheson et al. (2016) did not observe overall social skill improvements, yet did show a reduction in time spent in solidarity. Q45 Bremer et al. (2015), again, did not see overall social skill improvement, despite significant changes in motor skill performance, though participants showed improvements in “appropriate play” (p. 987). Bremer and Lloyd (2016) saw improvements in social skills as measured by the Social Skills Improvement System, as well as in reported problem behaviors. In the other reviewed studies, although social skills showed significant improvements, they may have been reported by teachers but not parents (Koenig et al., 2012), or in one setting but not another (Macpherson et al., 2015).

Discussion

This review demonstrates substantial variability among the published literature regarding the type of PA provided and the identified social skills. As mentioned previously, while social skills and motor skills have a demonstrated relationship (MacDonald et al., 2013), recent research that has sought to improve motor skills has shown either no direct change in social skills (Colombo-Dougovito, 2017) or nonsignificant improvement (Bremer et al., 2015). In this review, overall, the findings provide confirmatory support that PA settings may provide an environment conducive to social skill development—similar to the findings of Reinders et al. (2019). However, in looking in depth at how social skills have been measured during the PA-based interventions, it is clear that there is limited consensus on the

appropriate social skills to measure in the PA setting and that there is presently no single measure of social skills that has been applied to the PA environment. In addition, the social skill components that were embedded in the PA-based interventions were not uniform, potentially contributing to the limited consensus regarding the impact of PA-based interventions on social skill development.

No Clear Set of Social Skills

Historically, improvements have been, and continue to be, challenging to identify due to limited consensus of the social skills construct and no gold standard assessment for social skills (Dowd et al., 2010). As “social skills” are, themselves, socially constructed, it could be assumed that the expectations of social communication may vary from setting to setting and assessor to assessor. Currently, social skill assessments are not developed for specific use in motor or PA-based interventions, nor are they designed with consideration for the potential differences that may be present in these environments or the sensitivity to capture change within the present interventions. Furthermore, the construct of social skills has had little feedback from the autistic community about what is relevant or needed. In order to determine the interconnectedness of the social and motor domain within individuals on the autism spectrum, there must be a better understanding of the social skills present in PA settings and which social skills are “important.” In this review, the studies that demonstrated the greatest improvements had clearly defined social skills constructs and used closely aligned measures. Furthermore, studies with demonstrated improvements, significant or not, had innate opportunities to practice.

Though the PA setting may provide a sizable opportunity and lower barrier to practice social skills (Colombo-Dougovito, 2017; Hawks et al., 2019; Lee & Vargo, 2017; MacDonald et al., 2013), these skills may take longer to become perceivable on standardized assessments, even if researchers are using the appropriate measure for the given situation. Furthermore, given the wide variety of measured skills, it is difficult to claim universal benefits from PA interventions, even though meaningful improvements may exist. For example, across the included studies, evidence suggests that there was meaningful impact, but it was (a) widely variable among participants (Rosenblatt et al., 2011); (b) a selective impact (e.g., an effect on some behaviors, but not all) (Pan, 2010); (c) short lasting, meaning significant changes at the end of the intervention, but not at a maintenance measurement (Movahedi et al., 2013); (d) no significant effect (Holm et al., 2014; Magnusson et al., 2012); (e) a significant impact, but was not generalizable (Macpherson et al., 2015); (f) inconsistently reported by different assessors, such as teachers versus parents (Koenig et al., 2012); and (g) a significant impact across all areas of measurement (Bremer & Lloyd, 2016; Gabriels et al., 2012; Guest et al., 2017). This highlights the necessity, as a field, to define the social skills construct, determine which elements would be most related to PA settings, and develop a measure sensitive enough to capture meaningful changes. Within the present, aggregated findings, it is difficult to determine whether (a) inconclusive impacts are related to the indiscernible impact that PA has on the social skill domain; (b) the measures used are not accurately capturing change; or (c) measurement improvements are due to the intervention itself, maturation, measurement error, chance, or some combination thereof.

How Much or How Often?

- Q48** Romanczyk, Callahan, Turner, and Cavalari (2014) identified high-intensity interventions (e.g., 30 hr/week) as being potentially more beneficial than low-intensity interventions (e.g., about 10 hr/week). Based on the recommendations of Romanczyk et al., however, none of the reviewed studies in this review met the standard for high intensity; Ketcheson et al. (2016) was the closest to obtaining this intensity at 20 hr/week. When it comes to intervention duration, Romanczyk et al. showed that, on average, behavioral interventions ~~sustained~~ **Q49** 21 months, with a range from 3 to 52 months. If this standard is applied, the majority of studies in this review used a relatively short duration as the longest duration of the included studies was 4 months (i.e., 16 weeks; e.g., Jam et al., 2018; Koenig et al., 2012), although a few studies (Bremer et al., 2015; Ketcheson et al., 2016) suggested that future research be conducted for a longer duration (e.g., 18 weeks or beyond).

Considering the elements of a PA-based intervention, one must consider whether high intensity (e.g., 30 hr/week) or duration (e.g., 21 months) is appropriate or feasible. Though not a new issue in PA interventions—Colombo-Dougovito and Block (2019) highlighted this area as a needed focus of further motor skill intervention research—~~limitations of study findings~~ will continue to ~~occur~~ without an understanding of the appropriate frequency and dosage needed to enact or achieve change. PA outcomes may not need as intense a frequency and dosage as other developmental areas; however, when other domains use far greater durations and intensities for similarly measured behavior (i.e., social skills), it could be assumed that this may be why inconsistent results are reported in the present findings.

Differences Across Ages

- Q50** Another difference that might provide insight into a lack of consensus is the wide range of ages in the included studies, as participants ranged from 3 to 24 years of age. This range covers multiple, vastly different stages of development from young childhood to adolescence to young adulthood, and the social expectations vary greatly at each stage (Hartup, 1989). Differences within studies covering similar ages and in similar settings further confound this issue as little similarity was shown in the measured social skills construct. For example, although Movahedi et al. (2013) and Koenig et al. (2012) covered similar ages (5–16 and 5–12 years, respectively) and individual sports (karate and yoga, respectively), there was no similarity in the social skills measured. Movahedi et al. measured social interaction/dysfunction, while Koenig et al. measured social communication, activities of daily living, adaptive behavior, and general social skills. Without a unified construct of which social skills are present during similar ages and in certain PA contexts (e.g., physical education), it becomes difficult to gather supporting evidence or make broader comparisons. Despite the increased likelihood for practice (Barnett & Weber, 2008) and a potential bidirectional relationship (Reinders et al., 2019), social skills, like motor skills, may need to be taught and practice experiences may need to be constructed.

The Autism Constellation

Another area that may be contributing to the limited congruence of findings is the lack of a confirming diagnostic assessment or, even, detailed sample characteristics in reference to autistic characteristics. A large number (42%) of the reviewed studies did not include a confirmatory measure of the participant's diagnosis or provide characteristic information about the exact needs of the sample. Without this information, comparisons become very difficult as it is hard to determine if the intervention, or the modifications thereof, would be beneficial.

As autism spectrum disorder may be more of a constellation than a spectrum (Hendren, Beroglio, Ashwood, & Sharp, 2009; Mumper, 2012), it is essential to recognize that presenting characteristics, daily needs, and strengths in PA settings, as well as affinity for certain social skills, may be vastly different, despite the same or similar diagnostic label. Notably, there is a dearth of research that includes those with co-occurring conditions, such as epilepsy or attention deficit hyperactivity disorder, or that ~~limits participation to those~~ with an intelligence quotient ~~above~~ 70, in spite of high rates of reported co-occurring conditions among the broader populations of those on the autism spectrum (Simonoff et al., 2008; Sundelin et al., 2016). With limited sample data, it is hard to generalize findings for the use of a particular intervention.

In a rare example, Ketcheson et al. (2016) provided a comprehensive examination of their sample population by conducting the Autism Diagnostic Observation Schedule, second edition (Lord, Luyster, et al., 2012; Lord, Rutter, et al., 2012). In doing so, Ketcheson et al. offered information that allows future research to situate and compare the study's findings within their own sample. Functioning labels—such as “high functioning” or “low functioning”—have been shown to be of little value and potentially stigmatizing (Gillespie-Lynch, Kapp, Brooks, Pickens, & Schwartzman, 2017). Therefore, research should use actual measures and provide detailed information about the participant's actual abilities to allow a clearer comparison.

Uneven Recruitment

Overwhelmingly, the included studies recruited far more male participants than female participants. Of the reviewed studies, 79% of the participants were male (357/452) and 21% were female (95/452). Although this represents the generally agreed-upon breakdown in the current understanding of the prevalence of autism (Baio et al., 2018), it also further demonstrates the vast overrepresentation of male participants on the autism spectrum in current research and the necessity for actively recruiting female participants. In the only study to include a ~~predominant sample population~~ of females on the autism spectrum, Guest et al. (2017) provided one of the few ~~accounts of an intervention~~ that ~~had~~ a higher likelihood of working for ~~females on the autism spectrum~~. Many studies did not include *any*, or a highly disproportionate number of, female participants, therefore limiting findings to only males on the autism spectrum. One study (Najafabadi et al., 2018) did not report whether the participants were male or female. Future research must actively seek female participants to ensure the universality of ~~the PA~~ intervention.

Limited Fidelity Measures

Another limiting factor of the reviewed studies was the lack of indicators to evaluate procedural fidelity, though this seems to be a common issue among PA and exercise studies (Dillon et al., 2017). Without fidelity measures, findings are limited due to limited assurance that the intervention components were delivered consistently and as planned. Some types of indicators, such as lesson-by-lesson adherence rates, can be calculated simply by the facilitator or through observer logs. Similar to procedural fidelity, attendance or completion rates can be an indicator of the actual exposure or dose that the participants received. This analysis yielded many PA-based interventions that did not provide indicators for procedural fidelity or attendance rates. Intervention success, above all other measures discussed, might be dependent upon the level of treatment integrity, as a high level of integrity with rigorous methodology can increase the likelihood of changed outcomes (Pereplechikova & Kazdin, 2005). Similar to treatment integrity, attendance rates of the participants should be reported to assure that the participants were exposed to the intervention dose as planned. Future research should incorporate such indicators to ensure procedural integrity and completion rates.

Finally, when providing interventions for individuals, it is vital to incorporate sustainability (and social validity) for any of the given skills to ensure that development can be maintained once the research is completed. In many of the included studies, trained personnel, such as the horse trainers or the researchers, directly provided the intervention, even though intervention settings were relatively authentic, such as schools and community-based facilities. While encouraging appropriate treatment fidelity, limiting intervention delivery agents to trained instructors or researchers will limit the potential continued benefits of a study. Future research should explore parents, caregivers, siblings, or peers within the individual's social sphere. By doing so, this would increase the potential benefits from the study and allow for a higher likelihood of continued practice. Peers, for example, may provide for a more naturalistic opportunity to work on age-appropriate social skills and may create more opportunities to build relationships that will last.

Limitations

Like many reviews, the inclusion criteria outlined by the authors limit this analysis. The selection criteria may have inadvertently excluded studies that were not present during the search process. To combat this, the authors used inclusive language and search terms while conducting the initial searches. Furthermore, references of review studies were searched for studies that were not present during the search. Regardless, despite comprehensive search terms used, this analysis may have captured studies that worked on social skills as an outcome but did not overtly define the study's presentation mode as being PA. An additional limitation of this review due to the scope of the analysis was the omission of other criteria related to the rigor of the studies, such as (a) inclusion of a generalization phase or maintenance phase and (b) social validity measures. Finally, it was unclear exactly how much each PA intervention afforded the opportunity for social interaction between participants. One could argue that the results of this scoping review are too

varied to allow for a clear picture; however, the varying evidence is the critical result highlighted through this review. Thus, the ~~researchers~~ recommend that future reviews include these variables to evaluate further the quality of PA-based interventions.

Conclusion and Future Recommendations

Overall, the outcomes yielded from this scoping review suggest that the PA environment may provide a beneficial setting to engage in building social skills, suggesting—similar to Reinders et al. (2019)—that PA may have some influence on social outcomes of individuals on the autism spectrum. However, little consensus exists about which social skills are present or which may benefit from a PA-based intervention. While the PA environment may provide social opportunities that are more natural and have a lower barrier for entry for autistic persons to work on social skills, it may also be true that intentional, structured opportunities to build social skills are needed. Furthermore, without a gold standard measurement and ~~different~~ conceptions of what composes “social skills,” ~~research~~ findings will continue to be limited. Future research should seek to identify how the definition of social skills is constructed in different PA settings and at different ages and by different people (e.g., individuals, parents, instructors). Furthermore, future research should look at how to identify differences in growth among the heterogeneous samples of individuals on the autism spectrum as well as how this may differ in individuals not typically included (e.g., females or people of color). Finally, future research of PA-based interventions needs to include appropriate fidelity measures and provide justifications for dosages and frequencies of the intervention, which may prove to be different between settings.

Overall, there appears to be evidence to suggest the potentially positive association of PA and social skills. However, a lack of consensus on how to define social skills hinders the ability to make definitive statements regarding this relationship or, even, to measure it appropriately. Clearly, moving one’s body affords a naturalistic opportunity to work on social skills, yet these opportunities may need to be constructed to ensure maximal benefits. Furthermore, individuals on the autism spectrum should be included in the construction of this construct. If an “expert” developed construct has little relevance, there will be little motivation to engage in such skill practice. Until a consensus of the composition of social skills and PA-specific social skills is reached, the implications of this body of research will continue ~~to be limited~~.

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Asterisk denotes reviewed article.

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Queries

REVISED

12:47 pm, Jul 16, 2020

Please confirm that changes made to the sentence beginning “Based on a review . . .” preserve the intended meaning.

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

As per journal style, repeats of words in the article or journal title are not allowed in keywords. Hence, the keywords "physical activity" and "intervention" were deleted. Please check.

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please ensure author information is listed correctly here and within the byline.

REVISED

1:26 pm, Jul 19, 2020

Please provide the complete reference details for “Tyler et al., 2014” to be included in the reference list.

APPROVED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please check that changes made to the sentence beginning “Typically, in many . . .” preserve the intended meaning.

REVISED

1:26 pm, Jul 19, 2020

Please provide the complete reference details for “Berkeley et al., 2001” to be included in the reference list.

REVISED

1:26 pm, Jul 19, 2020

Please provide the complete reference details for “Provost et al., 2007” to be included in the reference list.

REVISED

2:23 pm, Jul 13, 2020

The year of publication for the reference “Bremer et al., 2014” cited here has been changed to "2015" to match with the reference in the list. Please verify.

REVISED

12:41 pm, Jul 16, 2020

Please clarify the sentence beginning “Age-appropriate motor skills . . .”.

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please provide the complete reference details for “Hawks et al., 2019” to be included in the reference list.

APPROVED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please check that changes made to the sentence beginning “What are the protocols . . .” preserve the intended meaning.

REVISED

1:29 pm, Jul 13, 2020

Please provide the complete reference details for “Peters et al., 2015” to be included in the reference list.

REVISED

1:30 pm, Jul 19, 2020

Please provide the complete reference details for “Tricco et al., 2018” to be included in the reference list.

REVISED

12:41 pm, Jul 16, 2020

Please rephrase the sentence beginning “As the authors screened . . .” for clarity.

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please ensure that the quotation beginning “experiences in physically demanding . . .” in the sentence beginning “For this review . . .” is reproduced correctly, especially the subject-verb disagreement between “experiences” and “results.”

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

The sentence beginning “The inclusion criteria . . .” has been rephrased for structural continuity. Please check that changes preserve the intended meaning.

REVIEWED

By Andrew Colombo-Diagnositis at 12:43 pm, Jul 16, 2020

Please confirm that changes made to the sentence beginning “The exclusion criteria . . .” preserve the intended meaning.

REVIEWED
By Andrew Coleman-Douglas at 11:43 pm, Jul 13, 2020

Please confirm that changes made to the sentence beginning "Exclusion criteria also extended to . . ." preserve the intended meaning.

REVISED
12:41 pm, Jul 13, 2020

Please provide manufacturer name and location details (city, state [if US], and country) for "Excel spreadsheet."

REVISED
11:28 am, Jul 13, 2020

Please check if "n" vales in Figure 1 are correct (as the total of 111+160+102+88 equals 461 not 462)."

REVISED
12:41 pm, Jul 13, 2020

Please provide in-text citation for Figure 1.

REVISED
12:41 pm, Jul 13, 2020

Please note that only 19 articles (instead of 25) are mentioned in the sentence "#Of the 25 articles, five (20%) used . . ." Please check.

REVISED
12:41 pm, Jul 13, 2020

Please check Table 1 for consistency in usage of "Con" and "Cont" in reference to control group.

REVISED
1:32 pm, Jul 13, 2020

Please provide the complete reference details for "Alexander, 2008" to be included in the reference list.

REVISED
1:33 pm, Jul 13, 2020

Please provide complete reference details for "Baker (2003)" to be included in reference list.

REVISED
12:41 pm, Jul 13, 2020

Please provide significance of "*" in Table 1.

REVISED
12:41 pm, Jul 13, 2020

Please confirm whether "GARS-2" or "GAR-2" is correct and ensure consistent usage throughout.

REVISED
11:40 am, Jul 13, 2020

Please check the phrase "12-week Caputo et al. implemented multi-systemic aquatic therapy" for clarity. Also provide complete details of "Caputo et al." to be included in reference list.

REVISED
1:51 pm, Jul 13, 2020

Please provide the complete reference details for "Venuti (2001)" to be included in the reference list.

REVISED
1:53 pm, Jul 13, 2020

Please provide the complete reference details for "Breslin & Liu (2014)" to be included in the reference list.

REVISED
11:41 am, Jul 13, 2020

Please assess the phrase "short form of BTMP-2, short form" for redundancy.

REVISED
2:02 pm, Jul 13, 2020

Please provide complete reference details for "Conners Neuropsychological Questionnaire (2007)" to be included in reference list.

REVIEWED
By Andrew Coleman-Douglas at 11:42 am, Jul 13, 2020

Please check if the manufacturer name and location details added for "ActiGraph" are correct.

REVISED
11:43 am, Jul 13, 2020

Please check whether "solidarity" is the intended word in the sentence beginning "No effects were found . . ." rather than "solitary" or "solitude."

REVISED
11:46 am, Jul 13, 2020

Please clarify the sentence beginning "Video modeling using . . ."

REVISED
11:51 am, Jul 13, 2020

Please check if "modified Romber test (balance)-measured pre- post-Parents filled out surveys" is correct.

Q37. Please provide the complete reference details for "Ames, 1992" to be included in the reference list.

REVISED
12:01 pm, Jul 13, 2020

Please provide an end quotation mark to the quoted phrase "engaging in goal . . ."

REVISED
12:27 pm, Jul 13, 2020

Please provide expansion for "IV, DV, I/NI, ABCA, GAR-2, Con, PDMS-2, THR, BOT-2, CY-PSPP, CSAPPA, SS, B phase, SP-CQ, AB, PDD, TARGET, SPARK, rec., sig., and comm." in Table 1.

REVISED
12:28 pm, Jul 13, 2020

Please rephrase the sentence beginning "Those that used yoga . . ." for clarity.

REVISED
12:35 pm, Jul 13, 2020

Please rephrase the sentence beginning "Ketcheson et al. suggested . . ." for clarity.

REVISED
12:40 pm, Jul 13, 2020

Please provide expansion for "THR, cert., DSM-IV-TR, and APE."

REVIEWED
By Andrew Colombo-Dougiovito at 12:41 pm, Jul 13, 2020

Please note that "ID, DS, and ADHD" expansions deleted from footnote in Table 2 as they are not mentioned in the table.

REVISED
12:43 pm, Jul 13, 2020

Please clarify the meaning of the sentence beginning "In general, the facilitator . . .".

REVISED
12:44 pm, Jul 13, 2020

Please confirm that the word "solidarity" is used intentionally in the sentence beginning "Ketcheson et al. (2016) did not observe . . ." rather than "solitude" or "solitary."

REVISED
12:46 pm, Jul 13, 2020

Please check if the phrase "widely variable among participants" is correct.

REVISED
12:46 pm, Jul 13, 2020

Please check if "no significant effect" can be changed to "not a significant effect."

REVISED
12:49 pm, Jul 13, 2020

Please provide the complete reference details for "Romanczyk et al., 2014" to be included in the reference list.

REVISED
12:51 pm, Jul 13, 2020

Please check the sentence beginning "When it comes to intervention duration . . ." for clarity.

REVIEWED
By Andrew Colombo-Dougiovito at 1:02 pm, Jul 13, 2020

The sentence beginning "Another difference that night . . ." has been reworded for clarity. Please check that the intended meaning is preserved.

REVISED
12:59 pm, Jul 13, 2020

Please revise the sentence beginning "In the only study . . ." for clarity.

REVISED
1:01 pm, Jul 13, 2020

Please clarify whether you mean "with different conceptions" or "without different conceptions" in the sentence beginning "Furthermore, without a gold standard . . .".

REVIEWED
By Andrew Colombo-Dougiovito at 1:06 pm, Jul 13, 2020

The publication year has been updated for the reference "García-Gómez et al. 2014". Please check for accuracy.

REVIEWED
By Andrew Colombo-Dougiovito at 1:07 pm, Jul 13, 2020

Please provide issue number for the reference "Gillespie-Lynch et al., 2017."

REVIEWED
By Andrew Colombo-Dougiovito at 1:08 pm, Jul 13, 2020

The year of publication for the reference "Reichow & Volkma, 2009" here has been changed to "2010" to match with the in-text citation. Please verify.

REVIEWED
By Andrew Colombo-Dougiovito at 1:09 pm, Jul 13, 2020

Please provide issue number for the reference "Reinders et al., 2019."

REVIEWED
By Andrew Colombo-Dougiovito at 1:07 pm, Jul 13, 2020

Please provide issue number for the reference "Ross et al., 2016."

REVISED
1:09 pm, Jul 13, 2020

Please provide in-text citation for the reference "Sorensen & Zarrett, 2014"

REVIEWED
By Andrew Colombo-Dougiovito at 1:07 pm, Jul 13, 2020

Please provide issue number for the reference "Zhao & Chen, 2018."

REVIEWED
By Andrew Colombo-Dougiovito at 1:08 pm, Jul 13, 2020

Please check if the expansion added for PRISMA is correct.