



Improving Social Knowledge and Skills among Adolescents with Autism: Systematic Review and Meta-Analysis of UCLA PEERS® for Adolescents

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Accepted: 12 January 2021

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Abstract

UCLA PEERS® for Adolescents is a widely applied program among a number of social skills training programs developed over the years. We synthesized current research evidence on the PEERS program to evaluate the treatment effect on four commonly used outcome measures. 12 studies met inclusion criteria for the review and nine met the criteria for meta-analysis. Results showed moderate to large pooled effects across measures and informants in favor of the PEERS program, with the largest effect seen in social knowledge improvement and the smallest effect in the frequency of get-togethers. The heterogeneity of effects across studies were examined and the limitations of the current evidence were discussed.

Keywords Social skills training · Adolescents · Autism · Meta-analysis · Effect sizes

Social skills training (SST) is an established evidence-based intervention for individuals with autism spectrum disorder (ASD) (Steinbrenner et al. 2020; Wong et al. 2015). Group social skills interventions (GSSIs) for children, adolescents, and young adults with ASD have become increasingly common and been delivered across a variety of settings (e.g., outpatient clinics, schools, and summer camps). GSSIs are often manualized with a combination of strategies including direct instruction (i.e., didactic lessons), modeling (e.g., in-person or video-based), role-play practice, and performance feedback. Many GSSIs are informed by behavioral and cognitive-behavioral strategies (Koenig et al. 2010; Koning et al. 2013; Kroeger et al. 2007; Laugeson and Park 2014; Palmen et al. 2008) as well as theory of mind strategies (Begeer et al. 2015; Ozonoff and Miller 1995). In their simplest form, GSSIs are delivered directly to a group of

individuals with ASD only, while more recent GSSIs often involve parents (Laugeson et al. 2009) and neurotypical peers (Corbett et al. 2014; Kamps et al. 2014) which have been shown to lead to more positive gains (Wolstencroft et al. 2018).

While GSSIs have been implemented successfully across different age groups, adolescent years present a particularly opportune time for intervention. During adolescence, the frequency of peer interactions and social demands increase as the rules of social engagement and relationships become more nuanced and complex. Consequently, with social communication and skills deficits, adolescents with ASD are more prone to negative social experiences than their neurotypical peers and peers with other disabilities (Humphrey and Symes 2011), such as peer rejection, bullying, and social exclusion by their peer group (Adams et al. 2017; Chamberlain et al. 2007; Jones and Frederickson 2010; Locke et al. 2010). Studies have shown that these experiences are associated with high rates of loneliness (Chamberlain et al. 2007; Locke et al. 2010), and further, depressive and anxiety symptoms in youth with ASD (Gotham et al. 2014; Mazurek and Kanne 2010). Given the unique social challenges faced by adolescents with ASD, there is a critical need for effective social skills treatment during this developmental stage. Thus, the current study focuses on the GSSIs designed for adolescents with ASD.

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There are currently a number of named (e.g., SENSE Theatre, Corbett et al. 2014; the SOSTA program, Freitag et al. 2016; and the START Program, Vernon et al. 2016) and unnamed (Koning et al. 2013) GSSI programs for adolescents. Though these GSSIs have accumulated empirical evidence over the years, recent reviews and meta-analyses have shown varying degrees of effectiveness of these programs in improving social knowledge and skills (Cappadocia and Weiss 2011; Gates et al. 2017; McMahon et al. 2013; Wolstencroft et al. 2018). While often utilizing combined evidence-based strategies, current GSSI programs differ in specific components, structures, and delivery procedures in their designs, which likely have contributed to the observed wide range of effects. Moreover, it is common for practitioners, schools, and clinics to adopt one of the published programs to meet the needs of their targeted population for treatment in real-life settings. Therefore, synthesizing research evidence for a specific GSSI program will provide a more focused evidence base that could provide guidance for choosing a program. Perhaps no other GSSI for adolescents is as widespread or as well studied as the UCLA PEERS® (Program for the Education and Enrichment of Relational Skills) for Adolescents (PEERS), which has been translated into over a dozen languages and used in over eighty countries (UCLA PEERS Clinic 2020). However, individual studies on the PEERS for adolescents program often have limited sample sizes, and the empirical evidence has not yet been reviewed systematically and synthesized to understand the overall effectiveness of the program. With the availability of independent investigations across multiple research groups, conducting a systematic review and meta-analysis is a viable and needed step: (1) to assess the quality of current research evidence, (2) to precisely identify specific areas of possible improvement resulting from treatment, (3) to guide clinical practice using the PEERS® Program, and (4) to inform decisions about directions of future research. Thus, the findings of a meta-analysis and systematic review specifically focusing on the PEERS could be useful in advancing both research and practice in social skills training for adolescents.

The current study aims to identify and synthesize the existing research evidence for the PEERS for adolescents program. Additionally, we plan to examine and compare the effects of PEERS across multiple outcome measures, as previous reviews of GSSIs have pointed out the discrepancy in the effects related to the acquisition of social skills knowledge versus the application of social skills (Gates et al. 2017).

Descriptions of PEERS

PEERS for adolescents is a manualized GSSI that can be delivered both in a clinic- or a center-based setting and at school. PEERS consists of concurrent adolescent and parent sessions on topics such as conversations, humor, get-togethers, and teasing and bullying (See Supplementary Table S1 for social skills topics covered in the clinic-based and the school-based PEERS programs). Adolescent group sessions are comprised of didactic teaching of specific social skills followed by role-play practice, while parents receive didactic instruction of the weekly skills and strategies to coach their adolescents outside of the group. Weekly homework of practicing skills are assigned for the teen-parent dyads to complete and are reviewed at the beginning of the next session. For PEERS delivered in a clinic or a center, both the adolescent and parent groups meet for a 90-min session weekly for 14 weeks. While at school, 30-min adolescent sessions are delivered daily after school for 16 weeks (based on the Laugeson 2013 manual, while the Laugeson et al. 2014 study reported a 14-week program) with parents receiving psycho-education via weekly handouts with coaching instructions and homework to facilitate the intervention. More detailed lesson scripts can be found in the PEERS manuals (Laugeson 2013; Laugeson and Frankel 2011).

Method

Protocol and Registration

The methodology and reporting of this systematic review and meta-analysis were conducted according to the PRISMA and PRISMA-P statement (Moher et al. 2009; Shamseer et al. 2015), and the review was registered with PROSPERO (Registration No.CRD42020171395).

Search Strategy and Study Selection

Literature searches were conducted in six electronic databases that are known for their coverage of social and behavioral studies: PubMed, Embase, Web of Science, ERIC, CINAHL, Cochrane, using search terms listed in supplementary Table S2.

The search results were compiled, and the duplicates were removed. The articles that passed the abstract screening phase were imported to the Rayyan platform (Ouzzani et al. 2016) for further screening and article selection.

Studies were included if they: (1) were written in English; (2) were published in peer-reviewed journals from 1/1/2000 to 2/13/2020; (3) included adolescents with ASD (Age: 10

to 21 [maximum age limit for high school]); (4) followed the intervention guidelines in the UCLA PEERS® for Adolescents program handbooks; (5) reported data on at least one of the following measures as outcomes reported by adolescents, parents/caregivers, or teachers: Social Responsiveness Scale (SRS, Constantino 2005), Test of Adolescent Social Skills Knowledge (TASSK, Laugeson et al. 2009), Social Skills Improvement System (SSiS, or previously Social Skills Rating System [SSRS], Gresham and Elliott 2008), Quality of Socialization Questionnaire (QSQ, Frankel and Mintz 2008), which were the most commonly reported primary outcome measures in the PEERS efficacy studies (see supplementary Table S3 for detailed descriptions).

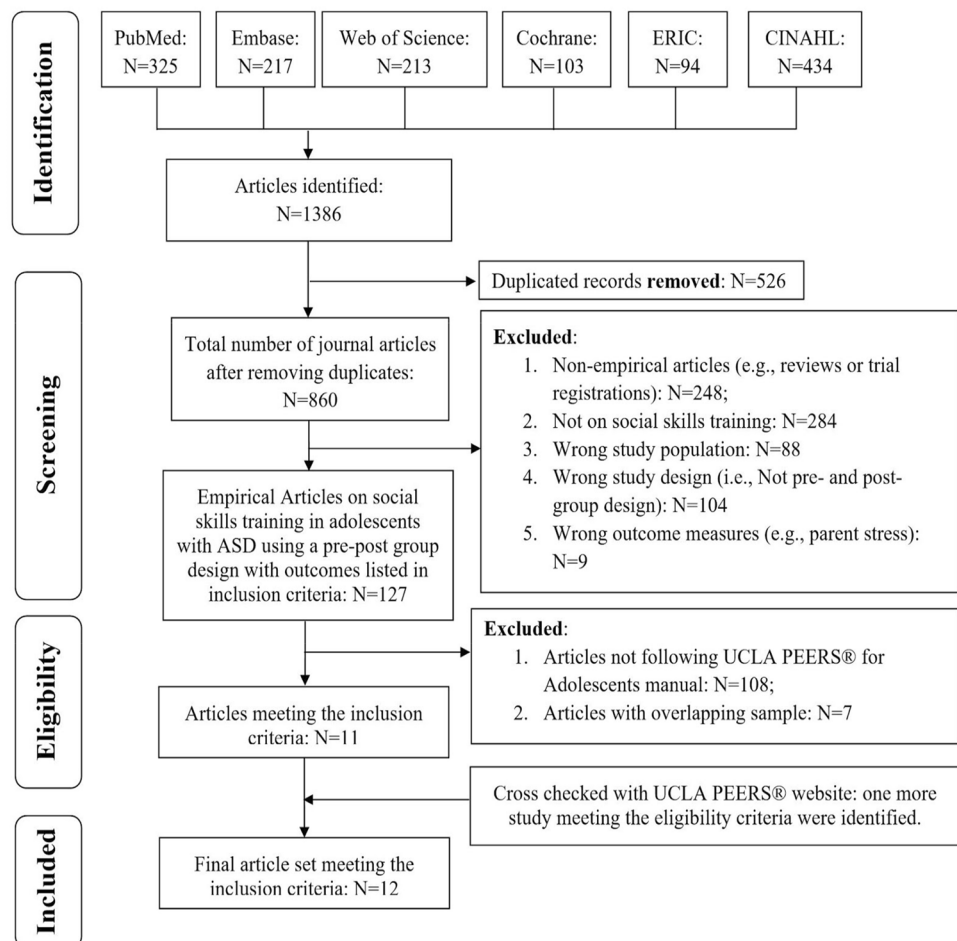
Two reviewers (SZ and ES) initially screened all 860 non-duplicated articles to exclude articles that were not empirical studies, then independently selected studies based on the eligibility criteria, and met to review decisions and resolve discrepancies. Next, studies were examined for the possibility of overlapping samples. When studies indicated the use of overlapping samples with a previous study, only original efficacy studies of PEERS were included. Six studies (Chang

et al. 2016; Hong et al. 2019; Karst et al. 2015; Mandelberg et al. 2014; Matthews et al. 2019; McVey et al. 2017) were excluded for this reason. Lastly, the final article set was cross-checked with the article list on the UCLA PEERS® for Adolescents website (<https://www.semel.ucla.edu/peers/research>), and one additional study meeting the eligibility criteria (Marchica and D'Amico 2016) was identified and included. The inclusion of the Cochrane database and review of the PEERS website were designed to search for possible unpublished studies that might be eligible for the review. At the end, 12 studies satisfied all inclusion criteria and were included in the current systematic review and meta-analysis (See Fig. 1 PRISMA flow-chart).

Systematic Review

Each study was reviewed and coded for the two sets of information: (1) study characteristics, including study design, sample size(s), age range, cognitive scores, setting, the number/frequency/duration of sessions, inclusion criteria, language and country(region); (2) major findings of the

Fig. 1 PRISMA study selection flow chart



intervention outcomes. One of the authors (HK) served as the primary reviewer and extracted the information from the selected articles, and another author (KA) cross-referenced the information extracted for the systematic review table with the articles to ensure the accuracy of the information.

Risk of Bias

The risk of bias of the included studies was assessed by two authors (SZ, HK) independently, using an adapted version of “Risk of Bias In Non-Randomized Studies-of Interventions (ROBINS-I)” (Sterne et al. 2016) recommended by Cochrane. The risk of bias was assessed in the following domains: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result. The overall risk of bias for each study was assigned based on the domain level ratings. Two authors reviewed the ROBINS-I guideline together and calibrated their coding on one study (Laugeson et al. 2009) to reach the consensus on the coding scheme. Then they independently coded the rest of the studies and met to discuss and resolve discrepancies.

Statistical Analysis

Data Extraction

Seven articles reported pre- and post-treatment data, and five articles reported change scores data. The following data were extracted for all available outcome measures: (1) group means at pre- and post-intervention or mean difference scores; (2) standard deviations (SD) of the pre- and post-treatment group means, or the difference scores; and (3) sample sizes of each group. Outcome measures included self, parent, and/or teacher-report SRS, self-report TASSK, self- and/or parent-report QSQ, self- and/or parent-report SSiS. When available, additional information, such as age ranges, sex ratios, intervention settings, cognitive ability scores, and numbers of sessions completed, was also extracted.

Descriptive Analysis

Participant (e.g., age, sex ratio, IQ, adaptive behaviors), intervention (e.g., sample size, number of intervention sessions), and methodological characteristics (e.g., study design, study quality measures) were described. The total sum, weighted means and pooled standard deviations were generated when sufficient information was available using Microsoft Excel.

Meta-analysis

As within-group effect sizes (ESs) should be avoided in meta-analysis (Cuijpers et al. 2017), the current analysis only included studies with data on outcome measures available for both the PEERS intervention and delayed control groups that allow calculations of between-group ESs. For the studies with no control groups, within-group ESs were calculated with pre- and post-treatment data and reported when sufficient information was available.

During the current meta-analysis, we calculated *Hedge's g* using the extracted data. *Hedge's g* is defined as standard mean difference (SMD) and accounts for standard error and is a better indicator especially for studies with small sample sizes than *Cohen's d* which tends to overestimate the ESs when sample sizes are small (Hedges and Olkin 2014). For the studies reporting pre- and post-treatment data, *Hedge's g* was calculated as the standardized mean difference between the treatment and comparison group at post-treatment on outcome variables; while for those with difference scores, *Hedge's g* was calculated with the difference scores and standard deviations of the difference scores on the outcome variables between the two groups. We then fitted the calculated ESs with the Random-Effects model to pool effect sizes across studies. Ninety-five percent confidence intervals (95% CI) were calculated to indicate the degree of precision of the estimate and the significance of the mean ESs. ESs of 0.20, 0.50, and 0.80 are considered small, medium, and large, respectively. Forest plots were generated for each outcome measure.

The between-study heterogeneity was assessed by examining the I^2 index, an indicator of the homogeneity of the ES distribution for each outcome variable (Higgins and Thompson 2002). An I^2 index greater than 25% indicates a heterogeneous distribution of ESs (Higgins et al. 2003; Huedo-Medina et al. 2006). Publication bias was examined statistically with the Egger's test, and visually with funnel plots of *Hedge's g* for asymmetric patterns and data points outside of the funnel, which indicate the presence of potential publication bias (Egger et al. 1997; Lipsey and Wilson 2000).

Data analyses were conducted in R version 4.0.0. R package *ecs* (Lüdtke 2019) was used to calculate ESs for each outcome variable in individual studies. R package *meta* (Schwarzer 2020) was used for fitting the random effect models to pool ESs, and to examine the between-study heterogeneity and publication bias.

Results

Study Characteristics

Our current review identified 12 studies meeting all eligibility criteria with sample sizes varying from 5 to 40

participants. A total of 441 of adolescents with ASD (196 in control and 245 in intervention) with mean ages from 12.9 to 18.8 years old (PEERS intervention group mean = 14.4; SD = 1.4, Control group Mean = 13.7, SD = 1.5) were included across these studies. While the majority of the studies worked with adolescents between the ages of 12 and 18, three studies (Laugeson et al. 2014; Shum et al. 2019; Yamada et al. 2020) included adolescents as young as 11 years old, and there was one study (Wyman and Claro 2019) that included young adults up to age 21. Among these studies, the large majority of participants were male, ranging from 64 to 93%. Eight studies reported the IQs, all of which were within the average range (PEERS intervention group mean = 99.5; SD = 17.3; Control group Mean = 100.2; SD = 17.2). Five studies reported overall adaptive behavior scores on the Vineland Adaptive Behavior Scale (Laugeson et al. 2009, 2012; Matthews et al. 2018; Schohl et al. 2014; Yamada et al. 2020), with an average score of 78.9 (SD = 16.4) for the PEERS intervention groups and 70.0 (SD = 16.2) for the control groups, indicating low to moderately low in adaptive behaviors. Table 1 provides information of study characteristics for the included studies.

All of the studies used the inclusion criteria from the initial PEERS publication (Laugeson et al. 2009) with small variations in cognitive measures and treatment settings as noted in Table 1. Five studies used Kaufman Brief Intelligence Test 2nd Edition (KBIT-2) (Hill et al. 2017; Laugeson et al. 2009, 2012; Matthews et al. 2018; Schohl et al. 2014), and three studies used Wechsler Intelligence Scale for Children (WISC) (Rabin et al. 2018; Shum et al. 2019; Yamada et al. 2020) to evaluate IQ and include adolescents with verbal IQ ≥ 70 . The remaining three studies either included students from a specific school that did not have students with intellectual disability (ID) (Laugeson et al. 2014), included students with ID (Wyman and Claro 2019), or did not report on cognitive measures or status of cognitive disabilities (Marchica and D'Amico 2016).

Outcome Measures

In terms of the outcome measures extracted from the studies, five studies reported change scores on measures and seven studies reported the means for pre-treatment and post-treatment. Across all studies, the most frequently used outcome measures were the QSQ parent and adolescent forms and the TASSK (see Table 2 for summarized findings on the outcome measures).

Treatment Characteristics

Ten studies followed the clinic-based PEERS protocol in outpatient settings. One study, Laugeson et al. 2009, utilized 12 weekly 90-min sessions and eight studies utilized

14 weekly 90-min sessions for adolescents and their parents. One study (Rabin et al. 2018) had two additional sessions to break down some of the topics due to feedback from clinicians and families in Israel. Two studies (Laugeson et al. 2014; Wyman and Claro 2019) followed the teacher-mediated PEERS protocol in a school-based setting with the same session topics but shorter and more frequent sessions (i.e., 30-min daily sessions in Laugeson et al. 2014; 45-min sessions twice a week in Wyman and Claro 2019). Also, Wyman and Claro (2019) added two more sessions on bullying and managing reputations.

Study Designs

Nine studies used a delayed treatment control group, and three used a repeated measures design (i.e., pre- and post-treatment comparisons only; Marchica et al. 2016; Hill et al. 2017; Wyman and Claro 2019).

Language and Country/Region

Eight studies from the United States or Canada used the original PEERS curriculum. Four studies from Korea (in Korean; Yoo et al. 2014), Israel (in Hebrew; Rabin et al. 2018), Hong Kong (in Chinese; Shum et al. 2019), and Japan (in Japanese; Yamada et al. 2020) used translated versions of PEERS.

Risk of Bias Results

Risk of Bias ratings indicated seven studies with moderate, two with serious, and three with critical overall risk (see Fig. 2). All included studies were judged to have at least a moderate risk of bias in the measurement of outcomes as almost all of the data were parent-report or self-report, and these raters were not blind to the intervention assignment. The majority of the studies did not explicitly describe other interventions participants might be receiving during the study period. Three studies (Marchica et al. 2016; Hill et al. 2017; Wyman and Claro 2019) had no control group and were rated to have critical risk.

Meta-analysis

Pooled Between-Group ESs

Between-group ESs were synthesized for the outcome variables reported in more than one study with both treatment and control groups. Nine studies with a control group were included in the meta-analysis of three outcome types: (1)

Table 1 Systematic review table of study characteristics

Author (year)	Study design, Number of cohorts/classes participants	Age range (years), Mean(SD)	Cognitive Measures, Mean Scores(SD)	Inclusion criteria	Setting, # of sessions, Frequency, Duration	Language/Country (Region)
Laugeson et al. (2009)	- Randomized delayed treatment - 5 cohorts - Treatment: 17 - Delayed: 16	13–17 - Treatment: 14.6(1.3) - Delayed: 14.6(1.6)	- KBIT-2 Verbal - Treatment: 96.0(16.1) - Delayed: 88.3(21.1)	- Common Inclusion Criteria* - KBIT-2 Verbal IQ > 70	- Clinic - 12 sessions, Weekly, 90 min	English/USA
Laugeson et al. (2012)	- Randomized delayed treatment - 3 cohorts - Treatment: 14 - Delayed: 14	12–17 - Treatment: 15.0(1.0) - Delayed: 14.3(1.4)	- KBIT-2 Verbal - Treatment: 94.1(20.2) - Delayed: 104.5(18.8)	- Common Inclusion Criteria* - KBIT-2 Verbal IQ > 70 - Enrolled in middle school or high school	- Clinic - 14 sessions, Weekly, 90 min	English/USA
Laugeson et al. (2014)	- Randomized active control treatment (Super Skills) - 4 cohorts - Treatment: 40 - Control: 33	12–14 - Treatment: 12.7(0.7) - Delayed: 12.7(0.7)	- Not specified; students with ASD without Intellectual disability (ID)	- Common Inclusion Criteria* - Attending Village Glen Middle School for students with ASD without ID - No comorbid mood disorders	- School - 70 sessions, 5 days/week, 30 min	English/USA
Schohl et al. (2014)	- Randomized delayed treatment - ≥ 2 cohort - Treatment: 29 - Delayed: 29	11–16 - Treatment: 14.0(1.3) - Delayed: 13.3(1.7)	- KBIT-2 Verbal IQ - Treatment: 102.2(16.2) - Delayed: 98.5(15.9)	- Common Inclusion Criteria* - KBIT-2 Verbal IQ > 70 - Enrolled in school; between 6th grade of elementary school to 3rd grade of high school	- Clinic - 14 sessions, Weekly, 90 min	English/USA
Yoo et al. (2014)	- Randomized delayed treatment - 3 cohorts - Treatment: 23 - Delayed: 24	12–18 - Treatment: 14.0(1.6) - Delayed: 13.5(1.5)	- KEDI-WISC-R Verbal IQ - Treatment: 99.3(18.1) - Delayed: 100.7(17.0)	- Common Inclusion Criteria* - KEDI-WISC-R Verbal IQ > 65 - Enrolled in school; between 6th grade of elementary school to 3rd grade of high school	- Clinic - 14 sessions, Weekly, 90 min	Korean/Korea
Marchica et al. (2016)	- Pre-Post - Treatment: 11	13–17, 14.6(1.3)	- No cognitive measures	- Common Inclusion Criteria* - Below-average to average intelligence (IQ > = 70)	- Setting not specified - 14 sessions, Twice a week, 90 min	English/Canada
Hill et al. (2017)	- Pre-Post - Treatment: 5	13–15 - Treatment: 13.4(0.9)	- KBIT-2 Verbal IQ - Treatment: 97.0(25.2)	- Common Inclusion Criteria* - KBIT-2 Verbal IQ > 70	- Community clinic - 14 sessions, Weekly, 90 min	English/USA
Matthews et al. (2018)	- Randomized delayed treatment - 2 cohorts - Treatment: 10 - Delayed: 12	13–17 - Treatment: 15.1(1.3) - Delayed: 15.4(1.1)	- KBIT-2 Verbal IQ - Treatment: 96.9(11.9) - Delayed: 96.8(18.0)	- Common Inclusion Criteria* - KBIT-2 Verbal IQ > 70 - Enrolled in high school - Spent at least 80% of educational time in general education setting	- Community-based non-profit autism center - 14 sessions, Weekly, 90 min	English/USA
Rabin et al. (2018)	- Randomized delayed treatment - Treatment: 20 - Delayed: 21	12–17 - Treatment: 14.0(1.8) - Delayed: 14.0(1.7)	- WISC-IV/ WAIS-III	- Common Inclusion Criteria* - No comorbid intellectual impairment (IQ > = 70) or severe behavioral problems	- Clinic - 16 sessions, Weekly, 90 min	Hebrew/Israel

Table 1 (continued)

Author (year)	Study design, Number of cohorts/classes participants	Age range (years), Mean(SD)	Cognitive Measures, Mean Scores(SD)	Inclusion criteria	Setting, # of sessions, Frequency, Duration	Language/Country (Region)
Shum et al. (2019)	- Randomized delayed treatment - Treatment: 33 - Delayed: 33	11–15 - Treatment: 13.4(0.9) - Delayed: 13.6(1.0)	- WISC-IV Verbal IQ - Treatment: 96.4(18.7) - Delayed: 94.7(17.8)	- Common Inclusion Criteria* - WISC-IV Verbal IQ > = 70 - Enrolled in school, between 6th grade of elementary school to 3rd grade of high school - Moderate to severe deficits in social interactions based on the ADOS	- Community service centers - 14 sessions, Weekly, 90 min	Chinese/Hong Kong
Wyman et al. (2019)	- Pre-Post - 4 classes - Treatment: 63	15–21	- ASD group: 27.6% with ID - Cognitive deficit(CD) group: 76.5 with ID	- Enrolled in private school for students with a range of developmental disabilities - Attended work-oriented training program	- School - 32 sessions, Twice a week, 45 min	English/USA
Yamada et al. (2020)	- Randomized delayed treatment - 2 cohorts - Treatment: 14 - Delayed: 14	11–15 - Treatment: 13.0(1.3) - Delayed: 13.2(1.0)	- WISC-IV Full Scale IQ - Treatment: 103.4(16.3) - Delayed: 107.4(14.8)	- Common Inclusion Criteria* - WISC-IV Verbal IQ > = 70 - 6th grade of elementary school to 3rd grade of high school - Born and raised in Japan	- Clinic - 14 sessions, Weekly, 90 min	Japanese/Japan

1. *KBIT-2* Kaufman Brief Intelligence Test 2nd Edition; *KEDI-WISC-R* Korean Educational Development Institute Wechsler Intelligence Scale for Children-Revised; *WISC-IV* Wechsler Intelligence Scale for Children (WISC) 4th Edition; *WAIS-III* Wechsler Adult Intelligence Scale 3rd Edition

2. * Common Inclusion Criteria (Laugeson et al. 2009)

- Diagnosed with Autism Spectrum Disorders (i.e., Autistic Disorder, Asperger's Disorder or PDD-NOS [DSM-IV]) from a licensed mental health professional (e.g. licensed psychologist, psychiatrist, pediatrician)

- Social problems as reported by the parent

- Willingness to participate in the treatment

- No history of major mental illness (e.g. bipolar, schizophrenia, psychosis) as reported by parent

- No hearing, visual or physical impairment that would prevent them from participating in outdoor sports activities

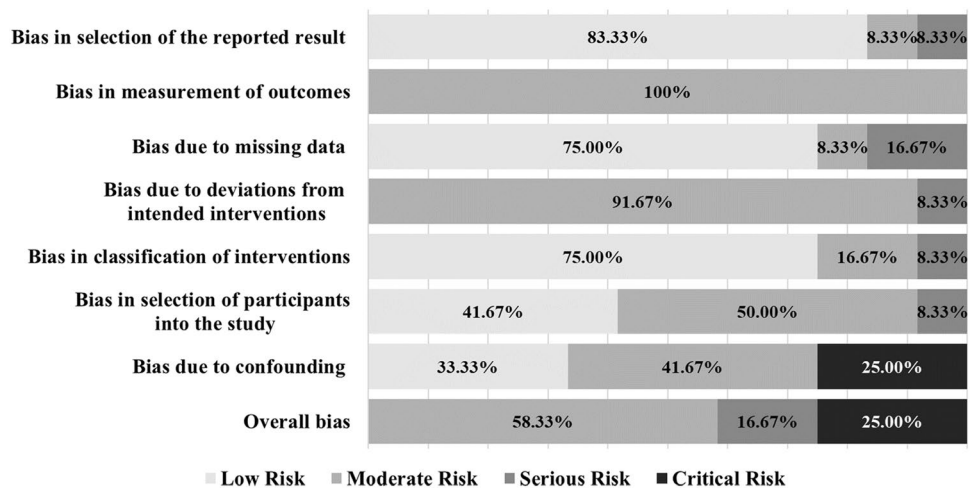
- Willingness to fill out forms at the beginning and end of study

Table 2 Summary of study findings

Author (year)	Main Treatment Outcomes (TASSK, QPQ/QSQ, SSiS/SSRS, SRS)	Other Treatment Outcomes
Laugeson et al. (2009)	- Significant improvements in social knowledge (TASSK), hosted get-togethers (QSQ-parent), and social functioning on the SSRS-parent - No significant findings in SSRS-teacher	- Significant increase in FQS
Laugeson et al. (2012)	- Significant improvements in social knowledge (TASSK), hosted get-togethers (QSQ-parent), social functioning on the SSRS-parent, and social communication deficits on the SRS-parent - 14 weeks follow-up showed maintenance of the changes	
Laugeson et al. (2014)	- Significant improvements in social knowledge (TASSK), hosted and invited get-togethers (QSQ-parent), and social communication deficits on the SRS-teacher	
Schohl et al. (2014)	- Significant improvements in social knowledge (TASSK), hosted and invited get-togethers (QSQ-parent), problem behaviors on the SSRS-parent and teacher, and social communication deficits on the SRS-parent	- Significant decrease in SIAS
Yoo et al. (2014)	- Significant improvements in social knowledge (TASSK), hosted get-togethers (QSQ-parent), social functioning on the SSRS-parent and SRS-parent	- Significant improvements in autism related difficulties (SCQ, ADOS), interpersonal relationship, play/leisure time adaptive skills on the VABS, mood measured on the CDI and STAI-S; behavior problems on the CBCL
Marchica et al. (2016)	- Significant improvements on the SSiS-self (assertion), and QSQ-parent, self (number of get-togethers, friends, and conflicts) - 7-week follow-up showed significant improvements on the SSiS-self (social skills, problem behaviors, internalizing) and QSQ-parent (number of conflicts)	
Hill et al. (2017)	- Significant improvements in social knowledge (TASSK), social engagement, internalizing and autistic symptoms on the SSiS-parent, and social cognition, social communication, social motivation on the SRS-parent	
Matthews et al. (2018)	- Significant improvements in social knowledge (TASSK) and, invited get-togethers (QSQ-parent)	- Significant improvements in R-UCLA and Autism Knowledge Questionnaire
Rabin et al. (2018)	- Significant improvements in social knowledge (TASSK), hosted get-togethers (QSQ-self), and social functioning measured on the SSiS-parent - 14 weeks follow-up showed maintenance of the changes	- Significant improvements in empathy (EQ) and CASS (showed greater involvement, asked more questions and were more physically relaxed during a live role-play assessment with an unfamiliar peer)
Shum et al. (2019)	- Significant improvements in social knowledge (TASSK), number of conflicts on the QPQ-parent, and autism mannerisms on the SRS-parent - 3 months follow-up showed maintenance of the changes	
Wyman et al. (2019)	- Significant improvements in social knowledge (TASSK), hosted get-togethers on the QSQ-self	
Yamada et al. (2020)	- Significant improvements in social knowledge (TASSK) and autistic mannerisms on the SRS - 3 months follow-up showed maintenance of the most changes	- Significant improvements in adaptive functioning (VABS) and behavioral and emotional problems (CBCL)

ADOS Autism Diagnostic Observation Schedule, CASS Conversational Assessment of Social Skills, CBCL Child Behavioral Checklist, CDI Child Depression Inventory, EQ Empathy Quotient, FQS Friendship Qualities Scale, QPQ/QSQ Quality of Play Questionnaire/Quality of Socialization Questionnaire, R-UCLA Revised UCLA Loneliness Scale, SCQ Social Communication Questionnaire, SIAS Social Interaction Anxiety Scale, SRS Social Responsiveness Scale, SSiS/SSRS Social Skills Improvement System/Social Skills Rating System, STAI-S State and Trait Anxiety Inventory, TASSK Test of Adolescent Social Skills Knowledge, VABS Vineland Adaptive Behavior Scale

Fig. 2 Risk of bias plot



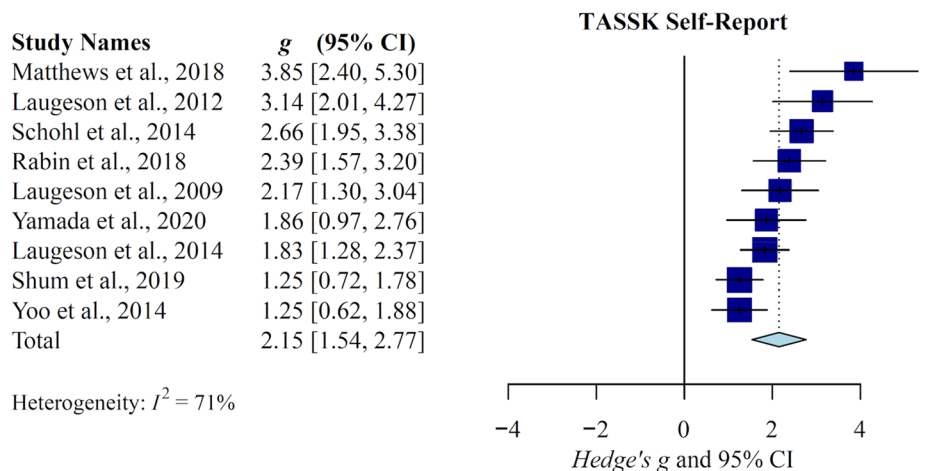
self-reported social knowledge, (2) parent-reported social functioning, and (3) frequency of get-togethers.

Self-reported Social Knowledge The largest effect was found on the self-report TASSK with a pooled ES of 2.15 (95% CI [1.54, 2.77]) across all nine studies (see Fig. 3). Additionally, the ESs on the TASSK were the most heterogeneous across studies with an I^2 index of 71%. While all the studies found large effect sizes (*Hedge's g* > 1), larger effects were found in the studies using the clinic-based and parent-assisted format conducted by the original group who developed the PEERS program (Laugeson et al. 2009, 2012) and in the replication studies delivered in English in the US (Matthews et al. 2018; Schohl et al. 2014). Though the study of the Hebrew version (Rabin et al. 2018) showed comparable effect sizes to the studies of the English version, the studies of the Japanese (Yamada et al. 2020), Korean (Yoo et al. 2014) and Chinese (Shum et al. 2019) adaptations showed smaller effects.

Parent-Reported Social Functioning Medium ESs were found on two standardized, parent-report measures in favor of the PEERS intervention group compared to the delayed treatment control, with similar effect seen on the SSiS (SMD=0.71, 95% CI [0.26, 1.15], across 5 studies; see Fig. 4 for forest plot) and the SRS (SMD=0.72, 95% CI [0.33, 1.10], 5 studies; see Fig. 5). Little heterogeneity of ES distributions between studies was observed on either of the standardized measures (SSiS: $I^2=4% < 25%$; SRS: $I^2=0%$).

Get-togethers Lastly, the smallest effects were found on both adolescent self-report and parent-report numbers of get-togethers on the QSQ. The beneficial effect on self-reported numbers of get-togethers on the QSQ (SMD=0.60, 95% CI [0.27, 0.93], 9 studies; see Fig. 6) were similar to the parent-report benefit in QSQ get-togethers (SMD=0.55, 95% CI [0.16, 0.93], 6 studies; see Fig. 7). Moderate heterogeneity of ES distributions was observed for the adolescent-report QSQ ($I^2=49%$ with studies done by the original group

Fig. 3 Forest plot for pooled effect size on TASSK adolescent self-report



showing larger effect sizes), but no clear heterogeneity was seen on the parent-report QSQ ($I^2 = 12\%$).

Publication Bias The Egger’s test was not significant for the SRS ($p = 0.48$), the SSiS ($p = 0.07$) or the QSQ self-report ($p = 0.11$) but was significant for the QSQ parent-report (intercept: 4.18, CI: 3.20–5.16, $t = 8.07$, $p = 0.0001$) and the TASSK (intercept: 5.02, CI: 2.27–7.76, $t = 3.57$, $p = 0.009$),

indicating the possibility of publication bias. The funnel plots for each outcome measure were visually examined (see Supplementary Material Figures S1 to S5). Specifically, the TASSK funnel plot showed two outliers (Shum et al. 2019; Yoo et al. 2014) with large sample sizes but relatively small effect sizes.

Fig. 4 Forest plot for pooled effect size on SSiS parent report

Study Names	<i>g</i>	(95% CI)
Laugeson et al., 2012	1.29	[0.47, 2.10]
Matthews et al., 2018	0.94	[0.05, 1.83]
Laugeson et al., 2009	0.81	[0.10, 1.52]
Schohl et al., 2014	0.44	[-0.08, 0.96]
Rabin et al., 2018	0.40	[-0.23, 1.02]
Total	0.71	[0.26, 1.15]

Heterogeneity: $I^2 = 4\%$

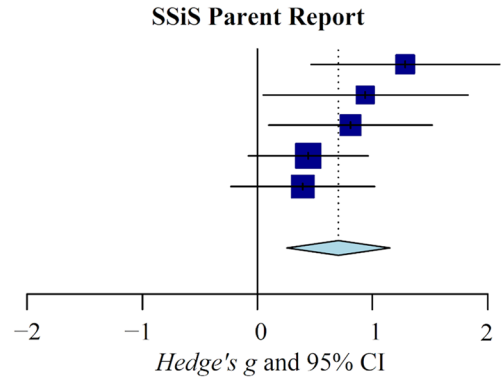


Fig. 5 Forest plot for pooled effect size on SRS parent report. The effect sizes were reversed to positive numbers to show improvements in favor of the PEERS group, i.e., lower scores or decreases in social communication impairments in the PEERS groups

Study Names	<i>g</i>	(95% CI)
Laugeson et al., 2012	1.34	[0.34; 2.35]
Schohl et al., 2014	0.90	[0.36; 1.44]
Matthews et al., 2018	0.67	[-0.20; 1.53]
Shum et al., 2019	0.52	[0.03; 1.00]
Yamada et al., 2020	0.44	[-0.31; 1.19]
Total	0.72	[0.33; 1.10]

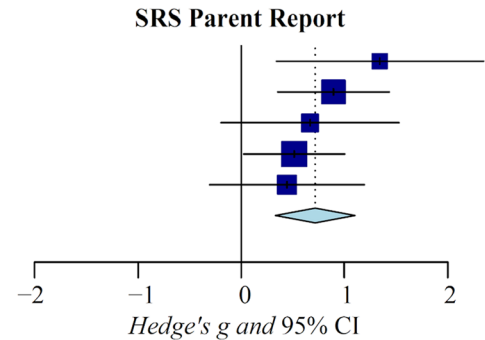


Fig. 6 Forest plot for pooled effect size on QSQ adolescent self-report

Study Names	<i>g</i>	(95% CI)
Matthews et al., 2018	1.27	[0.35; 2.20]
Laugeson et al., 2009	1.12	[0.39; 1.86]
Laugeson et al., 2012	0.82	[0.05; 1.59]
Laugeson et al., 2014	0.79	[0.31; 1.27]
Yamada et al., 2020	0.68	[-0.08; 1.45]
Schohl et al., 2014	0.68	[0.15; 1.20]
Yoo et al., 2014	0.42	[-0.15; 1.00]
Rabin et al., 2018	0.32	[-0.30; 0.94]
Shum et al., 2019	-0.17	[-0.65; 0.32]
Total	0.60	[0.27; 0.93]

Heterogeneity: $I^2 = 49\%$

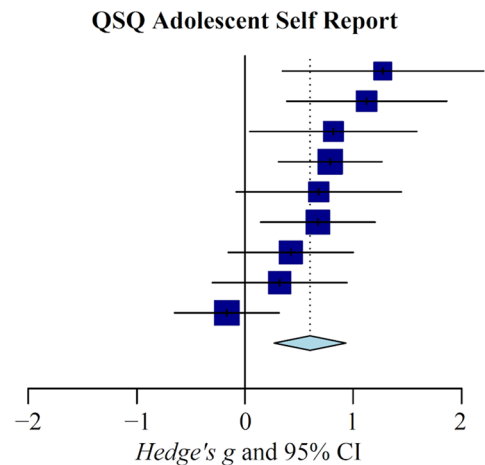
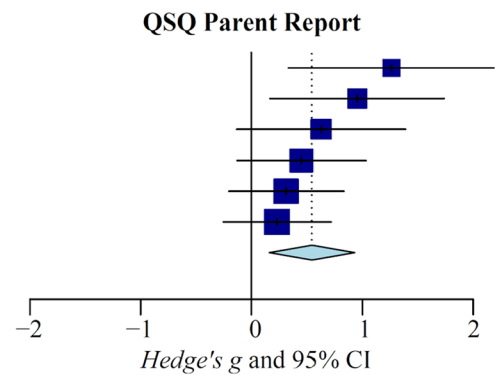


Fig. 7 Forest plot for pooled effect size on QSQ parent report

Study Names	<i>g</i>	(95% CI)
Laugeson et al., 2012	1.26	[0.34, 2.19]
Matthews et al., 2018	0.95	[0.17, 1.74]
Yamada et al., 2020	0.63	[-0.13, 1.39]
Yoo et al., 2014	0.45	[-0.13, 1.03]
Schohl et al., 2014	0.31	[-0.20, 0.83]
Shum et al., 2019	0.23	[-0.25, 0.72]
Total	0.55	[0.16, 0.93]

Heterogeneity: $I^2 = 12\%$



Within-group ESs

For the three studies without a control group, the ESs varied largely across studies, with the smallest ESs observed in Wyman et al. 2019. Specifically, the within-group ESs on the SRS parent report ranged from 0.05 to 1.01; those on the SSiS parent report ranged from 0.17 to 0.38; QSQ parent-report ranged from 1.19 to 1.30; QSQ self-report ranged from 0.09 to 1.74. However, the within-group ESs on the TASSK were very similar on both the Hill et al. 2017 study (SMD = 1.74) and the Wyman et al. 2019 study (SMD = 1.75) (see Table 3).

Discussion

This systematic review and meta-analysis evaluating the efficacy of the PEERS for adolescents program across different measures found that the PEERS program had medium to large advantageous effects in the outcomes reviewed. Pooled ESs varied according to the type of outcome measure assessed, and ranged from the largest effect seen in gains

in social knowledge, to smaller but still sizable beneficial effects in parent-perceived social functioning, to moderate effects on parent and self-reported get-togethers.

The pattern of varying effects across informants and measures was expected and consistent with previous review findings of GSSIs (Gates et al. 2017), especially with the largest effect seen in social knowledge gains. The TASSK used in all the studies reviewed was a set of multiple-choice and true-false questions related to the content of the PEERS didactic lessons. Increases in social knowledge could set a cognitive foundation for skill acquisition (Bibok et al. 2008), and likely indicates that adolescents paid attention and learned the knowledge of the strategies taught during the session. Nevertheless, judging merely based on the TASSK, it remains unclear if and how much this specific knowledge change translates to generalizable social skills and social performance.

Meanwhile, PEERS showed medium to large ESs on both parent-report standardized measures (i.e., the SSiS and the SRS), which were similar to and relatively larger ESs than those of many other GSSIs (Corbett et al. 2017; Gantman et al. 2012; Koning et al. 2013). While these parent-report

Table 3 Within-study effect sizes

Outcomes	Author (year)	Hedge's <i>g</i>	SE	95% Confidence Interval
Self-report TASSK	Hill et al. (2017)	1.74	0.77	0.25–3.25
	Wyman et al. (2019)	1.75	0.21	1.34–2.16
Parent-report SRS	Hill et al. (2017)	1.01	0.68	–0.32–2.34
	Wyman et al. (2019)	0.05	0.18	–0.30–0.39
Parent-report SSiS	Marchica et al. (2016)	0.17	0.43	–0.67–1.01
	Hill et al. (2017)	0.38	0.64	–0.87–1.64
Parent-report QSQ	Marchica et al. (2016)	1.30	0.47	–0.37–2.22
	Hill et al. (2017)	1.19	0.70	–0.18–2.56
Self-report QSQ	Marchica et al. (2016)	1.74	0.51	0.75–2.74
	Hill et al. (2017)	1.09	0.69	–0.25–2.44
	Wyman et al. (2019)	0.09	0.18	–0.26–0.44

measures capture social functioning beyond simple knowledge changes, they are still limited in ecological validity as parents may only see the adolescents in limited settings and are likely biased by knowledge of the treatment assignment.

Among all the outcomes reviewed in the current study, the parent- and self-reported numbers of get-togethers on the QSQ is possibly the closest proxy of social skill application in real-life settings. The medium effect sizes of increased frequency of get-togethers showed that adolescents learned skills useful to organize and/or participate in get-togethers with peers. It is also important to recognize that during the PEERS program, adolescents were first taught specific skills needed for hosting and participating in get-togethers, and then assigned weekly homework to have get-togethers with peers outside the PEERS treatment group (in fact, get-togethers among group members over the course of the group were not permitted). Admittedly, it might be hard to conclude the degree to which the observed effect of get-togethers could be maintained and generalized after PEERS. Still, the increased frequency of get-togethers with peers is an ecologically valid measurement of increased social engagement, and is promising as adolescents have more social opportunities to interact with peers and practice skills taught in the PEERS curriculum. Overall, across all the outcome measures, the effect sizes decreased as the measures progressed from testing knowledge to assessing social skill and performance. One reason for this emerged pattern could be that social skills and skill applications take more time and practice to acquire through experiences than knowledge (Lerner and Mikami 2012), and the immediate post-treatment data might not fully capture the ensuing improvements in skills. In fact, a long-term follow-up study of PEERS observed additional improvements in social skills and functioning (measured on SRS and SSIS) (Mandelberg et al. 2014), indicating possible further improvements occurring after the treatment ended. Meanwhile, another possible reason of the observed ES pattern could also imply that the PEERS program might be more effective in improving social skill knowledge than social skill application and performance.

Though medium to large ESs were seen across the commonly used measures included in the current study, the concerns around the generalizability of the learned social knowledge and skills to real-life interactions and relationship building are an important point to consider (Lerner et al. 2012). Future studies on PEERS and other GSSIs should consider including outcome measures with better ecological validity to capture daily social functioning. For example, Contextual Assessment of Social Skills (CASS: Ratto et al. 2011) is an in-vivo measure coding behaviors observed during the interaction with a partner, and has been used in efficacy studies on PEERS (Dolan et al. 2016; Rabin et al. 2018). Additionally, some studies included in the current analysis also reported on other effects that may relate to

social performance, such as behavioral problems, anxiety, depression, and adaptive skills (Schohl et al. 2014; Yamada et al. 2020; Yoo et al. 2014). Effects of PEERS on these outcomes (e.g., mental health, academic performances) should be further examined and synthesized, as improvement of social knowledge and skills might mitigate social difficulties which are integrally related to mood, behaviors, and academic performance in adolescents with ASD.

Notably, we observed some heterogeneity of treatment effect across studies, with the largest effects from the studies done by the group who developed the PEERS program. One possible reason is that PEERS treatment in those studies was delivered with higher fidelity by the developer than the other studies. Moreover, the adaptations of PEERS in different languages and cultures had smaller effects than those delivered in English and in North America with majority White participants. Whereas all four studies conducted in non-English language or culture reported adaptations to fit the social and cultural norms, it is unclear whether the decreased ESs were the result of the translations and adaptations that altered the active treatment ingredients, or the limited cultural accommodations that might insufficiently incorporate the social norms. Given that social skills and social norms are highly dependent on the culture and the society one lives in (Furnham 1989), it is undoubtedly challenging to teach social skills and social nuances across cultures or within multiracial/multiethnic societies using the exact same treatment program. Thus, data-driven program adaptations based on feedback from stakeholders is necessary to ensure the treatment fits the social and cultural norm where the PEERS program is delivered. Moreover, future studies should attempt to identify the active ingredients of the PEERS program to understand the necessary components for the treatment to be most effective across cultures.

One limitation of the current study is that with only nine studies eligible for meta-analysis, we were underpowered to conduct moderator or regression analysis (Higgins and Thompson 2002) to identify individual study or study population characteristics that might be associated with treatment outcomes of the PEERS program. There have been studies exploring the effect of gender (McVey et al. 2017) and age (Hong et al. 2019) on the treatment responses to PEERS. Neither of the studies found significant effects of differential responses by gender or age. However, the majority of studies on the PEERS program shared the inclusion criteria with the original study by Laugeson et al. 2009, resulting in a limited range of variances of sample characteristics. Notably, the samples in the current review were largely male and with the mean IQ within the average range, which limits the findings from the current review to this particular group of adolescents with ASD. Diagnosis is another factor to consider for a better understanding of who would

benefit the most from PEERS and whether the program could benefit individuals across a range of diagnoses besides ASD. Future studies could include more diverse samples with broader ranges of sample characteristics and other diagnostic groups who might also be in need of social skills training. Besides the child characteristics, the treatment factors, such as duration, intensity, and inclusion of parents, could also have an impact on the treatment effects. For example, Wolstencroft et al. 2018 found that GSSIs that include parent-groups and are of longer duration or higher intensity showed larger effect sizes. In a study assessing the effect of an accelerated version of the PEERS program, the researcher found that when all the sessions in the PEERS program were delivered twice a week for seven weeks, it was as effective as when they were delivered once a week for 14 weeks (Matthews et al. 2019). These findings highlight the importance of conducting future studies to examine changes in the duration and intensity of treatment to determine the optimal method of delivery for the PEERS program (Lerner et al. 2012).

Another consideration in interpreting the results is that all the studies analyzed in the current studies were judged to have moderate or higher levels of risk of bias. Though largely limited by practical reasons for clinical treatment studies (e.g., nonblind raters, nonrandom treatment assignment, lack of information on concurrent treatments received), there were areas of biases that could be improved in future studies. For example, statistical methods could be applied to account for the confounding pre-treatment characteristics of participants in the two groups. Additionally, PEERS is a group-based intervention, yet none of the PEERS studies included in this review took the group effects into considerations in their analysis of treatment effect. Future studies should use the more conservative adjustment to account for the confounding of group effects for those who received treatment together (Bauer et al., 2008), which may provide more accurate estimates of treatment effects. The concern of biases across current studies calls for high-quality future studies to address these concerns of confounding factors and add to the evidence base of the PEERS program.

Conclusion

In summary, the evidence identified in the current review indicates that the PEERS program produces large beneficial effects in social skills knowledge and moderate benefits in parent-ratings of adolescents' social skills and the frequency of social get-togethers. The declining effect sizes from knowledge to measurement of actual implementation of social skills, and the limitations in the

measurement of social skills raises some questions about the practical value and application of the learned skills. Future studies can expand upon the current knowledge base with larger and more culturally diverse samples, novel measurements of real-life social skill, and improvements in study design to reduce bias and improve external validity.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10803-021-04885-1>.
Acknowledgments The authors would like to thank Dr. Evans Whittaker for his help in identifying search strategies and search terms for the current review, and to thank Dr. Young-Shin Kim for her mentorship on the project. We appreciate Dr. Kim taking the time to kindly review a previous version of the manuscript and provide helpful feedback. Dr. Zheng would also like to thank Dr. Somer L. Bishop for her mentorship and critical thoughts for the interpretation and discussion of the results.

Author Contributions SZ, HK, and ES initiated the study and completed the literature search. SZ, ES, and KA completed the screening of the articles and decided on the final set of articles to be included in the review. SZ led the design and the implementation of data extraction, analysis, and interpretation, with support from SB. Specifically, HK extracted information for the systematic review and KA reviewed and confirmed the information; ES extracted data for meta-analysis with the support from SZ and KA; SZ and HK completed the Risk of Bias rating; and SZ completed the meta-analysis. SZ drafted the initial manuscript, with support from HK, ES, and KA. SZ and SB edited and revised the manuscript and all authors reviewed and approved the final version of the manuscript.

Compliance with Ethical Standards

Conflict of interest The authors have no conflict of interests related to the current study.

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