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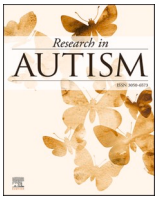

Effectiveness of physical activity on repetitive behaviors and independence in autistic adults: A systematic review

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ABSTRACT

Importance: A higher frequency of disruptive repetitive behaviors is associated with a decrease in independence, lowering the quality of life among autistic adults.
Objective: Summarize existing literature examining the effectiveness of physical activity on disruptive repetitive behaviors and decreased independence in autistic adults.
Data sources: Review registered in PROSPERO (ID: CRD42023448585). Databases searched on July 11th, 2023, included Medline, CINAHL, PsycInfo, and Scopus.
Study selection and data collection: Guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses were used for data abstraction. Peer-reviewed articles published globally were evaluated. Nine met the inclusion criteria. Studies completed with autistic children were excluded due to the recent systematic reviews that have been conducted on this topic. A total of 469 participants were assessed. Risk-of-bias assessments were performed. Studies were divided by outcome, repetitive behaviors, and independence.
Findings: Participation in moderate to vigorous intensity physical activity was shown to reduce repetitive behaviors and increase independence in activities of daily living or an autonomous completion of routines. Small sample size, challenges recruiting adult participants, and lack of consistency in the studies limited the strength of the findings.
Conclusions and relevance: Results from this systematic review provide moderate evidence to support the use of physical activity in reducing repetitive behaviors and increasing independence in autistic adults. Physical activity interventions at a moderate to vigorous intensity for at least 20 min, twice a week is a treatment option to consider targeting these outcomes.
What this article adds: Provides information helpful in determining the usefulness of physical activity as an intervention for autistic adults.

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Literature review

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that causes behavioral and psychological differences in individuals across their lifespan (Mughal et al., 2022). Three key features of ASD include persistent difficulties in social communication, daily functioning, and repetitive behaviors that begin in early childhood. A diagnosis of ASD requires two characteristics; (1) lasting deficits in social-emotional reciprocity, non-verbal communication, and maintaining and understanding relationships and (2) the manifestation of two out of four repetitive behaviors: stereotyped or repetitive motor movements, insistence on sameness, highly fixated interests, and hyper- or hypo-reactivity to sensory input (American Psychiatric Association, 2013). The demonstration of these traits may cause a decrease in functional independence for autistic adults, with the presence of more disruptive repetitive behaviors being associated with a lower quality of life (Johansson & Sandin, 2023). The purpose of this systematic review is to examine the effectiveness of physical activity interventions on reducing disruptive repetitive behaviors and promoting independence among autistic adults.

Repetitive behaviors

Repetitive behaviors can be described as repetitive patterns of behaviors, interests, or activities that include stereotyped motor movements, verbal or nonverbal rituals, and an extreme fixation on objects in the environment (American Psychiatric Association, 2013). Repetitive behaviors have been subdivided, in some studies, as either (1) higher-level behaviors or (2) lower-level behaviors (Turner, 1999). Higher-level behaviors include circumscribed interests, insistence on sameness, repetitive language, and object attachments. Lower-level behaviors encompass stereotyped motor movements such as tics, repetitive manipulation of objects, and repetitive forms of self-injurious behavior.

Researchers suggest that children often display more lower-level behaviors such as hand and finger mannerisms for sensory-motor movements when compared to adults, who tend to present with more higher-level behaviors including compulsions and rituals of the same routine (Bishop et al., 2006). Repetitive behaviors appear more severe in early childhood, decreasing during adolescence, until a plateau is reached and maintained into adulthood. Although repetitive behaviors may lessen with age, addressing the ones that are disruptive as an adult is pertinent for supporting daily functioning and independence. According to Kapp et al. (2019), the repetitive behaviors that should be targeted for intervention are those that are injurious and/or harmful to societal inclusion and quality of life. For the purpose of this review, these will be described as disruptive repetitive behaviors. Lower adaptive functioning skills are associated with the presence of disruptive repetitive behaviors due to the interference they have on self-care and the autonomous completion of routines (Gabriels et al., 2005).

Independence

Independence can be defined as an individual's ability to participate in necessary and preferred activities in a self-directed, satisfying manner (American Occupational Therapy Association, 2002). The following systematic review will include the specific categories of activities of daily living (self-care) and the autonomous completion of routines as addressed in several of the available studies revolving around independence.

Decreased independence in activities of daily living such as grooming, bathing, dressing, and toileting is commonly seen in autistic individuals throughout their life (García-Villamisar and Dattilo, 2010). The inability to complete these actions alone is associated with the presence of disruptive repetitive behaviors (Hume et al., 2009). In the case of one participant recruited in Howlin's study, the individual's ability to be independent was compromised by their compulsive rituals and rigid routines (2004). This inflexibility can cause significant anxiety due to difficulties in adapting to change. As a result, autistic individuals may experience a delay in completing tasks or avoiding activities altogether to prevent an undesired outcome which can hinder their capacity to function independently within multiple daily life contexts. The level of distress generated by a person's need for predictability allows someone to only do some much with their time. Limitations to independence, such as these, can create an increased need for caregiver support. However, once continual care is implemented, a dependency cycle can be developed, ultimately causing these individuals to rely exclusively on their caregivers, a process that causes a further long-term reduction in independence for autistic adults (Hume et al., 2009).

Results of a longitudinal study examining the link between age and activity of daily living skills indicated that significant changes occurred in autistic individuals' level of independence over a 10-year period. In this study, activity of daily living skill independence improved in adolescence, plateaued in the later twenties, and eventually declined in the early thirties (Smith et al., 2012). These findings suggest that adolescence is a time of improvement, but that period of improvement ends, on average, by the time autistic individuals reach the age of 30. By the end of the study, the participants were failing to complete over a third of their measured activity of daily living skills independently (Smith et al., 2012). Researchers in another study evaluating the relationship between autism severity and independence in activities of daily living found that all participants in the study needed some form of assistance in grooming, bathing, dressing, and toileting (Ozboke et al., 2021). Further analysis from the study revealed that participants with a mild to moderate level of autistic traits had higher scores in activities of daily living than participants with traits categorized as severe (Ozboke et al., 2021). The following results from both studies (Ozboke et al., 2021; Smith et al., 2012) indicate that a significant relationship exists between decreased independence and autism warranting the need for further review of these effects into adulthood.

Physical activity

According to the World Health Organization, physical activity can be defined as any movement produced by the skeletal muscles of the body that require an output of energy (2022). Research has shown that participation in physical activity can have beneficial effects on one's heart, body, and mind (World Health Organization, 2022). Aerobic exercise, a frequently used form of physical activity, is described by the American College of Sports Medicine as any activity that is rhythmic in nature and maintained continuously for a sustained period of time (Patel et al., 2017). Examples of aerobic exercise include biking, dancing, hiking, running, walking, and swimming (Patel et al., 2017). In this systematic review, aerobic exercise will be discussed in conjunction with physical activity to examine the effectiveness on reducing disruptive repetitive behaviors and promoting independence among autistic adults.

Another form of physical activity utilized by autistic individuals is physical engagement in multisensory environments. Multisensory environments (MSE) are skillfully designed spaces that provide multisensory equipment to support an individual's sensory processing needs through the stimulation of various systems of the body (Victorian Government Department of Education, 2023). Common equipment of MSEs include trampolines, swings, bouncing chairs, crash pads, balance beams, ball pits, and climbing walls to supply vestibular and proprioceptive input to the participant. A degree of physical exertion must take place through at least one interaction of an item in the room. Individuals can engage in activities, such as jumping, catching/throwing, balancing, climbing, and swinging using the equipment provided to them (Jucan et al., 2021). Physical activity is an intervention modality that can be used for autistic individuals.

Physical activity interventions for repetitive behaviors and independence

Physical activity interventions have been widely used among autistic children because of their reported effects on repetitive behaviors and increase in skills required to be independent (Toscano et al., 2017). Bremer et al. (2016) conducted a systematic review on the effects of exercise on behavioral outcomes in autistic children. Results demonstrated that physical activity interventions consisting of jogging, horseback riding, martial arts, yoga/dance, and swimming can result in reduced repetitive behaviors and improved adaptive functioning in daily living. In another systematic review, by Ferreira et al. (2019), physical activity interventions including walking, running, jumping, dancing, biking, and martial arts were found to both reduce repetitive behaviors and promote the development of new skills. The higher the repertoire of repetitive behaviors in autistic children, the lower the chances to understand and explore the environment independently (Ferreira et al., 2019). These studies indicate the effectiveness of physical activity as an intervention for reducing repetitive behaviors and increasing independence in autistic children, thus warranting the need for examination of these effects on autistic adults.

Gaps in current literature

The manifestation of repetitive behaviors has been shown to negatively impact a child's everyday life leading to a decrease in independence and the autonomous completion of routines (Siracusano et al., 2021). Participating in physical activity has been identified as an effective means for reducing repetitive behaviors and developing daily living skills for autistic children (Yılmaz, 2022). However, despite the many systematic reviews that have examined this relationship in children, one has yet to be completed on autistic adults. This review aims to summarize the evidence and determine whether physical activity is effective at reducing disruptive repetitive behaviors and promoting independence among autistic adults.

The findings from this review will provide greater insight into the relationship between physical activity interventions, repetitive behaviors, and independence in activities of daily living and the autonomous completion of routines in autistic adults. Evidence used in this review was selected to answer two questions: 1) Is physical activity effective at reducing disruptive repetitive behaviors for autistic adults? and 2) Is physical activity effective at increasing independence in activities of daily living and the autonomous completion of routines for autistic adults? Findings from this review can inform practitioners in designing effective intervention plans to reduce disruptive repetitive behaviors and promote independence in autistic adults.

Methods

Study design

This systematic review serves to summarize research regarding the effectiveness of physical activity on repetitive behaviors and independence in autistic adults. The following methods section aligns with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for conducting and reporting systematic reviews (Page et al., 2021).

Search strategy

A comprehensive systematic literature search was performed on July 11th, 2023, in multiple databases including Medline (Ovid), CINAHL (EBSCOhost), PsycInfo (Ovid), and Scopus. The search strings were produced by a reference librarian and peer reviewed by the members of the systematic review team. The search terms were focused on autism, repetitive behaviors, exercise, rehabilitation, as well as any other relevant synonyms. Depending on the search and functionality of each database, a combination of controlled vocabulary and keyword terms, proximity searching, and truncation were utilized to find relevant literature on the topic. An additional

cited reference search and examination within grey literature was done to prevent the omission of suitable records. The search included all articles published prior to the search date using the following terms as shown in Table 1.

Selection process

Covidence Systematic Review Management was used to complete the study selection in three phases: identification, screening, and eligibility. The first six authors independently screened 1215 titles and abstracts in phase I. Four hundred and forty-seven duplicates were removed by Covidence. Two reviewers were required to unanimously agree before an article was deemed eligible and moved into the next phase. Conflicts were resolved by a third reviewer who was not directly associated with the disagreement, so a decision could be made whether to include the article in the review. Articles included for the full text review consisted of (1) studies published in peer-reviewed journals (domestic and international), (2) examined autistic individuals, (3) included at least one participant aged 17 or older, (4) used physical activity interventions such as aerobic exercise or MSE's with an exercise component, (5) reported repetitive behaviors or independence as an outcome measure, (6) considered to be a level of evidence of III or greater, and (7) were written or translated into English. Study designs including case-control, single-subject, cohort, cross-sectional, and pre-posttest were included due to the limited availability of higher-level evidence on the topic. The reviewers excluded articles that (1) were systematic reviews or meta-analyses, (2) included participants aged 16 or younger, (3) examined participants without ASD, (4) did not involve physical activity including aerobic exercise or MSE's with an exercise component as an option for intervention, (5) research investigating competitive sports, and (6) were not written or translated into English. One hundred and seventeen studies were sought for retrieval in the full text review. Full texts of the remaining studies and their reference lists were analyzed following the same procedure. A final number of nine articles were included for extraction. See Fig. 1 for details.

Data collection

All articles were reviewed according to the Oxford Centre for Evidence-Based Medicine: Level of Evidence recommended by the American Occupational Therapy Association (OCEBM Levels of Evidence Working Group, 2009). Levels of evidence are used to rank the relative strength and reliability of research findings to help inform decisions. Not all studies are created equal; to bring consistency

Table 1
Search Strategies for Each Database.

Database	Search Terms	Articles
Medline (Ovid)	(Autism Spectrum Disorder/or exp Autistic Disorder/or exp Asperger Syndrome/or (autis* or "kanner* syndrome" or ASD or asperger*) **and** ((Stereotypic Movement Disorder/ or exp Stereotyped Behavior/ or stereotyp*) **or** (compulsive Behavior/or (compulsive* or compulsion* or anankastic or repetitive* or repetition* or ritualistic* or sameness) **or** (self Stimulation/ or ("self stimulati*" or self-stimulati* or stimming) **or** (Behavior Control/ or ((behaviour* or behavior*) adj3 (control* or manipulat*))) **and** ((Occupational Therapy/ or "occupational therap*) **or** ("Activities of Daily Living"/ or (adl or "daily living activit*") **or** (Exergaming/ or (exergam* or "active video gaming*" or "virtual reality exercise*") **or** (Rehabilitation/ or rehab*) **or** (Social Participation/ or ("social participat*" or "social engage*" or "social citizenship*") **or** (Exercise/ or exp Exercise Therapy/ or exp Physical Fitness/ or exp Physical Exertion/ or (exercis* or "physical activit*" or "physical fitness*" or "physical exert*" or fitness*)	387
CINAHL (EBSCOhost)	("Autistic Disorder") OR (MH "Asperger Syndrome") or autis* or "kanner* syndrome" or ASD or asperger*) **and** ((MH "Compulsive Behavior+") or compulsive* or compulsion* or anankastic or repetitive* or repetition* or ritualistic* or sameness or stereotyp*) **or** ("self stimulati*" or self-stimulati* or stimming) **or** (((behaviour* or behavior*) N3 (control* or manipulat*))) **and** (("Occupational Therapy+") or occupational therap*) **or** ("Activities of Daily Living+") or adl or "daily living activit* ") **or** ("Exergames") or exergam* or "active video gaming* " or "virtual reality exercise* ") **or** ("Rehabilitation+") or rehab*) **or** ("Social Participation") or "social participat* " or "social engage* " or "social citizenship* ") **or** ("Exercise+") OR (MH "Therapeutic Exercise+") OR (MH "Physical Fitness+") OR (MH "Exertion+") or exercis* or "physical activit* " or "physical fitness* " or "physical exert* " or fitness*)	259
PsycInfo (Ovid)	(Autism Spectrum Disorders/ or exp Autism/ or exp Aspergers Syndrome/ or (autis* or "kanner* syndrome" or ASD or asperger*) **and** ((Stereotyped Behavior/ or exp Stereotypic Movement Disorder/ or stereotyp*.mp.) **or** (Compulsions/ or (compulsive* or compulsion* or anankastic or repetitive* or repetition* or ritualistic* or sameness) **or** (Self-Stimulation/ or ("self stimulati*" or self-stimulati* or stimming) **or** ((Behavior Modification/ or ((behaviour* or behavior*) adj3 (control* or manipulat*)) **and** ((Occupational Therapy/ or "occupational therap*".mp.) **or** ("Activities of Daily Living"/ or (adl or "daily living activit*") **or** (exergam* or "active video gaming*" or "virtual reality exercise*") **or** (Rehabilitation/ or rehab*) **or** ("social participat*" or "social engage*" or "social citizenship*") **or** (Physical Exercise/ or exp Exercise/ or exp Physical Fitness/ or (exercis* or "physical activit*" or "physical fitness*" or "physical exert*" or fitness*)	341
Scopus	INDEXTERMS ("Autism Spectrum Disorder") OR INDEXTERMS ("Autistic Disorder") OR INDEXTERMS ("Asperger Syndrome") OR TITLE-ABS-KEY (autis* OR "kanner* syndrome" OR asd OR asperger*) AND INDEXTERMS ("Stereotypic Movement Disorder") OR INDEXTERMS ("Stereotyped Behavior") OR TITLE-ABS-KEY (stereotyp*) OR INDEXTERMS ("Compulsive Behavior") OR TITLE-ABS-KEY (compulsive* OR compulsion* OR anankastic OR repetitive* OR repetition* OR ritualistic* OR sameness) OR INDEXTERMS ("Self Stimulation") OR TITLE-ABS-KEY ("self stimulati*" OR self-stimulati* OR stimming) OR INDEXTERMS ("Behavior Control") OR TITLE-ABS-KEY ((behaviour* OR behavior*) W/3 (control* OR manipulat*)) AND INDEXTERMS ("Occupational Therapy") OR TITLE-ABS-KEY ("occupational therap*") OR INDEXTERMS ("Activities of Daily Living") OR TITLE-ABS-KEY (adl OR "daily living activit*") OR INDEXTERMS (exergaming) OR TITLE-ABS-KEY (exergam* OR "active video gaming*" OR "virtual reality exercise*") OR INDEXTERMS (rehabilitation) OR TITLE-ABS-KEY (rehab*) OR INDEXTERMS ("Social Participation") OR TITLE-ABS-KEY ("social participat*" OR "social engage*" OR "social citizenship*") OR INDEXTERMS (exercise) OR INDEXTERMS ("Exercise Therapy") OR INDEXTERMS ("Physical Fitness") OR INDEXTERMS ("Physical Exertion") OR TITLE-ABS-KEY (exercis* OR "physical activit*" OR "physical fitness*" OR "physical exert*" OR fitness*)	671

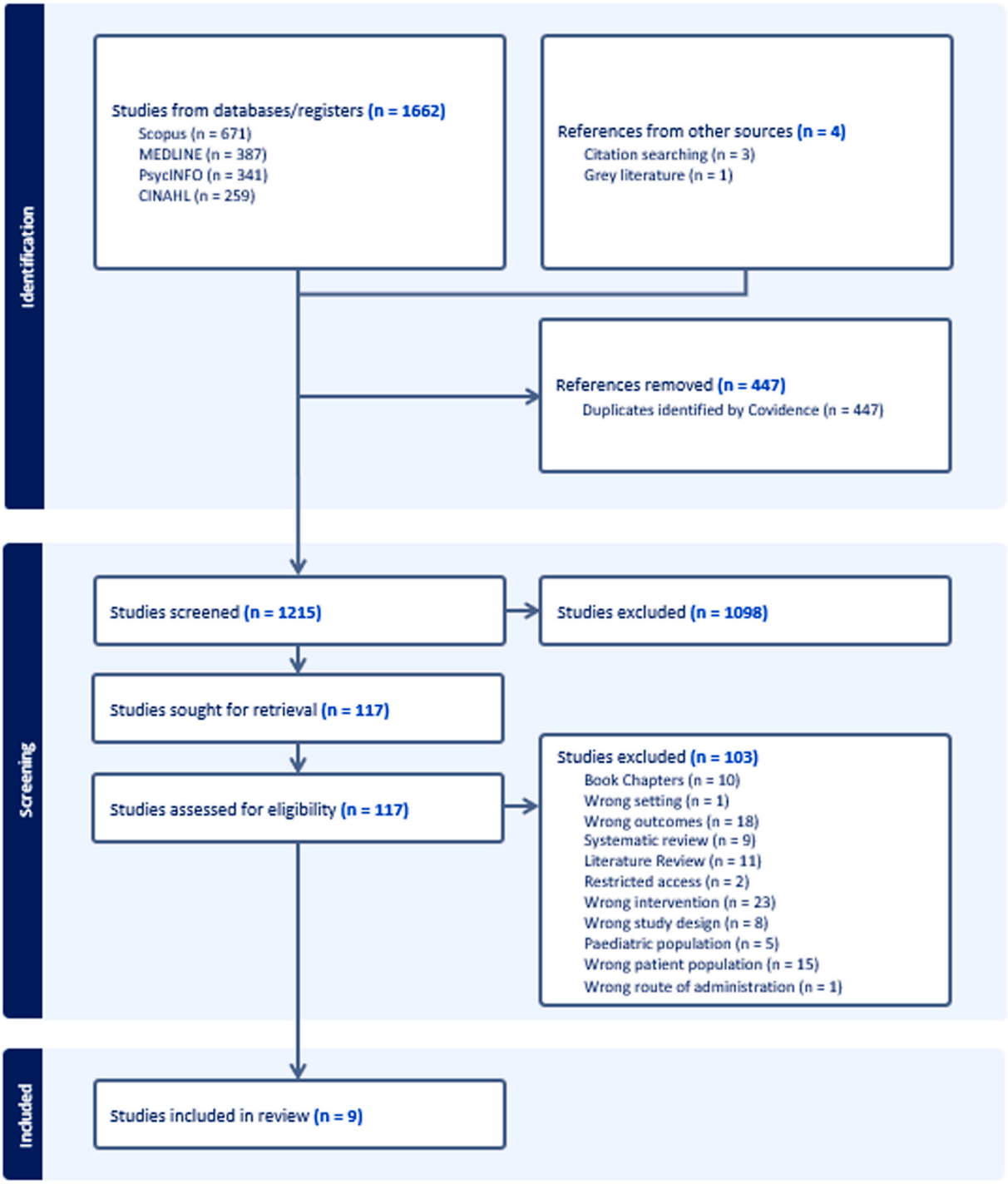

Fig. 1. *Flow Diagram for Study Selection Process.*

to this evaluation, the Oxford Centre for Evidence-Based Medicine developed a system for classifying evidence based on their quality, validity, and generalizability. The following system was used in this systematic review to ensure that conclusions were drawn from the most reliable and clinically relevant evidence available.

The six reviewers independently extracted data from the nine articles based on three characteristics in each report: study, participant, and intervention. Author, publication year, country of origin, sample size, and inclusion/exclusion criteria were considered. Gender distribution and age range were analyzed. Intervention setting, outcome measures, treatment intensity, and

control conditions were evaluated. Restricted access to full text articles were requested through the University of Texas Medical Branch, Moody Medical Library. A risk-of-bias assessment was performed for each of the included studies. By assessing the risk of bias, the reviewers sought to measure the methodological quality of the behavioral outcomes associated with a physical activity intervention on autistic adults. The types of biases assessed were selection, performance, detection, attrition, and reporting bias. A risk-of-bias table for randomized controlled trials (RCTs) and non-randomized controlled trials (non-RCTs) was developed using the format provided in the Cochrane Database of Systematic Reviews (Higgins et al., 2016). A second risk-of-bias table for pre-posttest studies with no control group was developed based on the format from the National Heart, Lung, and Blood Institute (National Heart, Lung, and Blood Institute, 2021). The exclusions of studies not written or translated into English introduces a potential linguistic bias which may affect the conclusions drawn in this systematic review if non-English publications report different results.

Synthesis

The nine articles selected for examination in this review present quantitative data to determine the effectiveness of physical activity interventions on repetitive behaviors and independence in autistic adults. An analysis was composed to determine the type, frequency, and intensity of physical activity required to achieve a behavioral outcome. Findings were compared across studies and divided into physical activity and exhibited change in repetitive behaviors or independence.

Results

Nine studies were assessed to evaluate the effects of physical activity on repetitive behaviors and independence in autistic adults. The number of participants across all nine studies totaled 469. The participants ranged from 17 years old to 55 years old. Two studies were completed in countries outside the United States including Spain and Italy (García-Villamisar and Dattilo, 2010; Keller et al., 2022).

Of the nine studies, two were Level 2B (Elliott et al., 1994; García-Villamisar and Dattilo, 2010) and seven were Level 3B studies (Ali et al., 2018; Allison et al., 1991; Bassette et al., 2018; George et al., 2023; Healy et al., 2022; Keller et al., 2022; Toms et al., 2019). The studies are summarized in Table 2.

Five of the nine studies presented with a moderate risk of bias (Allison et al., 1991; Bassette et al., 2018; García-Villamisar and Dattilo, 2010; Keller et al., 2022; Toms et al., 2019). The most common risk of bias across the studies in this systematic review was detection bias. Blinding of the outcome assessment for the objective measures was difficult to accomplish due to the design of the studies. However, four studies (Ali et al., 2018; Elliott et al., 1994; George et al., 2023; Healy et al., 2022) presented with a low risk of bias through the use of clearly described eligibility criteria that included real-world participants as well as reliable interventions and outcome measures. Only one of the nine studies was found to have a potential reporting bias due to focusing on predetermined exercise choices without addressing the effects of one's personally selected by the participants (Bassette et al., 2018). For instance, a participant requested to perform yoga, but the impact of the exercise on the acquisition of skills was not further explored (Bassette et al., 2018). The authors of this study highlight the need for future research to investigate the role of self-determination in physical activity and the acquisition of skills (Bassette et al., 2018). None of the studies included were determined to have a high risk of bias. The risk-of-bias for each study is outlined in Table 3 and Table 4.

The studies included in this systematic review were grouped by outcome: repetitive behaviors and independence. Interventions utilized reflect a wide range of physical activities including walking, biking, running, jumping/hopping, dancing, throwing/catching, climbing, resistance training, as well as other general gross motor activities. Grouping the studies by outcome allows for a clearer appraisal of the effects of physical activity interventions on repetitive behaviors and independence in autistic adults.

Repetitive behaviors

Six studies, one Level 2B (Elliott et al., 1994) and five Level 3B (Ali et al., 2018; Allison et al., 1991; George et al., 2023; Keller et al., 2022; Toms et al., 2019) evaluated the impact of physical activity on repetitive behaviors in a combined total of 35 participants. Assessment tools used to measure repetitive behaviors include the Repetitive Behavior Scale-Revised (Ali et al., 2018; Toms et al., 2019) and observation (Ali et al., 2018; Allison et al., 1991; Elliott et al., 1994; George et al., 2023; Keller et al., 2022; Toms et al., 2019), however, one study recorded the frequency and duration of repetitive behaviors observed using the Catalyst by DataFinch software (George et al., 2023).

Two studies (Elliott et al., 1994; Keller et al., 2022), examined the effects of walking on a total of 18 autistic adults. Elliott et al. measured the effects of vigorous treadmill walking on three targeted behaviors observed in each participant (1994). The participants engaged in treadmill walking for a duration of 20 min over 5 sessions. A substantial decrease in the targeted behaviors, identified prior to the intervention, were observed following the completion of individual sessions. The main targeted behaviors of this study that were reduced consisted of loud vocalization, slapping, clapping, rocking, and more aggressive behaviors (Elliott et al., 1994). Meanwhile Keller et al. examined the effects of walking outside for 3–4 h and/or 26 km a day on repetitive behaviors (2022). The fitness coach of the participants observed less repetitive behaviors and an improvement in social engagement post-intervention (Keller et al., 2022). Types of repetitive behaviors observed in the study were not described.

Two studies (Ali et al., 2018; George et al., 2023) evaluated the effects of biking on repetitive behaviors in a combined total of 13 autistic adults. The participants in the following studies biked for a duration of 20 min each session. The number of sessions each participant engaged in varied by study. George et al. (2023) examined the effects of repetitive behaviors using virtual reality biking

Table 2
Evidence Table of Included Studies.

Evidence Table					
Author/Year	Level of Evidence Study Design Risk of Bias (Quality Assessment)	Participants Inclusion Criteria Study Setting	Intervention and Control Groups	Outcome Measures	Results
Ali, S., Horton, S., Sutherland, C., & Azar N. (2017) https://doi.org/10.1615/CritRevPhysRehabilMed.2018029367	*Level of Evidence:* 3B *Study Design:* Case Control Study *Risk of Bias:* Low	*Participants:* N = 6 adults; 6 males (100 %), 0 females (0 %) *Inclusion Criteria:* Diagnosis of ASD & ID Engages in RB IQ of 20 −70 18 years of age or older Minimum score of 2 on at least one item in the RBS-R Completed PARmed-X by physician Available for 1 h, 2x a week for 8 weeks Understand and follow simple instructions *Intervention Setting:* CLEC facility	*Intervention:* Riding a stationary bike for 20 min at moderate to vigorous intensity for 16 sessions over 8 weeks.	Outcome Measures: Jebsen Hand Function TestCard TurningSmall Common ObjectsSimulated FeedingCheckersLarge Light ObjectsLarge Heavy ObjectsVideo ObservationRBS-R	*Significant Findings:* Changes that occurred in the reduction of RB following exercise were specific to each individual. The participants in the study made progress throughout the biking program. *Nonsignificant Findings:* Excitement may lead to positive RB that do not need to be reduced. RB may also not influence the performance of short-duration tasks.
Allison, D.B, Basile, V.C, and MacDonald, R.B (1991) https://doi.org/10.1007/BF02207001	*Level of Evidence:* 3B *Study Design:* Single Subject Design *Risk of Bias:* Moderate	*Participants:* N = 1 adult aged 24; 1 male (100 %), 0 females (0 %) *Inclusion Criteria:* Diagnosis of AD Resides in an ICF Below average IQ Engages in RB *Intervention Setting:* ICF	*Intervention:* Jogging for a total of 20 min every day at moderate to vigorous intensity over 13 weeks. *Control:* No exercise.	*Outcome Measures:* HRObservation	*Significant Findings:* Antecedent exercise significantly decreased aggressive RB. *Nonsignificant Findings:* No significant findings were found between HR during activity and aggressive behaviors. Lorazepam alone had no significant effect on RB.
Bassette, L., Kulwicki, J., Dieringer, S. T., Zoder-Martell, K. A., & Heneisen, R. (2018). https://doi.org/10.1007/s40617 − 018 −00285 −7	*Level of Evidence:* 3B *Study Design:* Cohort Study *Risk of Bias:* Moderate	*Participants:* N = 3 adults aged 18 −21 years (*M* age = 19 years; 1 male (33 %), 2 females (66 %)) *Inclusion Criteria:* 14 −22 years old Diagnosis of	*Intervention:* Phase 1: Completing 2 exercise reps (1 −5 min), increased until a total of 10. Phase 2: Completing 10 exercise reps. Phase 3: Chaining targeted	*Outcome Measures:* Social Validity Questionnaire3 Targeted Exercises	*Significant Findings:* Increase in participant's ability to perform PA skills independently across all three phases. All three participants showed an increase in independence compared to baseline. *Nonsignificant Findings:*

(*continued on next page*)

Table 2 (*continued*)

Evidence Table					
		ASD Sedentary lifestyle/low level of PA IQ of 55 or higher *Intervention Setting:* Local community fitness center (e.g. teaching trial setting, YMCA)	exercises to create a workout (15 −20 min) over 1 −4 weeks using verbal prompting. *Control:* No control group.		Increased awareness of the fitness facilities and options available to the participants and families.
Elliott, R. O., Jr, Dobbin, A. R., Rose, G. D., & Soper, H. V. (1994). https://doi.org/10.1007/BF02172138	*Level of Evidence:* 2B *Study Design:* Low Quality Randomized Controlled Trial *Risk of Bias:* Low	*Participants:* N = 6 adults; 3 males (50 %), 3 females (50 %) *Inclusion Criteria:* Diagnosis of AD/MR *Intervention Setting:* Controlled environment in a large furnished room	*Intervention:* Group 1: Non-exercise (e.g. tabletop activities) at a low intensity Group 2: General motor training at a low to moderate intensity Group 3: Aerobic exercise at a vigorous intensity *Control:* Non-exercise General motor training Aerobic exercise	*Outcome Measures:* HRObservation	*Significant Findings:* Vigorous aerobic exercise reduces RB and could be useful in facilitating community integration in adults with AD/MR. *Nonsignificant Findings:* General motor training did not reduce RB.
García-Villamisar and Dattilo (2010) https://doi.org/10.1111/j.1365 −2788.2010.01289.x	*Level of Evidence:* 2B *Study Design:* Pre-Posttest *Risk of Bias:* Moderate	*Participants:* N = 37 participants aged 17 −39 years; 22 males (59 %), 15 females (41 %) n = 34 adults aged 24 −38 years; 19 males (56 %), 15 females (44 %). *Inclusion Criteria:* Diagnosis of ASD or Asperger's *Intervention Setting:* Day program for Adults in Spain	*Intervention:* Recreational activities including media, exercise (e.g. swimming, catching, playing Frisbee, hiking, bowling), games, crafts, outings, and social gatherings for 2 h, 5 days a week over 12 months. *Control:* No exercise.	*Outcome Measures:* Quality of Life Questionnaire-Spanish Version The Stress Survey Schedule for Persons with Autism and Other Pervasive Developmental Disabilities	*Significant Findings:* Stress decreased and QOL increased for the experimental group compared to the control group. The empowerment/independence and social belonging/community integration scales all significantly improved from baseline. *Nonsignificant Findings:* No significant changes of stress or QOL were observed in the control group.
George, C. L., Valentino, A., D'Anna-Hernandez, K., & Becker, E. A. (2023). https://doi.org/10.1007/s41252 − 023 −00326 −5	*Level of Evidence:* 3B *Study Design:* One Group, Nonrandomized Pre-Posttest Study *Risk of Bias:* Low	*Participants:* N = 7 adults aged 20 −24 years; 7 males (100 %), 0 females (0 %). *Inclusion Criteria:* Diagnosis of ASD	*Intervention:* Riding a VR bike for 20 min over 10 months, 2x per week for 6 weeks, following a 6-week rest period. *Control:*	*Outcome Measures:*Pulse OximeterHRCatalyst by DataFinch SoftwareSalivaBio Oral Swab using Enzyme Linked Immunoassay KitIntervention Rating Profile 15-Modified (IRP−15)	*Significant Findings:* VR can have acute and cumulative effects on RB and cortisol levels in autistic adults. Long term exercise reduces RB. *Nonsignificant Findings:* Chronic effects of the

(*continued on next page*)

Table 2 (*continued*)

Evidence Table					
		Score of level 2 or 3 on the GARS−3 Parent consent *Intervention Setting:* Educational day program.	No control group.		intervention on cortisol levels were not significant.
Healy, S.; Brewer, B.; Hoopes, E.; Paller, A.; Mayberry, S.; Maguire, J.; Daly, J.; Laxton, P.; Patterson, F. (2022) https://doi.org/10.1016/j.dhjo.2022.101367	*Level of Evidence:* 3B *Study Design:* Cross Sectional Study *Risk of Bias:* Low	*Participants:* N = 360 adults and caregivers aged 18 −55 years. *Inclusion Criteria:* Diagnosis of ASD 18 −55 years of age Caregiver of an autistic adult aged 18 −55 years Provide care for an autistic adult over 10 h a week for the last three months or more *Intervention Setting:* Online	*N/A*	*Outcome Variables:* 7-item International Physical Activity Questionnaire Sedentary Behavior Questionnaire The 19-item Pittsburgh Sleep Quality Index	*Significant Findings:* A higher level of independence in ADLs was associated with meeting aerobic PA guidelines. Level of independence in ADLs emerged as a predictor variable for meeting aerobic PA recommendations (e.g. less independence, less likely to meet aerobic PA recommendations). *Nonsignificant Findings:* Lower levels of independence were associated with a sedentary lifestyle.
Keller, R., Ardizzone, F., Finardi, C., Colella, R., Genuario, C., Lopez, M., Salerno, L., Nobile, E., Cicinelli, G. (2022). https://doi.org/10.3389/fpsyt.2022.846619	*Level of Evidence:* 3B *Study Design:* One Group, Nonrandomized Pre-Posttest Study *Risk of Bias:* Moderate	*Participants:* N = 12 adults; 10 males (83 %), 2 females (17 %) *Inclusion Criteria:* Diagnosis of ASD 18 years of age or older *Intervention Setting:* Outside in Italy	*Intervention:* Phase 1: Walking for 3 −4 h, supervised by a fitness coach, for one year (started monthly, then every two weeks, and finally 2x a week). Phase 2: Walking 26 km a day for 1 month for a total of 235 km. *Control:* No control group.	*Outcome Measures:* ObservationFunctional Movement ScreenSit and Reach TestQueens College Step TestSTAI-Y−1STAI-Y−2Beck's Depression Inventory PedsQL (young adult version)	*Significant Findings:* The fitness coach observed a qualitative clinically relevant social behavior improvement and less severe stereotypies in participants. Significant differences were found in the motor tests of repeated observations. *Nonsignificant Findings:* No significant differences were found in walking for anxiety and the Queens College Step Test.
Toms, S.B., Janke, M., Loy, D., Watts, C. (2019). https://doi.org/10.18666/TRJ−2018-V53-I4 −9744	*Level of Evidence:* 3B *Study Design:* Single Subject Design *Risk of Bias:* Moderate	*Participants:* N = 3 adults aged 20 −40; males (100 %), 0 females (0 %). *Inclusion Criteria:* Reside at the facility Diagnosis of	*Intervention:* A1: Putting together a puzzle in the sensory room with all of the other equipment turned off. B: Participating in a MSE with all of the	*Outcome Measures:* ObservationFrequency of RB categorized into self-injurious, stereotyped, and compulsive	*Significant Findings:* MSE's have the potential to positively influence behavior and engagement for autistic adults, even if the change is not significant. *Nonsignificant Findings:* No consistent

(*continued on next page*)

Table 2 (*continued*)

Evidence Table			
	ASD Engages in RB Guardian consent *Intervention* *Setting:* Residential facility for adults with ID	equipment turned on (e.g. bubble column, sound machine, swing, waterbed, etc.) A2: Putting together a puzzle in the non-sensory room with all of the other equipment turned off. *Control:* Puzzle room	evidence was found for the effects of MSE's on reducing the frequency of RB compared to baseline. No consistent evidence of a decrease in RB was found when the individuals transitioned into the MSE room.

Note. ASD = Autism Spectrum Disorder, AD = Autistic Disorder, PA = Physical Activity, ID = Intellectual Disability, RBS-R = Repetitive Behaviour Scale-Revised (RBS-R), PARmed-X = Physical Activity Readiness Medical Examination, CLEC = Community Living Essex County, RB = Repetitive Behavior, HR = Heart rate, bpm = Beats per minute, VR = Virtual Reality, STAI-Y = Stai Scoring, PedsQL = Pediatric Quality of Life Inventory, MSE = Multi-Sensory Environment, ICF = Intermediate Care Facility, QOL = Quality of Life, MR = Mental Retardation, IQ = Intelligence Quotient

whereas Ali et al. (2018) used a stationary bike twice a week. One study found a significant decrease in repetitive behaviors including scripting, self-talk, physical and verbal stereotypy, anxious behavior, inappropriate volume for attention, and animated physical movements (George et al., 2023) while the other study had mixed results with half of the participants experiencing an increase and half experiencing a decrease in repetitive behaviors (Ali et al., 2018). An increase in repetitive behaviors could have been observed as a result of some behaviors representing a positive mood or feeling post-intervention, which may be considered less disruptive. The repetitive behaviors decreased in this study were tapping objects, using an object to tap another object/surface, clapping, scratching hand/face, finger movements, and in front of face and hand to mouth movements (Ali et al., 2018).

One study (Allison et al., 1991) examined the effects of running and lorazepam on repetitive behaviors in one autistic adult. The participant showed a decrease in repetitive behaviors including hitting, kicking, scratching, biting, or grabbing of self and/or other persons following the antecedent exercise routine that consisted of jogging for 20 min while maintaining a heart rate between 60–80 % of maximum at a moderate to vigorous intensity level (Allison et al., 1991). Lorazepam was necessary to add due to the increase in aggressive episodes that occurred during the second baseline phase of the study. Lorazepam is a commonly prescribed medication that decreases anxiety and associated symptoms. A decrease in repetitive behaviors was also observed when the participant was placed on lorazepam to complete the antecedent exercise routine. Although lorazepam plus exercise resulted in a decrease in repetitive behavior episodes, it was not as significant as exercise alone.

The three autistic adults in Toms et al. (2019) study, participated in the MSE twice a week for 30 min. The participants were required to engage in at least 15 min of physical activity. Repetitive behaviors were tracked according to the Repetitive Behavior Scale-Revised into three categories: stereotyped behaviors, self-injurious behaviors, and compulsive behaviors. Results of this study were mixed because, although their repetitive behaviors did not decrease, negative ones including self-injurious or harmful actions toward another person have the potential to change. In addition, "positive" repetitive behaviors, as long as they are safe, could be an indication of their excitement to engage with the MSE (Toms et al., 2019).

Four of the six studies found a significant decrease in the presence of repetitive behaviors among participants post-intervention (Allison et al., 1991; Elliott et al., 1994; George et al., 2023; Keller et al., 2022). Two studies (Ali et al., 2018; Toms et al., 2019) were inconclusive regarding whether biking or participation in a MSE room with a physical activity component had an effect on repetitive behaviors due to inadequate amount of data collected and irregular adherence to the intervention program.

Independence

Three studies, all Level 3B (Bassette et al., 2018; García-Villamisar and Dattilo, 2010; Healy et al., 2022) evaluated the effects of physical activity on independence in a combined total of 434 participants. García-Villamisar and Dattilo (2010) analyzed the impact of physical activity on the quality of life of 71 participants via the Quality of Life Questionnaire-Spanish Version and the Stress Survey Schedule for Persons with Autism and Other Pervasive Developmental Disabilities. The participants involved in the one-year leisure program exhibited effects on independence following the engagement in exercise and participation in recreational activities. According to the Quality-of-Life Questionnaire-Spanish Version, independence is determined based on how in control one feels in the decisions they make and the responsibilities they have in their everyday life. The data analysis of this study revealed a significant increase in the empowerment/independence scales in those who participated in the Leisure Programme (García-Villamisar and Dattilo, 2010). Another study (Bassette et al., 2018) measured independence characterized by autonomy in completing a physical routine across multiple community settings. The participants completed an exercise program over a four-month period. The exercise program had three phases which included yoga, strength training, and walking (Bassette et al., 2018). The study showed an increase in all three

Table 3
Risk of Bias Table for Randomized Controlled Trials and Non-Randomized Controlled Trials.

Citation	Selection Bias			Performance Bias		Detection Bias		Attrition Bias	Reporting Bias	Overall Risk of Bias Assessment
	Random Sequence Generation	Allocation Concealment	Baseline Differences Between Intervention Groups	Blinding of Participants During the Trial	Blinding of Study Personnel During the Trial	Blinding of Outcome Assessment: Self-Reported Outcomes	Blinding of Outcome Assessment: Objective Outcomes	Incomplete Outcomes Data	Selective Reporting	
Bassette, L., Kulwicki, J., Dieringer, S. T., Zoder-Martell, K. A., & Heneisen, R. (2018).	+	-	+	-	-	-	-	+	-	**M**
Elliott, R. O., Jr, Dobbin, A. R., Rose, G. D., & Soper, H. V. (1994).	+	+	+	+	-	-	-	+	+	**L**
García-Villamisar, D. A. & Dattilo, J. (2010)	+	?	+	?	+	-	-	+	+	**M**

Key: + = low risk of bias, ? = questionable risk of bias, - = high risk of bias, M = moderate overall risk of bias, L = low overall risk of bias

Table 4
Risk of Bias Table for Pre-Post Test Studies.

Citation	StudyQuestionorObjectiveClear	EligibilityorSelectionCriteriaClearlyDescribed	ParticipantsRepresentativeofReal – WorldPatients	AllEligibleParticipantsEnrolled	SampleSizeAppropriateforConfidenceinFindings	InterventionClearlyDescribedandDeliveredConsistently	OutcomeMeasuresPrespecified, Defined, Valid/ReliableandAssessedConsistently	AssessorsBlindedtoParticipantExposuretoIntervention	LosstoFollowUpAfterBaseline20 %orLess	StatisticalMethodsExamineChangeinOutcomeMeasuresfromBeforetoAfterIntervention	OutcomeMeasureswereCollectedMultipleTimesBeforeandAfterIntervention	OverallRiskofBiasAssessment
Ali, S., Horton, S., Sutherland, C., & Azar N. (2017)	Y	Y	Y	N	N	Y	Y	N	NR	Y	Y	**L**
Allison, D.B, Basile, V.C, & MacDonald, R.B (1991)	Y	N	Y	N	N	Y	N	N	Y	Y	N	**M**
George, C.L., Valentino, A., D'Anna-Hernandez, K., & Becker, E.A. (2023).	Y	Y	Y	N	N	Y	Y	NR	NR	Y	N	**L**
Healy, S., Brewer, B., Hoopes, E., Paller, A., Mayberry, S., Maguire, J., Daly, J., Laxton, P., & Patterson, F. (2022)	Y	Y	Y	Y	Y	Y	Y	N/A	N/A	N/A	N/A	**L**
Keller, R., Ardizzone, F., Finardi, C., Colella, R., Genuario, C., Lopez, M., Salerno, L., Nobile, E., & Cicinelli, G. (2022)	Y	Y	Y	N	N	Y	Y	N	NR	Y	N	**M**
Toms, S.B.; Janke, M.C., Loy, D.P., & Watts, C.E. (2019)	Y	Y	Y	N	N	Y	Y	N	N	Y	N	**M**

Key: Y = yes, N = no, NR = not reported, N/A = not applicable, M = moderate overall risk of bias, L = low overall risk of bias

participants' abilities to complete physical activities independently throughout all three phases (Bassette et al., 2018). All participants exhibited an increase in independence from baseline to the end of the intervention. Furthermore, the improvements made were maintained during the generalization phases of the study (Bassette et al., 2018). Finally, a study that observed 360 participants, who met the specified physical activity guidelines per week, found an increase in independence in activities of daily living including dressing and home management (Healy et al., 2022). The physical activity guidelines in this study required participants to engage in either 150 min of moderate intensity exercise (e.g. walking) or 75 min of vigorous intensity exercise per week (Healy et al., 2022).

Discussion

This systematic review examined the effectiveness of physical activity as an intervention for reducing repetitive behaviors and increasing independence in autistic adults. Of the nine studies included in the review, two were Level 2B (Elliott et al., 1994; García-Villamisar and Dattilo, 2010) and seven were Level 3B (Ali et al., 2018; Allison et al., 1991; Bassette et al., 2018; George et al., 2023; Healy et al., 2022; Keller et al., 2022; Toms et al., 2019). Six of the nine studies explored the effects of physical activity on a variety of repetitive behaviors that are prevalent among this population (Ali et al., 2018; Allison et al., 1991; Elliott et al., 1994; George et al., 2023; Keller et al., 2022; Toms et al., 2019). Four of the six studies demonstrated a decrease in repetitive behaviors (Allison et al., 1991; Elliott et al., 1994; George et al., 2023; Keller et al., 2022). Two studies, on the other hand, found mixed results after the physical activity intervention program (Ali et al., 2018; Toms et al., 2019). The overall level of evidence supporting physical activity as an intervention for repetitive behaviors is considered moderate based on the congruency of findings across multiple moderate quality studies.

Even though Ali et al. (2018) found an inconsistent reduction in repetitive behaviors after exercise, the results suggest that there may be an interaction between different repetitive behaviors and that some repetitive behaviors that are an expression of a positive mood or feeling may not need to be targeted for intervention. Ali et al. (2018), found that three of the participants demonstrated a decrease in repetitive behaviors while the other three participants demonstrated an increase. However, the observed repetitive behaviors for two of the three participants who demonstrated an increase after the intervention were different from the baseline repetitive behaviors observed beforehand. The researchers suggested that the different repetitive behaviors that emerged could have been an expression of a positive mood or feeling, rather than a disruptive repetitive behavior that needed to be targeted for intervention. The intervention effectiveness of biking was found to vary between participants due to the pace at which the individual preferred to pedal as opposed to the goal that was previously established to obtain the desired outcome. As a result, some participants in the Ali et al. (2018) study were only capable of reaching a low exercise intensity instead of the moderate and/or vigorous exercise intensity recommended from previous studies. Toms et al. (2019), on the other hand, found that all three participants showed inconsistent reductions in repetitive behaviors when participating in a MSE due to irregular adherence to the intervention program and the inadequate amount of data collected. Participants would either refuse or be found ineligible to participate as a result of medical status and health. Multiple sessions had to be cancelled for participants because of illnesses. The inability of participants to consistently attend the interventions outlined in Toms et al. (2019) affected the researcher's ability to interpret the effect of MSE's on repetitive behaviors. This, combined with a small sample size, may have created a discrepancy with the results when compared to the other studies. Although a reduction in repetitive behaviors was not significant, the participants did find enjoyment in the MSE, which could have caused the presence of more repetitive behaviors post-intervention. The results of both these studies align with Kapp et al. who emphasized that only those repetitive behaviors that are injurious and/or harmful to societal inclusion and quality of life should be targeted for intervention (2019).

Research examining independence is still very limited, which reduces the strength of the evidence in this systematic review. Three of the nine studies focused on the effects of physical activity on independence in activities of daily living and the autonomous completion of routines (Bassette et al., 2018; García-Villamisar and Dattilo, 2010; Healy et al., 2022). Each of these studies demonstrated an increase in independence after the implementation of a physical activity intervention program (Bassette et al., 2018; García-Villamisar and Dattilo, 2010; Healy et al., 2022). The overall level of evidence to support physical activity as an intervention for independence is moderate due to the existence of multiple moderate quality studies that demonstrate increased participation and engagement in activities of daily living without external assistance, following intervention.

While the studies varied in intervention design and outcome assessment, several trends emerged. A diverse number and type of assessment tools were utilized throughout each study. Two frequently identified assessments were the Repetitive Behaviors Scale-Revised and observation. Each study varied in length, frequency, and intensity level. However, no study was under 20 min in length, suggesting that the evidence supports a minimum of 20 min when implementing physical activity interventions for autistic adults. All but one study (Elliott et al., 1994) examined the effects of long-term physical activity by implementing the intervention at least 2 times per week. The findings provide evidence to support the use of physical activity for the reduction of repetitive behaviors and increasing independence. Four of the six studies targeting repetitive behaviors (Ali et al., 2018; Allison et al., 1991; Elliott et al., 1994; George et al., 2023) and two of the three studies targeting independence (Bassette et al., 2018; García-Villamisar and Dattilo, 2010) achieved the desired results with moderate to vigorous intensity exercise. Moderate to vigorous intensity exercise could be implemented to reduce disruptive repetitive behaviors and increase independence. Additional recommendations about intensity or the most beneficial properties of physical activity cannot be made due to the variability of outcome measures and lack of studies comparing relative effectiveness of physical activity interventions. All but two studies (Ali et al., 2018; Toms et al., 2019) found a consistent reduction in repetitive behaviors or an increase in independence, thus supporting the potential use of physical activity as an intervention for autistic adults.

Strengths and limitations

A strength of this review is that the studies included were conducted in a variety of settings (e.g., within the community, intermediate care facilities, extended living sites, therapy clinics, educational day programs, universities, etc.). The studies included in this review also covered a large age range from early adulthood to middle-aged adults. Additionally, consistent results were found in 7 out of 9 studies suggesting a relationship between physical activity, repetitive behaviors, and independence exists.

Several commonalities emerged when reviewing the limitations of each study. The studies were hindered in their ability to recruit adult participants, leading to the inclusion of one 17-year-old and relatively small sample sizes. Researchers often set restrictive inclusion and exclusion criteria (e.g. age range, diagnosis, comorbidities, intelligence quotient level, number of repetitive behaviors) to create a more uniform group of participants to reduce variability and isolate intervention effectiveness, thus limiting the overall sample size. These factors jeopardize the generalizability of the findings in this systematic review, as the intervention effects observed in the studies included can only be applied to individuals with the same/or similar characteristics among that of the participants. The strict research methods make drawing conclusions difficult as they may overlook important differences that exist across autistic individuals such as cognition, sensory processing, and behavioral manifestations, that could influence results. Future studies should aim to adopt more flexible intervention designs and employ recruitment strategies that engage a more diverse population.

Participants in many of the studies were constrained in their autonomy to choose the physical activity intervention they could engage in, which may have contributed to low motivation in completing the program. Since many autistic individuals have motor impairments, finding ways to adapt exercises to the individual participant is required. By not doing so, the studies included in this systematic review may have underestimated the true effects of physical activity on repetitive behaviors and independence, as irregular adherence could have limited participant outcomes. To avoid these issues in future research, studies should prioritize client-centered interventions by considering self-determination and incorporating volition from autistic individuals in treatment planning.

Finally, not accounting for outside factors such as medication, nutrition, and sleep could impact the results of the studies in this systematic review (George et al., 2023). The lack of control for these confounding variables introduces variability that can either mask or exaggerate the effects of physical activity on repetitive behaviors and independence. Results may look better or worse than they actually are because of other influential elements at play. To improve future studies, researchers should document these outside factors throughout the study period and use tools to help account for their impact when analyzing the results.

Weaknesses of this review include a lack of well-designed RCTs that led to less rigorous findings in the studies' results due to the limited blinding of participants and experimenters. Many of the control groups within the RCTs included an alternate form of treatment (Elliott et al., 1994) or no treatment at all (García-Villamisar and Dattilo, 2010). The majority of the studies included in the review were non-RCTs, pre-posttests, and quasi-experimental. Of the studies reviewed, the total number of participants were relatively low with five of the studies including 10 participants or less (Allison et al., 1991; Bassette et al., 2018; Elliott et al., 1994; George et al., 2023; Toms et al., 2019). Finally, the current research does not clearly differentiate between lower or higher-level behaviors as well as disruptive and non-disruptive repetitive behaviors, so although the findings are helpful overall, more studies such as Ali et al. (2018), need to more clearly make this distinguishment so interventions can be better targeted for functional changes.

Implications for practice and research

This review provides evidence to support physical activity as an intervention for autistic adults who engage in disruptive repetitive behaviors and have decreased independence in activities of daily living or autonomous completion of routines. By including physical activity in an autistic adult's treatment, the frequency of repetitive behaviors may be reduced, and the level of independence may be increased. Duration and intensity seem to be important for effective results. Physical activity can be used as either a preparatory activity or paired with functional tasks to address an autistic adults' everyday occupations.

The findings from this study have the following implications for practice:

- A physical activity intervention program implemented for at least 20 min, twice a week may contribute to both a reduction in repetitive behaviors and an increase in independence for autistic adults.
- Moderate to vigorous intensity physical activity may be used to facilitate the reduction of repetitive behaviors in autistic adults as seen in 4 of the 6 studies that targeted this outcome (Allison et al., 1991; Elliott et al., 1994; George et al., 2023; Keller et al., 2022).
- Moderate intensity physical activity may be used to facilitate an increase in independence in activities of daily living and the autonomous completion of routines as seen in all three of the studies that targeted this outcome (Bassette et al., 2018; García--Villamisar and Dattilo, 2010; Healy et al., 2022).
- The Repetitive Behaviors Scale-Revised and observation are two frequently used assessment tools that could be used to record the presence of repetitive behaviors pre- and post-intervention.

Current research examining the reduction of repetitive behaviors in autistic adults is limited, as the previous focus of this outcome revolved primarily around children. However, adults often continue to present with these symptoms throughout their life course. Therefore, future research is needed to focus on the specific intensity and duration of physical activity interventions to better guide practitioners in addressing these issues in autistic adults. Only moderate evidence was found to support this intervention due to the limited availability of higher-level studies. Future research consisting of higher-level studies, including well-designed RCTs and larger sample sizes, are needed to strengthen the evidence supporting the use of physical activity as an intervention for autistic adults. In addition, more similar outcome measures should be included so the comparison between different types of intervention effects on

repetitive behaviors and independence can be further studied. Due to the heterogeneity of physical activity intervention administration, further research into the optimal dosage of physical activity interventions on reducing repetitive behaviors and increasing independence in autistic adults, including frequency, intensity, and duration, could increase clinicians' understanding of the implementation of the intervention in practice. Other factors that were not assessed within the included articles that may have had an influence on the effectiveness of physical activity interventions include education level, socioeconomic status, and intelligence quotient level of the autistic adults. This is another area where future research is needed to better understand the optimal patient for this intervention. Current research involving the use of physical activity to reduce repetitive behaviors has mainly been researched on children, therefore; more research is needed to fully examine these effects on the adult population. Future researchers should also seek to identify which repetitive behaviors may be associated with a positive mood or feeling (e.g. non-disruptive) as compared to which one's are deemed maladaptive to daily functioning (e.g. disruptive) for adults. As further research is available, the strength of the evidence for using physical activity as an intervention for autistic adults may vary.

Conclusion

This systematic review examined the effectiveness of physical activity as an intervention for reducing repetitive behaviors and increasing independence in autistic adults. The overall purpose was to better understand whether physical activity is useful as an intervention for this population with these concerns. Moderate evidence supports the use of moderate intensity physical activity for at least 20 min, twice a week, to target repetitive behaviors and independence in autistic adults.

Authorship contribution/confirmation statement.

SR, HH, KM, CS, KK, LC, KR and CH contributed to project design. SR, HH, KM, CS, KK, LC, AD, KR and CH contributed to literature searches. SR, HH, KM, CS, KK, LC, KR and CH contributed to data analysis. SR, HH, KM, CS, KK, LC, KR and CH contributed to manuscript preparation.

CRediT authorship contribution statement

Karen Ratcliff: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Alison Hansen:** Writing – review & editing, Writing – original draft, Software, Methodology, Data curation. **Hilton Claudia L:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Camila Salazar:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Kaleigh Magnant:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Lillian Cates:** Writing – review & editing, Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Kayla Kubenka:** Writing – review & editing, Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Hope Hacker:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Sydney Rubal:** Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

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None.

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No data was used for the research described in the article.

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